



Scuola Superiore G.D'Annunzio



Università degli studi
"G. d'Annunzio"

Digitalization as a Driver of Sustainability:

Decoding the Footprints on ESG (Environmental, Social, and Governance) and Firm Performance.

Research Doctorate Program: Science and Technology For Sustainable Development
(37th Cycle)

Department: *Innovative Technologies in Medicine & Dentistry (DITM&O)*

Scientific Discipline Sector: *SECS-P/07 Business Administration and Management*

Academic Year: 2021/2024

Doctoral Candidate:

Muhammad Haseeb

MuhammadHaseeb

Ph.D. Coordinator:

Professor Piero di Carlo

Piero di Carlo

Supervisor(s):

Professor Augusta Consorti

Augusta Consorti

Professor Stefania Migliori

Stefania Migliori



Digitalization as a Driver of Sustainability:

Decoding the Footprints on ESG (Environmental, Social, and Governance)
and Firm Performance.

Muhammad Haseeb

Department of Innovative Technologies in Medicine & Dentistry
Center of Advanced Studies and Technologies (*CAST*)

Supervisor(s):

Professor Augusta Consorti.
Department of Management and Business Administration

Professor Stefania Migliori.
Department of Management and Business Administration.

Ph.D. Coordinator.

Professor Piero di Carlo.
Department of Innovative Technologies in Medicine & Dentistry

Scuola Superiore G. D'Annunzio, School of Advance Studies

G. D'Annunzio University of Chieti–Pescara, Italy.

*“Try not to resist the changes that come your way. Instead, let life live through you. And do not worry that your life is turning upside down. How do you know that the side you are used to is better than the one to come? ” — **Rūmī***

FOREWORD

I still remember I was sitting on a couch (at midnight) at home and kept looking for PhD positions and the results of the application that I had applied for. At that time, *Ud'A* announced an additional call for doctoral positions, and when it was time to submit my application to the portal, I forgot the login details, so I just recovered the credentials and logged into the system. To my surprise, a pop-up message appeared on the screen with the word “*Ammissione*,” and I had no clue what it meant to be, so I used “*Google Translate*” and then realized that my application to the PhD position was accepted two days ago, in the *Science and Technology and Sustainable Development* program.

This is the moment I was looking for. I just ran into the other room where my mom and sister were peacefully sleeping and shared the exciting news—I got accepted into the PhD program in Italy. My sister stirred awake at almost 3 a.m., threw some quick congratulations my way, and then snuggled back into her dreams. This is the point where my PhD journey started at the G. D’Annunzio University of Chieti–Pescara.

The early years of my PhD were quite an adventure, filled with ups and downs as I discovered more about my identity. When I first started my fellowship at *Ud'A*, one of my colleagues casually asked about my “*research area*,” which threw me off a bit. I wasn’t sure if they were asking about my educational background or something else entirely; it felt like such a broad question. My path to this PhD has definitely not been a straight line, and for a while, I wondered if this was truly where I belonged and how I could make a meaningful impact. Thankfully, I’ve been surrounded by amazing people who have supported me throughout this journey, helping me realize that I am exactly where I’m meant to be. Now, as I am near the finish line, my colleagues often ask me about my current focus and who I’m most excited to connect with in my research.

This dissertation wraps up my PhD journey, which has spanned over three years filled with ups and downs. Looking back, I’m actually glad I didn’t know all the challenges I’d face along the way; it might have felt overwhelming to my younger self. To me, the biggest win isn’t just finishing the thesis or the research papers but the fact that I never gave up. Quitting isn’t in my vocabulary, even during the tough times when things felt really challenging.

First and foremost, I am grateful to my exceptional supervisors, *Stefania Migliori* and *Augusta Consorti*, for believing in me and supporting me throughout this journey. Once, I asked *Stefania* what the meaning of ‘*Migliori*’ is in your name part? she replied to me, ‘*Best*.’ I have to say that yes, “*You’re the Best*.” I can’t thank-you enough for all the support and encouragement you’ve given me. Your guidance has been so valuable, and I really appreciate how you’ve always pushed me to explore my ideas and findings

in my own way. Your eye for detail and academic knowledge helped me become the researcher I am today. However, on top of your academic stuff, you're just an amazing person who genuinely cares about those around you, and you were always there when I needed you. Thanks for the long discussion (online) when I was in Denmark and Norway, and you managed time even when you were at home, providing me guidance and giving me tips on my ongoing work. Also, thanks for giving me time to work abroad (18 months) and a free hand. I also extend my gratitude to *Augusta Consorti* for selecting me for this program and providing me with unlimited support.

Of course, how can I forget the name of *Maria Josefina Figueroa*? She's opened CBS's doors for me with her heartfelt dedication, mentorship, and unwavering support. Thanks for believing in me and my work from the very early stages of my career. It opened new prospects along the way and provided me the opportunity to experience the distinctive research environment at the *Department of Management Society and Communication (MSC) in Denmark*. You are a super teacher and also an incredible person. Your kind support has given me an opportunity to feel at home in another country (*usually, which is not for beginners*). I will never forget our discussion about academic life, current world affairs, politics, US elections (*now Donald Trump won*), and climate issues. I really appreciate your insights. They help me see things in a new light and give me a different way to look at the world around us. Also, I will never forget the walks (*DHL relay and Christiania town*), during which we shared the town's history, visited the old warehouses, cheered beers together, and ate dinner at *Kanalhuset Restaurant*.

Thank you so much for inviting me to your home in *Roskilde*. Even though we were hit by that big snowstorm, I had a wonderful time on our walk down the road. I really enjoyed hearing all the interesting things you shared about the town. Also, your feedback was always to the point and instrumental in improving the quality of my work. Thank you for consistently dedicating your time to reviewing drafts, discussing my concerns, and prioritizing my research, even amidst your own demanding deadlines and work commitments.

To *Piero di Carlo*, thank you for your trust and guidance and for always being present on this path. You're such a genuinely kind and down-to-earth person. Your big smile brightens up the room. I can't tell you how much your support meant to me, especially when I was away from (home) university. It was so reassuring to know that I didn't have to sweat the admin stuff because you have it all covered. I really appreciate everything you do.

I want to give a huge thank you to *Khine Aye Myat Kyaw*, Professor at *NTNU Business School*, for welcoming me as a visiting scholar. Your support with research and access to the database using your ID has been invaluable. You are such a wonderful person, and I truly appreciate how you introduced me to the

Pakistani community (in Norway). I also have to mention how much I loved the beautiful city of *Trondheim*—with its stunning weather, breathtaking scenery, and fascinating history. It has been an unforgettable experience.

Moving forward, I want to take a moment to express my heartfelt gratitude to my amazing colleagues at the *Department of (MSC) Management Society and Communication*. You guys (*some of them assistants, associate professors, and especially administration staff*) have created such a warm and welcoming environment that I truly appreciate. To all the PhD fellows at MSC, many of whom have become such great friends, your constant inspiration, support, and companionship have meant the world to me during my time here (‘*kæmpe tak*’ for bearing me for more than one year). I feel so lucky to be part of such a vibrant PhD community (*MSC Superstar*). It’s honestly one of the best communities out there. Thanks for all the laughter and those joyful moments we shared over Beers and Nachos at Bartof Café.

I want to take a moment to thank the *Department of Management and Business Administration* and the amazing *AMBE PhD community*. Over the years, we’ve shared so many wonderful moments of joy and determination together. Each of you has played an important part, and our accomplishments really show how great we are as a team. Pursuing a PhD with such fantastic colleagues and friends has made this journey so much more enjoyable.

Special shoutout to our wonderful (*the real Boss*) *Emanuele*, whose support has truly meant the world to us all. Your contributions have made a real difference in our everyday work life.

Alongside the academic stuff, I want to give a shoutout to several close friends who’ve been there for me on this journey. Some of them still don’t quite get what I’m working on, and honestly, it took me a while to figure it out, too. But in a way, they’re all part of this process.

To my Parents, Mother, and Sister, a big “*Grazie*” for your endless patience. I have to give a special shout-out to my sister (Mahnoor)—she may be younger, but she always knows how to push me to be better. Your advice and support have been so helpful whenever I hit a rough patch; she truly helped me find my way. I feel so lucky to have this strong foundation in my life.

To wrap up these three pages, I just have to take a moment to thank myself. Believing in myself and pushing my limits has been a real journey. This marathon was no walk in the park, full of ups and downs, and I even had some frustrating moments along the way.

But you know what? I did it! So, a big, big, big thank you to myself. This one’s definitely for you!

Pescara, Italy.

Muhammad Haseeb.

ABSTRACT

In today's fast-changing world, businesses have a valuable opportunity to adapt and meet new challenges effectively. Environmental, Social, and Governance (ESG) and digitalization (the integration of digital technologies) are key aspects in today's constantly evolving business operations and market dynamics. These interconnected fields are critical for addressing present global challenges, making them highly relevant areas of research that hold the potential to drive positive change and forward a more sustainable world. This dissertation does not attempt to provide a definitive framework for understanding the relationship between digitalization, sustainability, and ESG performance of firms. Rather, it aims to offer a comprehensive exploration of how this relationship has been evolved, its implications to various stakeholders (customers, investors, employees, communities, NGO's, and regulators), and the challenges that are associated with; and remain unresolved. Specifically, this thesis seeks to investigate the role of digitalization (digital transformation) in shaping sustainability initiatives and also examine how ESG factors influence the performance of firms. Additionally, it explores the moderation effect of various factors—such as board gender diversity (BGD), ESG-related controversies, research and development (R&D) intensity, and stock market valuations—on the dynamics of this relationship. To achieve these objectives, this dissertation is structured around three independent but interrelated research articles, each contributing to distinct insights into the broader topic of investigation.

This first (1st) article of this doctoral thesis is a literature review that aims to provide a comprehensive and up-to-date review of how digitalization impacts the sustainability and performance of firms and synthesize the existing knowledge within an integrated framework. In this paper, we conducted a systematic literature review adopting bibliographic and bibliometric approaches. The descriptive section of bibliometric analysis includes (number of studies over the time-period, top publications, countries, journals, and authors) and Science Mapping analysis used to analyze the collaboration between countries (e.g., co-occurrence, co-authorship, and co-citation) providing a fundamental characteristic of the existing body of knowledge in this research field. The content analysis part of this study highlights four thematic clusters: *(i)* digitalization's impact on sustainable firm performance, *(ii)* sustainable corporate performance and green practices, *(iii)* integrating industry 4.0 technologies in sustainable supply chain management, *(iv)* digitalization as a driver of circular economy business model. This study minimizes the complexity and provides structure and clarity related to this area. It also concludes by discussing the most prominent emerging research themes and identifying key research patterns and areas that should be prioritized in future research agendas for those interested in sustainability and firm performance within the rapidly evolving landscape of digitalization.

The second (2nd) research article provides an in-depth empirical analysis of how digitalization influences the environmental, social, and governance (ESG) performance of firms. It also explores the moderating effect of digitalization on the relationship between ESG performance and stock market valuation (companies' values according to the financial market), taking into account sub-themes of ESG scores. In this study findings we reveal that the integration of digital technologies significantly enhances the performance of firms (across all dimensions) of ESG. Furthermore, digitalization strengthens the connection between stock market valuation and ESG performance, indicating that investors may recognize the positive impact of a firm's digital initiatives on its overall sustainability efforts. Notably, environmental pillar scores experience a favorable moderation due to digitalization, suggesting that technological advancement can lead to improved ecological practices. However, in this research, we also identified trends that were somewhat concerning. Digitalization appears to have a moderately negative effect on the relationship between the social and governance aspects of ESG. This finding highlights that while digital tools can drive environmental improvements, they may simultaneously create challenges in social responsibility and governance structure.

In the third (3rd) article, we adopted a quantitative approach to exploring and contributing to the existing literature with a fresh perspective on ESG that examines the nuanced relationship between digitalization and ESG performance within technological firms by exploring the causal link between digital transformation and ESG outcomes. The novelty of this approach is in examining the moderating effect of key governance dimensions such as board gender diversity (BGD), ESG controversies, and R&D intensity on the relationship between digitalization and ESG performance. Our study findings indicate that digital transformation plays a crucial role in boosting the ESG performance of firms in the technology sector. We also found that a diverse board (gender representation) has a strong positive effect on this association, suggesting that organizations with greater gender diversity are more likely to reap the benefits of digital transformation in their ESG practices. ESG controversies appear to have a negative impact on this dynamic, indicating that companies facing public criticism (or controversy) related to ESG issues may struggle to see the positive effects of digital initiatives. Additionally, R&D intensity appears to moderate this relationship positively, reinforcing the idea that investments in research and innovation can increase the effectiveness of digitalization in promoting ESG goals. However, our findings indicate that the impact of R&D intensity is weaker than that of BGD, which emphasizes the varying degrees of influence the moderating factors possess in shaping the dynamics between digitalization and ESG performance. This complexity underscores the need for organizations to contemplate these factors in their strategic planning and implementation of digital technologies.

Collectively, this dissertation makes a significant contribution to the macro-level literature on digitalization and corporate sustainability by exploring the drivers and mechanisms that influence companies' sustainable behaviors and their impact on firms' ESG (Environmental, Social, and Governance) performance. This thesis offers a range of theoretical contributions that address different streams of literature and enhance our understanding of sustainability, digitalization, and the behaviors associated with firms' ESG performance. This research provides several key insights: It examines the role of digitalization (transformation) in enhancing organizational performance and investigates its moderating influence on the relationship between the stock market and ESG performance. Moreover, the study explores how board gender diversity (BGD), research and development (R&D) intensity and ESG controversies moderate the link between digitalization and ESG outcomes. On a practical level, this doctoral thesis offers policy implications, providing recommendations on how digitalization and ESG strategies can be leveraged to support more informed decision-making. The findings ultimately lay the groundwork for advancing sustainability and business practices and contributing to more responsible corporate governance.

TABLE OF CONTENTS

PART I: KAPPE	21
1. INTRODUCTION	22
1.1.Navigating the Digital Future: The Fundamental Role of Digitalization in Business Success.....	22
1.2.Beyond Profit: The Growing Importance of ESG (Environmental, Social and Governance).....	23
1.3.Digitalization Meets ESG: How (Digital) Technology Improves ESG Performance and Investments Decisions.....	25
2. RESEARCH OBJECTIVE AND SCOPE OF THE STUDY	26
3. OVERVIEW OF DISSERTATION STRUCTURE	27
4. METHODOLOGIES AND STRATEGIES OF RESEARCH ANALYSIS	28
5. SUMMARY OF PAPERS	28
5.1. PAPER 1: Digitalization for Sustainability and its Effect on Firm Performance: A Systematic Literature Review with Bibliometric Approach	29
5.2. PAPER 2: Exploring the Nexus between Digitalization and Firm's ESG Performance: An Empirical Study of Danish-Listed Firms.....	30
5.3. PAPER 3: Understanding the Dynamics of Digitalization and ESG Performance and the Moderating Effects of Key Governance Factors	31
6. Contributions to Research and Practices in Digitalization, Sustainability initiatives, and ESG Performance are essential for fostering progress and promoting meaningful change	32
6.1.Theoretical Contributions	32
6.2.Practical and Policy Implications	34
6.3.Limitations and Future Research	35
7. CONCLUSION AND DISCUSSION	36
8. REFERENCES PART 1	40
PART II: PAPERS	45
9. PAPER 1	46
9.1.Introduction	49
9.2.Theoretical and Methodological Foundations of Review's Research/Studies	53
9.2.1. Data Collection Protocols	54

A. Research Questions and Boundaries of Study	55
B. Database Selection.....	55
C. Identifying Keywords of the Study	55
D. Selection of Articles Included	56
E. Data Extraction and Evaluation	56
9.2.2. Bibliometric Analysis	57
a. Performance Analysis	58
b. Science Mapping	58
9.3. Results from Bibliometric Analysis	58
9.3.1. Performance Analysis	59
A. <i>No Studies Over Time</i>	59
B. <i>Top Publication Sources</i>	59
C. <i>Top Publication Countries</i>	60
D. <i>Top Authors and Cited Publications</i>	61
9.3.2. Science Mapping Analysis	62
A. <i>Countries Collaboration Analysis</i>	62
B. <i>Co-Authorship Analysis</i>	62
C. <i>Co-Citation Analysis</i>	63
D. <i>Co-occurrence of keywords Analysis</i>	64
9.4. Content Analysis of Thematic Areas	64
I. Digitalization Impact on Sustainable Firm Performance.....	65
II. Sustainable Corporate Performance and Green Practices	66
III. Integrating Industry 4.0 Technologies for Sustainable Supply Chain Management.....	67
IV. Digitalization As a Driver of Circular Economy Business Model.....	68
9.5. Future Research Directions.....	69
9.6. Discussion and Conclusion.....	70
9.6.1. Theoretical Implications.....	76
9.6.2. Practical Implications	76
9.6.3. Limitations and Future Research Agenda	77

9.6.4. Additional Data File	78
9.7. FIGURES OF THE PAPER 1	79
9.7.1. <i>Figure 1. Research Methodology Framework (Toolbox)</i>	80
9.7.2. <i>Figure 2. Prisma Study Protocols</i>	81
9.7.3. <i>Figure 3. Studies Over-time Period</i>	82
9.7.4. <i>Figure 4. Geographical Contributions</i>	83
9.7.5. <i>Figure 5. Countries Collaboration Analysis</i>	84
9.7.6. <i>Figure 6. Co-Authorship Analysis</i>	85
9.7.7. <i>Figure 7. Co-Citation Analysis</i>	86
9.7.8. <i>Figure 8. Co-Occurrence of Keywords</i>	87
9.7.9. <i>Figure 9. Density Analysis</i>	88
9.8. LIST OF TABLES OF PAPER 1	89
9.8.1. <i>Table 1. Top Publications Sources/Journals</i>	90
9.8.2. <i>Table 2. Top Countries with Citations</i>	91
9.8.3. <i>Table 3. Top Authors and Publications</i>	92
9.8.4. <i>Table 4. Co-occurrence of Keywords</i>	94
a. <i>Table 5. a. Top articles in Red Cluster</i>	96
b. <i>Table 5 b. Top articles in Green Cluster 2</i>	97
c. <i>Table 5 c. Top articles in Blue Cluster 3</i>	98
d. <i>Table 5 d. Top articles in Yellow Cluster 4</i>	99
9.8.5. <i>Table 6. Future Research Directions</i>	100
9.9. References	102
10. PAPER 2	115
10.1. Introduction	117
10.2. Literature Review and Hypothesis Development	120
10.2.1. Digitalization Impact on Environmental, Social and Governance (ESG) Performance.....	120
10.2.2. The moderating influence of digitalization on the relationship between stock market valuation and ESG performance	122
10.3. Research Methodology	124

10.3.1. Theoretical Framework of Study	124
10.3.2. Sample and Data Collection	124
10.3.3. Evaluating ESG Performance	125
10.3.4. Assessing Digitalization	125
a. Thesaurus Construction	126
b. Data Collection	126
c. Text Analysis	126
d. Index Calculation	126
10.3.5. Other Variables and Measures	126
10.3.6. Economic Modelling	127
A. Direct Effect	128
B. Moderation Effect	128
10.4. Empirical Results	129
10.4.1. Descriptive Statistics	129
10.4.2. Correlation Matrix	130
10.5. Multi-variate Regression Model	131
10.5.1. Digitalization with Overall ESG Performance	131
10.5.2. The role of digitalization on a firm's Environmental performance	132
10.5.3. Digitalization influences a firm's Social Performance	133
10.5.4. The Effect of digitalization on firm's Governance performance	134
10.6. The moderating effect of digitalization on the association between stock market valuation and a firm's ESG (Environmental, Social, and Governance) Performance	135
10.7. Robustness Check	138
10.8. Conclusion and Discussion	140
10.9. Theoretical, Practical, and Policy Implications	142
10.9.1. Limitations and Future Research	143
10.9.2. Additional Data	144
10.10. FIGURE OF ARTICLE 2	145
10.10.1. Figure 1. <i>A theoretical framework of the study</i>	146
10.11. TABLES OF ARTICLE 2	147

10.11.1.	Table No 1.	<i>Analysis of descriptive statistics for the sample of publicly listed companies.....</i>	148
10.11.2.	Table No 2.	<i>Correlation analysis of publicly listed companies.....</i>	149
10.11.3.	Table No 3.	<i>Estimation of multivariate regression models I, II, and III: The dependent variable is ESG performance.....</i>	150
10.11.4.	Table No 4.	<i>Estimation of multivariate regression models IV, V, and VI: The dependent variable is Environmental performance.....</i>	151
10.11.5.	Table No 5.	<i>Estimation of multivariate regression models VII, VIII, and IX: The dependent variable is Social performance.....</i>	152
10.11.6.	Table No 6.	<i>Estimation of multivariate regression models X, XI, and XII: The dependent variable is Governance performance.....</i>	153
10.11.7.	Table No 7.	<i>Estimation of coefficients in multivariate panel data regression models (I-XII): The moderating effect of digitalization on the relationship between stock market valuation and firms' environmental, social, and governance (ESG) performance.....</i>	154
10.11.8.	Table No 8.	<i>Robustness Check, using a Two-Step Generalized Method of Movement (GMM) estimation model.....</i>	156
10.12.	References.....		158
11.	PAPER 3		166
11.1.	Introduction		168
11.2.	Literature Review and Hypothesis Development		172
11.2.1.	The Role of Digitalization in Shaping ESG Performance		172
11.2.2.	Board Gender Diversity as Moderator between Digitalization and ESG Performance.....		176
11.2.3.	ESG Controversies as a Moderator between Digitalization and ESG Performance.....		177
11.2.4.	R&D Intensity as a Moderator between Digitalization and ESG Performance.....		178
11.3.	Research Design		179
11.3.1.	Sample, Data, and Methodology		179
11.4.	Measurements		180
A.	Dependent Variable		180

11.4.1. <i>ESG Performance or Score</i>	180
B. Independent Variable	181
11.4.2. <i>Digitalization</i>	181
C. Moderating variables	181
11.4.3. <i>Board Gender Diversity</i>	182
11.4.4. <i>ESG Controversies Score</i>	182
11.4.5. <i>R&D Intensity</i>	182
11.5. Economic Model Setting	182
a. Direct Effect	182
b. Moderation Effect	183
11.6. Results and Discussions	184
11.6.1. Descriptive Statistics and Correlation Matrix	184
11.6.2. Baseline Regression Results and Discussion	185
11.7. Robustness Validation	190
A. Robustness Check with GMM	190
B. Robustness Check with One-Year Lagged OLS Model	190
11.7.1. GMM Model for Robustness Check	191
11.7.2. One-Year Lagged OLS Model for Robustness Test	192
11.8. Conclusion	192
11.9. Theoretical, Practical and Policy Implications	195
11.9.1. Limitations and Future Research	195
11.10. FIGURES OF ARTICLE 3	197
11.10.1. <i>Figure No 1. Theoretical Framework of the Study</i>	198
11.10.2. <i>Figure No 2. Structural Model of the Study</i>	199
11.11. TABLES OF THE ARTICLE 3	200
11.11.1. <i>Table No 1. Analysis of descriptive Statistics of publicly listed Northern European Firms</i>	201
11.11.2. <i>Table No 2. Correlation Analysis</i>	202
11.11.3. <i>Table No 3. OLS Baseline Regression Analysis – Full Sample</i>	203

11.11.4. <i>Table No 4. GMM Model of Robustness Check</i>	205
11.11.5. <i>Table No 5. Robustness Check: with lagged values (Lagged OLS Model)</i>	207
11.12. References.....	208
12. APPENDIX SECTION	220
A. Appendix A Paper 1	221
B. Appendix B Paper 2	222
C. Appendix C Paper 3	227

LIST OF FIGURES AND TABLES

PART I: KAPPE

Figure 1. Overview of dissertation structure.....	27
---	----

PART II: PAPERS

PAPER 1

Figures of Paper 1

Figure 1. Research Methodology Framework (Toolbox).....	80
Figure 2. Prisma Study Protocols.....	81
Figure 3. Studies over time period.....	82
Figure 4. Geographical Contributions of Studies.....	83
Figure 5. Countries Collaboration Analysis.....	84
Figure 6. Co-Authorship Analysis.....	85
Figure 7. Co-Citation Analysis.....	86
Figure 8. Co-Occurrence of Keywords.....	87
Figure 9. Density Analysis.....	88

Tables of Paper 1

Table 1. Top Publications Sources/Journals.....	90
Table 2. Top Countries with Citations.....	91
Table 3. Top Authors and Publications.....	92
Table 4. Co-occurrence of Keywords.....	94
Table 5a. Top articles in Red Cluster 1.....	96
Table 5b. Top articles in Green Cluster 2.....	97
Table 5c. Top articles in Blue Cluster 3.....	98

Table 5d. Top articles in Yellow Cluster 4.....	99
---	----

Table 6: Future Research Directions.....	100
--	-----

PAPER 2

Figures of Paper 2

Figure 1. A Conceptual framework of the study.....	146
--	-----

Tables of Paper 2

Table No 1. Analysis of descriptive statistics for the sample of publicly listed companies.....	148
--	-----

Table No 2. Correlation analysis of publicly listed companies.....	149
--	-----

Table No 3. Estimation of multivariate regression models I, II, and III: The dependent variable is ESG performance.....	150
--	-----

Table No 4. Estimation of multivariate regression models IV, V, and VI: The dependent variable is Environmental performance.....	151
---	-----

Table No 5. Estimation of multivariate regression models VII, VIII, and IX: The dependent variable is Social performance.....	152
--	-----

Table No 6. Estimation of multivariate regression models X, XI, and XII: The dependent variable is Governance performance.....	153
---	-----

Table No 7. Estimation of coefficients in multivariate panel data regression models (I-XII): The moderating effect of digitalization on the relationship between stock market valuation and firms' environmental, social, and governance (ESG) performance.....	154
---	-----

Table No. 8. Robustness Check, using a Two-Step Generalized Method of Movement (GMM) estimation model.....	156
---	-----

PAPER 3

Figures of Paper 3

Figure No 1. Theoretical Framework of the Study.....198

Figure No 2. Structural Model of the Study.....199

Tables of the Article 3

Table No 1. Analysis of descriptive Statistics of publicly listed Northern European Firms.....201

Table No 2. Correlation Analysis.....202

Table No 3. OLS Baseline Regression Analysis – Full Sample.....203

Table No 4. GMM Model of Robustness Check.....205

Table No 5. Robustness Check: with lagged values (Lagged OLS Model).....207

LIST OF ABBREVIATIONS

AI	Artificial Intelligence
ATO	Assets Turnover
BCT	Blockchain Technologies
BDA	Big data Analysis
BGD	Board Gender Diversity
BI	Business Intelligence
BVPS	Book value per share
CAD	Computer-Aided Design
CC	Cloud Computing
CE	Circular Economy
CEO	Chief Executive Officer
CSR	Corporate Social Responsibility
CSRD	Corporate Sustainability Reporting Standard
CSV	Comma Separated values
EPS	Earnings Per Shares
ESG	Environmental, Social, and Governance
FE	Fixed Effect
GI	Green Innovation
GMM	Generalized Method of Movements
I4.0	Industry 4.0
ICT	Information Communication Technologies
IoT	Internet of things
IOT	Internet of Things
KPI'S	Key Performance Indicators
LCA	Life cycle Assessment
LEV	Leverage
MD&A	Management Discussion and Analysis
OLS	Ordinary least square
RPA	Robotic Process Automation
R&D	Research and Development
RE	Random Effect
ROA	Return on Assets
SGD's	Sustainable Development Goals
SLR	Systematic Literature review
SSCM	Sustainable Supply Chain Management
WoS	Web of Science

AUTHORS OF THE INCLUDED PAPERS

Paper1: Muhammad Haseeb; Stefania Migliori¹ and Maria Josefina Figueroa.

Paper 2: Muhammad Haseeb; Maria Josefina Figueroa² and Stefania Migliori.

Paper 3: Muhammad Haseeb; Maria Josefina Figueroa; Stefania Migliori and Augusta Consorti³.

¹ Full Professor at the Department of Management and Business Administration. G. D’Annunzio University of Chieti–Pescara. Viale Pindaro N.42, 65127 Pescara – Italy.

² Associate Professor at the Department of Management Society and Communications (MSC). CBS Sustainability – Center for Business and Development Studies. Copenhagen Business School, Dalgas Have 15, 2000 Frederiksberg – Denmark.

³ Full Professor at the Department of Management and Business Administration. G. D’Annunzio University of Chieti–Pescara. Viale Pindaro N.42, 65127 Pescara – Italy.

PART I: KAPPE

1. INTRODUCTION

1.1. Navigating the Digital Future: The Fundamental Role of Digitalization in Business

Success

In a rapidly changing business environment, doing business and being competitive are essential. Organizations that fail to integrate digital technologies into their core business operations lose market share and competitive advantage (Zeng et al., 2022; Montero Guerra et al., 2023). In the modern business era, digitalization is mandatory for multiple reasons. Firstly, it enables organizations to analyze massive amounts of information inflows in real time, allowing them to make and implement better decisions. Further, (with digital transformation) automating the repetitive tasks also optimizes workflows, which can boost a company's productivity and efficiency. It allows businesses to reach out to new customers and penetrate emerging markets through (digital) channels, social media, and e-commerce platforms (Flyverbom et al., 2017).

Digitalization can be defined as a process of converting information and real-world objects into digital form. It involves using digital technologies, such as computers, devices, and internet services, to create stores and share digital information (Hinings et al., 2018; Peng & Tao, 2022). The primary goal of digitizing business processes is to improve efficiency and productivity and introduce innovation by making relevant information data more accurately accessible for stakeholders and easier to manage (Bril et al., 2022). According to Bloomberg 2018, digitalization is the application of digital technologies (AI, Blockchain, Cloud Computing, and the Internet of Things) to describe how social interactions are increasingly restructured through digital communication. It further explains how we transform analog to digital operations and how this shapes our lives.

Arthur (2017) categorized three key phases/dimensions in the evolution of digitalization (digital technology), each representing a substantial transformation. He argued that digitalization undergoes substantial changes roughly every two decades (20 years). The first major shift occurred between 1970s – 1980s with the invention of integrated circuits (IC's) technology, which accelerated computing power and reduced the size of devices. Secondly, in the 1990s – 2000s, computers were increasingly connected to the internet, causing physical actions or work to be carried out electronically (digitally). Now, the latest ongoing phases, starting from the 2010s onward, include low-cost sensor technology (Smart Chips), artificial intelligence, cloud computing, and the Internet of Things, which facilitate the collection of large amounts of (big) data that infiltrate almost every aspect of business activities.

From a corporate perspective, digitalization offers various opportunities for companies to improve their operations and better serve customers. For instance, the automation of repetitive tasks decreases, which

also lowers costs and human error. Software such as robotic process automation (RPA) and business intelligence (BI) can streamline the data entry process. Cloud-based technological solutions allow companies to scale up their infrastructure and make faster, more information-based decisions by utilizing real-time data across organizations (Harrmann et al., 2023; Wu & Lu, 2023). By integrating digital platforms (apps and websites), businesses can adjust their offerings to individuals' needs and use data to make personalized recommendations. AI-powered customer support systems, such as chatbots, can also improve response times and provide 24/7 assistance, leading to higher customer satisfaction. Digitalization offers opportunities for business model transformation, such as switching to subscription-based services/models, which provide recurring revenue and foster customer loyalty (Ancillai et al., 2022).

In the field of supply chain management, digitalization is introducing smart supply chain operations, where Internet of Things (IoT) devices, sensors, and AI tools improve tracking, predict demands, and optimize inventory management. This leads to more efficient supply chain processes and better resource allocation (AlMulhim, 2021). From a risk management viewpoint, predictive analytics may help firms identify possible risks, ranging from operational interruptions to financial fraud, by analyzing past (historical) data. Digital technologies can also automate compliance inspections, making it easier for organizations to comply with industry requirements. Digitalization has enormous potential for companies to improve productivity, enhance customer experience, innovate, and remain competitive in a digital-first world. To fully realize these benefits, however, successful digital transformation necessitates careful planning of appropriate technology investments and emphasis on security and compliance (Eller et al., 2020; Tremblay et al., 2022).

1.2. Beyond Profit: The Growing Importance of ESG (Environmental, Social and Governance)

According to (Bril et al., 2022) ESG is defined as Environmental, Social, and Governance criteria are used to measure the sustainability and social impacts of investments or businesses. These factors or criteria can be used to evaluate how companies perform in those areas beyond financial returns, focusing on their impact on the global aspects of environmental stewardship, social responsibility, and governance practices. Environmental factors concentrate on a company's efforts to minimize its carbon footprint, including waste reduction, energy efficiency, and sustainable resource utilization. Social criteria determine how companies handle their employees, customers, and communities, utilizing fair labor practices, diversity, and community involvement. Governance encompasses the structures and processes that guide corporate decisions, comprising executive compensation, board independence, and transparency in financial reporting.

ESG (Environment, Social, and Governance) also refers to a set of criteria that organizations use to evaluate their impact on the environment and society and disclose details about their corporate governance practices. By 2010, ESG consideration had become an integral part of both investment and corporate strategy, resulting in increased regulatory scrutiny and a growing concern about climate change, social justice, and corporate accountability. This can lead to improved sustainability practices and long-term financial and non-financial performance and thus increase stakeholders' trust (Friede et al., 2015; D. Z. X. Huang, 2021). Investors may now be interested in ESG information because they may believe that firms prioritizing ESG are more likely to succeed in the future. Firms that consider relevant indicators may be more appealing to lenders since they are viewed as lower-risk lenders. The emergence of impact investing and sustainable finance in recent years has highlighted the increasing recognition that ESG metrics may contribute to financial growth and risk mitigation. As a result, investors and stakeholders are progressively looking into ESG measures to assess a company's ability to manage both financial and non-financial risks (Nollet et al., 2016), assuring sustainable performance and growth. This shift in focus reflects the broader realization that long-term corporate success is linked not only to financial performance but also to a company's ability to solve today's wider social and environmental concerns (Masocha, 2018).

As we have observed in the literature (Lozano, 2011a; Esposito De Falco et al., 2021), ESG performance has grown more incorporated into business strategy, and it is evident that it is intrinsically related to company performance. Companies that integrate ESG criteria typically have excellent long-term financial performance, a low level of risks, and more substantial customer (brand) loyalty. Better ecological practices, e.g., can result in cost savings through energy efficiency, waste management, and reductions. In contrast, solid governance structures are frequently associated with increased decision-making transparency and lower risk associated with regulations. Socially responsible practices like., fair labor policies and diversity initiatives may increase employee satisfaction and loyalty, resulting in higher productivity and more robust market positions.

Organizations typically use ESG criteria to assess their potential risks and opportunities. The data enable them to identify problematic sectors while improving their current operations. ESG-related factors also guide firms and enlighten stakeholders and society, allowing businesses to attract and retain clients and employees who value sustainability initiatives (Amankwah-Amoah & Syllias, 2020). Firms operating in sensitive sectors and producing, e.g., disposable plastic goods, may face increased scrutiny and obligations from investors due to the potential negative environmental impacts. In response to new problems, companies may engage in research and development to create more sustainable production means or minimize their own carbon footprint (Garcia et al., 2017a).

ESG performance indicators represent a shift in how businesses and investors evaluate potential risks, future opportunities, and long-term value. ESG continues to evolve as a powerful lens through which organizations, businesses, and investors can assess corporate social responsibilities (CSR) and their implications. As the global focus on sustainability, social justice, and good governance grows, ESG will likely become an even more integral part of the business and financial landscape (Cai et al., 2012; Sardana et al., 2020).

1.3. Digitalization Meets ESG: How (Digital) Technology Improves ESG Performance and Investments Decisions

Digitalization has brought about significant developments in the field of sustainable finance. Most recently, innovations in digital transformation have opened up new possibilities or avenues for investors to integrate ESG criteria (regardless of the firm's high and low performance) into portfolio construction. These new investments in organizations evolve alongside the technological changes in society at large (Bril et al., 2022).

Recently, the role of digitalization or digital transformation within ESG-related investment decisions has been debated a lot. The starting point for such discussions is usually the recognition that "traditional" ESG data does not provide investors with comprehensive insights into companies' ESG performance (Bril et al., 2022). Some issues arise regarding the fact that most ESG data are self-reported (although after the implementation of the CSRD framework, it is now mandatory for companies) and, consequently, likely to be biased. Other issues arise when focusing on what rating agencies do with this data and the divergence of evaluations, that are created due to raters using different approaches. Given these constraints, digital tools can be used to advance portfolio decision-making, especially in situations where investors want to include extra financial information (e.g., news, social media) in the analysis (Arvidsson & Dumay, 2022).

Digital transformation in an organization can strengthen ESG engagement because it changes not only the firm's internal behavior but also the relationship between the company and external stakeholders (Tremblay et al., 2022). According to (Bidar, 2019; Lee, 2021), digitalization can contribute to a successful ESG strategy in several ways. Firstly, Supply chain transparency, which is facilitated by technologies such as blockchain, ensures improved traceability and accountability in supply chain operations. It allows businesses to verify the sustainability of raw materials and products they utilize. Such transparency is crucial in addressing key ESG issues, including ethical sourcing, rights of labor, and ecological impacts. Additionally, digital tools assist companies in monitoring their suppliers' practices, ensuring adherence to environmental and social standards.

Secondly, Digitalization also benefits employee engagement and well-being. Remote working technologies or software applications (E.g., MS Teams, Zoom, Skype, and Google Meets) reduce commute and office space, which will help companies lower their carbon footprints. These digital tools (technologies) also promote a greater work-life balance, offering employees more flexibility and supporting socially sustainable objectives. Digital platforms allow companies to collect feedback from employees in real time, which will lead to better governance and transparency scores, make it easier to address concerns, and boost organizational culture (Denicolai et al., 2021; Zhou et al., 2021).

Thirdly, Digitalization also contributes to governance by enabling businesses to track board activities, shareholders' engagements, and risk management processes. Governance platforms make it convenient to ensure compliance with regulations and ensure transparency in the decision-making process. These platforms also provide a means to engage with stakeholders, address concerns, and adjust governance strategies as necessary. That is why 80% of G20 firms recently reported using artificial intelligence to analyze and develop risk scenarios (Aboud & Diab, 2019).

While the integration of digitalization and ESG performance provides numerous benefits, businesses must address these challenges (Flyverbom et al., 2019; Bril et al., 2022). Data privacy and security concerns are essential when handling sensitive data related to employees' business operations and supply chains. Furthermore, the lack of standardized ESG reporting frameworks and the complexity of integrating digital tools across industries can make it difficult to implement. Smaller firms or companies may be unable to secure the financial and technical resources that are necessary to develop the required digital infrastructure. Digital infrastructure often requires substantial investments in relevant systems. Implementing these strategies also requires a shift in organizational culture and the ability to enhance workers' or employees' capabilities. It entails the formation of a sustainable mindset among staff and engages various departments, providing training on digitalization-related technology. Companies, at the same time, must provide transparent and meaningful communication with their stakeholders and consider the rapidly evolving regulatory framework surrounding ESG and digitalization (Flyverbom et al., 2017).

2. RESEARCH OBJECTIVE AND SCOPE OF THE STUDY

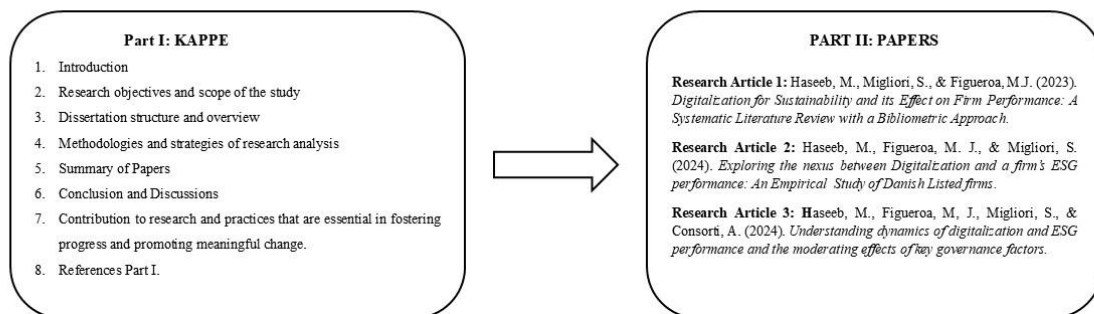
Therefore, based on the above discussion in the literature, this dissertation does not aim to provide a conclusive mapping of the relationship between digitalization, sustainability, and a firm's ESG (Environmental, Social, and Governance) performance. Instead, the objective is to offer insights into how this relationship has evolved or emerged (so far), its impact on various stakeholders, and the challenges that remain to be addressed. For this, the primary objective of this dissertation is to explore/investigate the role of digitalization (transformation) in shaping-up sustainability-initiatives and examine how ESG factors

influence the performance of firms. Additionally, this research will investigate the moderation impact of various factors, e.g., board gender diversity (BGD), Research and Investment (R&D) intensity, ESG controversies, and stock market performance as well. Although these dimensions are very different, all are related and highlight the aspects meaning the governance dimensions within ESG.

3. OVERVIEW OF DISSERTATION STRUCTURE

To achieve the objectives of this dissertation, we divided it into two distinct sections (parts). This first part is the so-called “*kappa*” or framework. Which comprises the research objectives and the scope of the study, methodologies, and strategies of research analysis, and a summary of articles that are part of this thesis. I intentionally skip the literature review of digitalization–sustainability-related initiatives and firm performance. Instead, I focused on citing and discussing the key literature extensively within the three articles included. I concluded Part I of this dissertation with theoretical and practical implications and discussion, as well as limitations and future avenues of research. The second part (Papers) consists of three research articles, each of which has been developed to address the specific objectives of this dissertation.

Dissertation Structure: An Article-Based Approach



In the first research paper (study), we systematically investigated and aimed to provide a comprehensive and up-to-date review of how digitalization impacts sustainable firms' performance and synthesize existing knowledge within an integrated framework. In this study, we also minimize the complexity and provide structure and clarity related to this topic of investigation. The second research article is about the quantitative explores or empirical investigation of digitalization's role in firm ESG

(Environmental, Social, and Governance) performance in the Danish context. It further examines the moderating influence of digitalization on the relationship between stock market valuation and ESG performance, including environmental, social, and governance pillar scores.

Finally, the third research study on this topic examines the impact of digitalization (digital transformation) on the overall ESG performance of Northern European technological firms. While examining the moderation role of ESG controversies, research and development (R&D) intensity and board gender diversity (BGD) in this relationship so far, have been observed.

4. METHODOLOGIES AND STRATEGIES OF RESEARCH ANALYSIS

Different methodologies have been adopted to study this research area within the integrated framework of this thesis. In our first research article, we conducted a systematic literature review adopting a comprehensive bibliometric and bibliographic approach to examine the impact of digitalization on sustainable firm performance. In this study, two different databases were considered for the data collection: **(1)** the Web of Science (WOS) and **(2)** Scopus; in order to identifying 305 English language publications from the period of 2013 to 2023 (ten years).

For the second research study, we employed Ordinary Least Square (OLS), Random Effect (RE), and Fixed Effect (FE), a multiple linear regression model on panel data retrieved from the ⁴Refinitiv Eikon™ database. For the Robustness and heterogeneity concerns, we employed the Two-Step (GMM) Generalized Method of Moments incorporating longitudinal panel data from 67 listed Danish public firms (excluding financial sectors) from the period of 2015 to 2022 (eight-year timespan).

Finally, in the third scholarly article, we utilized data from 145 publicly listed Northern European technological firms from the period 2019 to 2023 (a five-year time period) using the Refinitiv Eikon™ database. To address the potential endogeneity bias, a pooled regression model was applied, and for the robustness validation, two additional quantitatively analyses were performed: (1) The Two-step Generalized Method of Movements (GMM) and (2) the Lagged Ordinary Least Square (OLS) model.

5. SUMMARY OF PAPERS

This doctoral dissertation aims to explore how digitalization influences sustainability initiatives and examine the ESG (Environmental, Social, and Governance) factors that shape this relationship. It also looks at the moderating roles of board gender diversity (BGD), ESG controversies, research and

⁴ (LSEG Annual Report - 2023_ *Partnering to Transform.Pdf*, n.d.)

development (R&D) Intensity, and stock market valuation performance of firms. Although these dimensions are very different, all are related and emphasize the aspects that define the governance dimensions within ESG.

In this section, we provide a brief overview of the three research articles (papers) that form the basis of the dissertation and contribute to the study of this topic. The research findings and the three manuscripts are organized as outlined below.

5.1. ⁵Paper 1: When Digitalization Meets Sustainability: Insights from a Bibliometric and Systematic Literature Review of its impact on firm performance

Paper 1 is co-authored by *Stefania Migliori* and *Maria Josefina Figueroa*. The purpose of the topic of investigation is that digitalization is a growing path for firms to transform their operational strategies, streamline processes, and improve performance. It also provides valuable benefits for organizations and unique opportunities to address the challenges aligned with the United Nations 2030 sustainable agenda (Camodeca & Almici, 2021). This study aims to provide a comprehensive and up-to-date review of how digitalization impacts sustainable firms' performance and synthesize the existing knowledge within an integrated framework. This study also minimizes the complexity and provides structure and clarity related to this topic.

In this study, we conducted a systematic literature review using a comprehensive bibliometric approach (B-SLR) to examine the impact of digitalization on sustainable firm performance. We collected data from Scopus and Web of Science (WOS) databases to identify 305 English-language publications from 2013 to 2023. The descriptive part of bibliometric analysis includes (No. of studies over-time, top publications, countries, sources, and authors) and Science mapping technique are used to analyze the collaboration between countries (including co-occurrence, co-authorship, and co-citation), providing a fundamental characteristic of the existing body of knowledge in this research field. The content analysis highlights four thematic clusters: **(1)** digitalization's impact on sustainable firm performance, **(2)** sustainable corporate performance and green practices, **(3)** integrating industry 4.0 technologies in

⁵ This study was first presented at the Journal of Management Studies Professional Development Workshop, sponsored by the Journal of Management Studies and the Society for the Advancement of Management Studies, held at the University of Edinburgh, UK, on Monday, March 4th, 2024.

Second-time it was presented at the Department of Management Society and Communication (MSC), CBS–Sustainability Center, Copenhagen Business School, Denmark, on Thursday, November 8th, 2023, under the title “Digitalization Initiative for Sustainability.” This article is under review in the Journal of Management Decisions. According to academic journal guidelines for 2024, this journal ranked 2*.

sustainable supply chain management, and (4) digitalization as a driver of circular economy business models. Further, this paper concludes by discussing the most prominent emerging research themes and identifying key research patterns and areas that should be prioritized in future research agendas for those interested in sustainability and firm performance within the context of digitalization.

5.2. ⁶Paper 2: Exploring the Nexus between Digitalization and Firm's ESG Performance: An Empirical Study of Danish Listed Firms

Paper 2 is also co-authored by *Maria Josefina Figueroa* and *Stefania Migliori*. In this study, we stated that the integration of digitalization and the implementation of ESG (Environmental, Social, and Governance) practices can significantly transform business operations and improve a company's financial performance. This study empirically investigates digitalization's role on firms' ESG performance, incorporating longitudinal panel data from sixty-seven publicly listed Danish companies over an eight-year timespan (2015-2022). It also examines the moderating role of digitalization in the relationship between stock market valuation (companies' values according to the financial market) and firm ESG performance (Pillar scores).

To test the hypothesis of our study, we employed Ordinary Least Square (OLS), Random Effects (RE), and Fixed Effects (FE) multiple linear regression models on panel data retrieved from the Refinitiv Eikon™ database. For robustness and to address heterogeneity concerns, the two-step Generalized Method of Moments (GMM) was also employed. The findings indicate that digitalization improves firms' ESG dimensions performance. Furthermore, the relationship between stock market valuation and ESG performance, as well as the environment performance, are positively moderated by digitalization. However, digitalization has been observed to have a moderately adverse effect on the relationship from social and governance perspective.

This study's contribution is threefold: First, it sheds light on the role of digitalization in enhancing firms' ESG performance (including pillar scores). Second, it explores the moderation impact of digitalization on the relationship between stock market valuation and firms' ESG performance. Finally, it provides policy implications, offering insights into the coordination of digitalization and ESG strategies for informed decision-making.

⁶ This article was presented at the Department of Management Society and Communication (MSC), CBS–Sustainability Center, Copenhagen Business School, Denmark. It was submitted to the *Journal of Business Strategies and the Environment*, which is in the “Under-Review” stage. According to academic journal guidelines for 2024, this journal ranked 3.

5.3. ⁷Paper 3: Understanding the Dynamics of Digitalization and ESG Performance and the Moderating Effects of Key Governance Factors

Paper 3 is also co-authored by *Maria Josefina Figueroa, Stefania Migliori, and Augusta Consorti*. In this topic of investigation, we stated that in the present digital age, organizations must be aware of the challenges of digital transformation. Despite its growing importance, there is a lack of research exploring the effects of digitalization on a firm's ESG (Environmental, Social, and Governance) performance. In this study, we examine the impact of digitalization on ESG performance while assessing the moderation roles of board gender diversity, ESG controversies, and research and development (R&D) intensity. Although these three dimensions are very different, all are related and highlight the aspects meaning the governance dimensions within ESG.

We utilized panel data from 145 publicly listed firms in Northern Europe between 2019 and 2023, sourced from the Refinitiv Eikon™ database. To address potential endogeneity bias, an Ordinary Least Square (OLS) regression model was applied. Findings reveal that digitalization significantly improves ESG performance. Board Gender Diversity is identified as a strong positive moderating impact, whereas ESG Controversy adversely influences the relationship between digitalization and ESG performance. R&D intensity, while positively moderating this relationship, shows a comparatively weaker impact.

To validate the robustness of these findings, additional analyses were performed using dynamic panel methods, including the two-step Generalized Method of Moments (GMM) and lagged OLS approach. These robustness checks confirm that core findings are consistent and not compromised by endogeneity concerns. This research provides valuable insights for stakeholders and policymakers and highlights how board gender diversity, ESG controversies, and R&D intensity shape the interplay between digitalization and ESG performance. The results offer a foundation for making informed decisions and fostering sustainable and responsible business practices.

⁷ The authors would like to express sincere gratitude to the Department of Management and Business Administration (DEA), G. D'Annunzio University of Chieti–Pescara, Italy, as well as to the discussion panel and audience for their invaluable and thoughtful contributions during the presentation. The feedback received has greatly enhanced the quality of this study.

6. Contributions to research and practices in digitalization, sustainability initiatives, and ESG performance are essential for fostering progress and promoting meaningful change

How are ESG practices evolving and implemented, and what are the main tensions arising for practitioners in digitalization-sustainability initiatives? The three research papers address these questions by analyzing the role of digital transformation in shaping sustainability initiatives and examining how ESG (Environmental, Social, and Governance) factors influence firm performance through different theoretical lenses. Although each of these papers addresses unique aspects of their subject matter, they are interconnected and collectively enrich the expanding scholarly field that explores the intersection of digitalization and sustainability initiatives. Together, they provide valuable insights that advance our understanding of how technological advancements can promote sustainable business practices.

6.1. Theoretical Contributions

This dissertation contributes to the academic discourse on digitalization (digital transformation) by exploring its core components, specifically in relation to the measurement and management of sustainability issues and their impact on corporate (firms) ESG performance. By employing a systematic literature review and incorporating empirical insights, this study moves beyond existing tensions identified in the literature to offer a nuanced understanding of the challenges faced by practitioners. In doing so, it situates itself within the growing body of literature that examines the impact of digitalization practices alongside emerging debates on sustainability measurements while integrating ESG performance perspectives.

From a professional point of view, this dissertation shows that companies embracing digitalization can experience significant improvements in their performance. One key area of impact is stakeholder engagement, where the use of digital platforms to communicate information plays an important role in shaping market reactions. As a result, companies must manage their digital reputations carefully, as doing so can generate value for stakeholders and enhance both financial and non-financial outcomes (Q. Huang et al., 2023). It is recommended that companies investing in digital technologies should focus on strengthening their digital presence to fully leverage the benefits of these changes. Moreover, transparent non-financial reporting – covering areas such as economic, social, and environmental performance – guides companies to build trust with stakeholders (Ren et al., 2023). Organizations that consistently report on their progress toward sustainable development goals improve the quality of information they provide. By adhering to high standards for non-financial reporting, companies ensure that the data is accurate and assessable, making it more meaningful and reliable for those who rely on it (Girón et al., 2021; Rauf et al., 2024).

The first article (study) of this dissertation is a systematic literature review (with a bibliographic and bibliometric approach) that identifies a growing academic and practical interest in the emerging intersection of digitalization and sustainability topic of investigation over the past decade. This approach gives valuable insights for companies or firms to address key (emerging) sustainability challenges, such as greenhouse gas emissions, water waste management, energy consumption, and the utilization of resources (Rauf et al., 2024). To build a sustainable development strategy, organizations should adopt tools as outlined in the UN 2030 agenda to standardize digital reporting in order to reduce information asymmetries between businesses and stakeholders. By aligning their goals with the Sustainable Development Goals (SDGs) framework, organizations can articulate their sustainability strategies more effectively. This approach fosters greater trust and garners support from the market (Cf, 2015; Gupta & Vegelin, 2016).

In the second article of this thesis, empirical evidence from this research supports the theoretical perspective that digitalization positively influences ESG (environmental, social and governance) performance. Digital transformation not only improves ESG outcomes (overall and each sub-theme) but also strengthens the relationship between investments in sustainability and financial performance (Garcia et al., 2017b). In addition, our research underscores the significance of both firm size and firm growth when examining how these factors interact with firm stock market performance. The interaction plays a critical moderating role in the association between digitalization and environmental, social and governance (ESG) performance. Our findings suggest that the impact of digitalization on ESG outcomes may vary depending on the overall size of firms and their growth trajectory, all while being influenced by the firm's performance in the stock market valuation.

In the third article of this dissertation, the study underscores the critical importance of actively engaging with Environmental, Social and Governance (ESG) strategies. We argue that companies prioritizing profit maximization without considering the interests of stakeholders are likely to jeopardize investors' confidence and tarnish their corporate reputation. Firms that overlook the wider social and environmental ramifications of their operations may encounter severe long-term consequences. These can include a significant erosion of stakeholders' trust and increased vulnerability to multiple risks such as corruption and environmental degradation. By adopting a holistic approach that values sustainable practices and stakeholder engagement, companies can foster a more resilient and trustworthy business model approach (Arthur, 2009; Flyverbom et al., 2019).

This thesis deepens our theoretical understanding of the ways in which digital transformation can serve as a catalyst for environmental, social, and governance (ESG) initiatives, resulting in improved corporate sustainability practices. It highlights the critical necessity of harmonizing business strategies with both financial objectives, which prioritize shareholders' interests and non-financial objectives, which focus

on the needs and concerns of broader stakeholder groups. Exploring these connections, this thesis underscores the significant role technology (digitalization) plays in fostering sustainable business practices that benefit the entire ecosystem.

6.2. Practical and Policy Implications

Gaining insights into the ways digitalization can support sustainability objectives and enhance ESG performance within firms is important not only from a theoretical perspective but also has substantial practical and policy implications.

From a practical perspective, this dissertation implies significant implications for multiple stakeholders (managers, regulatory bodies, NGOs) who are interested in understanding the intertwined relationship between digitalization and the ESG (environmental, social and governance) performance of firms. This field of investigation is relatively new and underexplored, and this thesis addresses the pressing need for additional empirical investigations on this research topic. Managers should make strategic investments in digitalization processes, including technologies like blockchain, artificial intelligence and the Internet of Things. These technologies have demonstrated the potential to promote green innovations and drive sustainability efforts. For example, artificial intelligence plays a necessary role during production processes. Further, the Internet of Things enhanced real-time data monitoring of environmental compliance, which contributes to greater transparency and efficiency in public welfare infrastructure. Together these technologies help to mitigate advanced environmental, social and governance objectives (Flyverbom et al., 2017, 2019). Similarly, regulatory bodies are instrumental in promoting digital transformation, especially for organizations with limited resources for digital investments. By fostering a supportive environment, they can empower these organizations to leverage digital tools and capabilities effectively, which leads to significant growth and innovation.

In the digital economy, companies must accelerate digital transformation to improve economic and social values, which in turn supports and boosts sustainable competitiveness. Digital transformation enables firms to address environmental issues more effectively, strengthening stakeholder connections and reducing agency conflicts and information asymmetry to improve ESG performance. By embracing digital tools within the ESG framework, firms can unlock profound social and environmental values, transforming traditional business practices to meet the inspiring demands of a sustainable future (Antoncic, 2020).

From a policy implication perspective, we must focus on the key considerations at hand. Firms must implement training programs to upskill employees in digital competencies focusing on ESG outcomes and collaborate with universities or educational institutions to integrate ESG-focused digital skills into their prospectuses. Providing subsidies or low-interest-based loans to firms for adopting digitalization that leads

to better ESG performance. For example, carbon footprint monitoring software and governance risk management systems will facilitate access to these tools. Also, they can foster public-private partnerships between the government, private sectors, and technological companies to drive innovation and share best practices across industries, contributing to a more sustainable and responsible business environment.

In addition governments should introduce financial incentives, such as tax breaks or subsidies, for digital innovations demonstrating advanced sustainability and encouraging widespread adoption. To strengthen governance, policies mandating or incentivizing board gender diversity may prove beneficial, as research suggests that diverse boards are more effective in overseeing ESG outcomes, particularly when employing digital tools (Sila et al., 2016). Moreover, policymakers might consider implementing mandatory digital frameworks for ESG risk monitoring, which could enhance transparency and aid firms in managing reputational risk associated with ESG controversies. Furthermore, requirements for detailed disclosure of R&D investments, particularly those aimed at sustainability, could foster greater accountability and ensure alignment with ESG objectives. For board members, digital literacy training programs in ESG could improve their capacity to govern this initiative effectively.

6.3. Limitations and Future Research

After delineating this thesis's theoretical and practical contributions, it is crucial to acknowledge the overarching limitation and future research direction that applies to all components of this study. First, this thesis includes three research articles employing distinct research approaches: a literature review with bibliometric and bibliographic data, empirical analysis, and quantitative investigations. While this diversity of papers constitutes a strength, it also implies that the primary database offered by this thesis is limited to one experimental study.

The bibliometric analysis relies on Scopus and Web of Science databases, which may exclude relevant studies or articles that are not indexed in these two databases. Future research should expand the selection of databases (Ei Compendex and Inspec) to provide a more comprehensive review. The citation-oriented methodology approach may take time to capture emerging trends, and alternative tools might offer a more thorough analysis. Data is drawn from the Refinitiv Eikon™ databases for empirical analysis. Future studies could widen the scope by considering additional databases (Sustainalytics, Bloomberg, DataStream, and WARDS) to improve the generalizability of the results. This dissertation primarily focuses on digitalization's impacts on Sustainability initiatives and ESG performance of firms. Future work could examine its effect on other performance metrics, such as financial, operational, and market outcomes. Investigating the moderation role of digitalization on ESG performance relationships in the context of institutional factors such as corporate governance would offer additional insights.

In this dissertation, the use of econometric estimation techniques (OLS, FE, RE, GMM) brings to light the potential for biases that may arise from omitted variables. It is essential to recognize how these gaps can influence our findings and interpretations, adding an intriguing layer of complexity to the analysis. Employing a broader range of estimation methods could mitigate these limitations. Future research could replicate this study in different country contexts, extend the analysis period timeframe, and apply alternative estimation methods to track how digitalization and ESG practices evolve over time. Adopting a mixed-methodological approach could also provide a broader understanding of these dynamics.

7. CONCLUSION AND DISCUSSION

This thesis's overarching aim was to understand the association between digitalization-sustainability initiatives and firms' ESG (Environmental, Social, and Governance) performance. Additionally, the study examines the potential moderating effects of multiple associated factors, such as board gender diversity (BGD), research and development (R&D) intensity, ESG controversies, and stock market valuation on this association.

To fulfill the objective of this dissertation, three (3) research papers were developed. The first of these, titled **(1)**, *“When Digitalization Meets Sustainability: Insights from a Bibliometric and Systematic Literature Review of its Impact on firm performance,”* employs a comprehensive bibliometric and bibliographic methodological approach to address the fragmented nature of existing research on the role of digitalization in improving sustainable firm performance. This study aims to establish a clear framework for future investigations in a domain that has yet to be fully defined. In this study, we synthesize the multiple perspectives currently presented in the literature regarding the impact of digitalization on firm sustainability and performance, also highlighting both positive and negative outcomes. Then, we apply a systematic review methodology incorporating both bibliometric and bibliographic approaches to offer a structured overview of the current state of knowledge. This provides a contextual framework to guide future scholars and practitioners in navigating the complexities of the field.

The significant contribution of this study is the identification of four major key thematic clusters: **(i)** the impact of digitalization on sustainable firm performance, **(ii)** sustainable corporate performance and green practices, **(iii)** integrating industry 4.0 technologies for sustainable supply chain management, **(iv)** digitalization as a driver of circular economy business models. Further, through an in-depth content analysis of these four thematic areas/themes, we identified and highlighted twenty emerging research areas for further investigation, thereby providing a foundation for future research agendas. As the first (research paper) of this dissertation, this study not only clarifies the existing literature but also offers a coherent

framework for addressing the potential challenges associated with digitalization and sustainability, helping to structure the fragmented research in this emerging (topic) field.

The Second (2) Paper of this dissertation, *"Exploring the Nexus between Digitalization and Firm ESG Performance: An Empirical Study of Danish Listed Firms,"* empirically investigates the role of digitalization in shaping firms' ESG performance, with a specific focus on the sub-themes (Environmental, Social, and Governance) pillar scores. This study's empirical findings support the positive relationship between digitalization and ESG performance, including (ESG) sub-themes suggesting that adopting digitalization (digital technologies) enhances firms' performance (Peng & Tao, 2022; Q. Huang et al., 2023). This performance improvement primarily reflected the efficient utilization of resources and the development of new products and services within the assembly lines, strengthening a firm's market position, reputation, and customer loyalty (Fang et al., 2023). Additionally, this study highlights that digital transformation opens new doors for growth (opportunities), which reinforces the broader impact on both (firms) operational and sustainable (ESG) performance.

These findings further demonstrate that (digital) transformation improves a company's environmental, social, and governance performance. Digital initiatives enable firms to share data and resources with key stakeholders, optimizing their resources and boosting ESG performance (Cappa et al., 2021). Further, these results indicate that digitalization also positively moderates the impact on the stock market and environmental performance of firms. Companies invest in digital technologies not just to adapt to environmental changes but to establish a competitive advantage (Bahadori et al., 2021). These findings emphasize that smaller firms, despite their limited resources, tend to produce or emit less pollution and demonstrate improved environmental practices due to greater external pressures. In contrast, larger companies engage with a broader array of stakeholders and comply with stringent government regulations. They must adeptly manage diverse environmental data and allocate resources in a more effective and efficient manner (Ribeiro-Navarrete et al., 2021; Broccardo et al., 2023).

However, results also reveal that digitalization negatively moderates the association between stock market valuation and Social and Governance performance. These findings underscore the growing uncertainty and complexity within the business environment. Investing in carbon reduction technologies and embracing renewable energy represents a significant step forward in promoting sustainability (Qin et al., 2022). By focusing on the construction of green buildings and factories, as well as the development of low-carbon products, we make substantial progress towards a healthier environment. Additionally, integrating digital technologies into these efforts enhances transformation potential while providing opportunities to effectively manage and mitigate associated risks. Together, these initiatives pave the way for a more sustainable and resilient future. It is important to recognize that these factors include substantial

capital expenditures, which, while aimed at improving ESG performance, may lead to higher operational costs and a negative impact on the financial, social, and governance outcomes of companies (Broadstock et al., 2021; Feng et al., 2022). While digitalization enhances ESG performance, it also presents challenges, particularly in terms of cost and risk management.

Finally, the third **(3)** paper of this dissertation, *“Understanding the Dynamics of Digitalization and ESG Performance and the moderating effects of key governance factors,”* empirically examines the role of digitalization on the ESG (environmental, social, and governance) performance of firms operating in technological sectors. We also discuss the moderating influence of board gender diversity (BGD), ESG Controversies, and research and development (R&D) intensity in relationships. The finding highlights that digitalization (digital transformation) significantly impacts a firm ESG performance. It underscores the fundamental role of digital technologies in enhancing operational efficiency, promoting transparency, and encouraging meaningful engagement with stakeholders (Fang et al., 2023). Incorporating digital processes into corporate reporting enhances the accuracy and timeliness of decision-making processes, leading to improved ESG ratings. These outcomes also provide evidence of digitalization's transformative effect on corporate practices and its capacity to drive sustainable business outcomes. The innovative adoption of cutting-edge digital technologies like cloud computing, artificial intelligence, blockchain, and big data analytics gives practical solutions for boosting firm ESG capabilities and is emerging as a powerful driving force to endorse ESG developments (Tan & Zhu, 2022; Rauf et al., 2024).

This thesis also highlights that increasing board gender diversity (BGD) has a positive influence on firms' digital transformation and ESG performance. The findings highlight that female directors enhance a firm's digital transformation by prioritizing stakeholders' interests and adapting services to meet customers' evolving needs. The use of digital tools to engage with customers is crucial in enhancing a company's financial stability and overall success (Kyaw et al., 2017; Muhammad & Migliori, 2023). However, ESG controversies are negatively associated with this relationship. The results suggest that controversies generate negative perceptions among stakeholders, undermining the benefits of digitalization efforts. Controversies like, (negative media coverage, lawsuits, data privacy, governance, and ethics) resulting firms losing market share due to negative corporate social responsibility-related media coverage and also adversely impact stakeholders (Nirino et al., 2021; Brinette et al., 2024). In the meantime, the intensity of R&D positively moderates the relationship between digitalization and ESG performance, although the statistical significance is somewhat less pronounced (insignificant). However, we have seen in the literature (Brown et al., 2012; J. Huang et al., 2021; Muhammad et al., 2022), that the strategic value of R&D investments, especially in the technological sector, confers a competitive advantage, reduces dependence on external financing, and mitigates growth risks through participation in strategic knowledge

networks. Digital tools allow firms to optimize their R&D capabilities, facilitate more targeted efforts, and promote cross-departmental knowledge sharing. R&D intensity has been associated with the advancement of green innovations, including the development of environmentally friendly products and processes that positively influence ESG performance (Banerjee & Gupta, 2019).

Overall, understanding and comprehending the relevance of ESG is critical for managers who want to secure their firm's survival and legitimacy by meeting the demands of all stakeholders, including employees, investors, customers, and society at large. Proactive participation in ESG efforts can boost corporate value and develop stakeholder trust. Firms that focus primarily on financial activity and prioritize short-term gains undermine investors' perceptions and stakeholder relationships. Companies engaged in contentious operations may face risks to their legitimacy and may need to ramp up their reputation and legitimize their conduct (Lozano, 2011b; Esposito De Falco et al., 2021).

8. REFERENCES PART 1

- Aboud, A., & Diab, A. (2019). The financial and market consequences of environmental, social and governance ratings: The implications of recent political volatility in Egypt. *Sustainability Accounting, Management and Policy Journal*, 10(3), 498–520. <https://doi.org/10.1108/SAMPJ-06-2018-0167>
- AlMulhim, A. F. (2021). Smart supply chain and firm performance: The role of digital technologies. *Business Process Management Journal*, 27(5), 1353–1372.
- Amankwah-Amoah, J., & Syllias, J. (2020). Can adopting ambitious environmental sustainability initiatives lead to business failures? An analytical framework. *Business Strategy and the Environment*, 29(1), 240–249. <https://doi.org/10.1002/bse.2361>
- Ancillai, C., Marinelli, L., & Pascucci, F. (2022). Digital-Driven Business Model Innovation: The Role of Data in Changing Companies' Value Logic. In M. Ratajczak-Mrozek & P. Marszałek (Eds.), *Digitalization and Firm Performance: Examining the Strategic Impact* (pp. 73–98). Springer International Publishing. https://doi.org/10.1007/978-3-030-83360-2_4
- Antonicic, M. (2020). Uncovering hidden signals for sustainable investing using Big Data: Artificial intelligence, machine learning and natural language processing. *Journal of Risk Management in Financial Institutions*, 13(2), 106–113.
- Arthur, W. B. (n.d.). *Where is technology taking the economy?*
- Arthur, W. B. (2009). *The Nature of Technology: What It Is and How It Evolves*. Simon and Schuster.
- Arvidsson, S., & Dumay, J. (2022). Corporate ESG reporting quantity, quality and performance: Where to now for environmental policy and practice? *Business Strategy and the Environment*, 31(3), 1091–1110. <https://doi.org/10.1002/bse.2937>
- Bahadori, N., Kaymak, T., & Seraj, M. (2021). Environmental, social, and governance factors in emerging markets: The impact on firm performance. *Business Strategy & Development*, 4(4), 411–422. <https://doi.org/10.1002/bsd2.167>
- Banerjee, R., & Gupta, K. (2019). The effect of environmentally sustainable practices on firm R&D: International evidence. *Economic Modelling*, 78, 262–274. <https://doi.org/10.1016/j.econmod.2018.09.024>
- Bidar, F. (2019). Digitalisation of supply chain management and firm performance: Structural equation modelling and empirical findings. In *Digitalisation of Supply Chain Management and Firm Performance: Structural Equation Modelling and Empirical Findings*. Nova Science Publishers, Inc. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85089047356&partnerID=40&md5=b896d8651c5f666ebfd0415c1fdff3bb>
- Bloomberg, J. (n.d.). *Digitization, Digitalization, And Digital Transformation: Confuse Them At Your Peril*. Forbes. Retrieved 20 December 2024, from <https://www.forbes.com/sites/jasonbloomberg/2018/04/29/digitization-digitalization-and-digital-transformation-confuse-them-at-your-peril/>

- Bril, H., Kell, G., & Rasche, A. (Eds.). (2022). *Sustainability, Technology, and Finance: Rethinking How Markets Integrate ESG*. Routledge. <https://doi.org/10.4324/9781003262039>
- Brinette, S., Sonmez, F. D., & Tournus, P. S. (2024). ESG Controversies and Firm Value: Moderating Role of Board Gender Diversity and Board Independence. *IEEE Transactions on Engineering Management*, 71, 4298–4307. *IEEE Transactions on Engineering Management*. <https://doi.org/10.1109/TEM.2023.3236667>
- Broadstock, D. C., Chan, K., Cheng, L. T. W., & Wang, X. (2021). The role of ESG performance during times of financial crisis: Evidence from COVID-19 in China. *Finance Research Letters*, 38, 101716. <https://doi.org/10.1016/j.frl.2020.101716>
- Broccardo, L., Truant, E., & Dana, L.-P. (2023). The interlink between digitalization, sustainability, and performance: An Italian context. *Journal of Business Research*, 158, 113621. <https://doi.org/10.1016/j.jbusres.2022.113621>
- Brown, J. R., Martinsson, G., & Petersen, B. C. (2012). Do financing constraints matter for R&D? *European Economic Review*, 56(8), 1512–1529. <https://doi.org/10.1016/j.eurocorev.2012.07.007>
- Cai, Y., Jo, H., & Pan, C. (2012). Doing Well While Doing Bad? CSR in Controversial Industry Sectors. *Journal of Business Ethics*, 108(4), 467–480. <https://doi.org/10.1007/s10551-011-1103-7>
- Camodeca, R., & Almici, A. (2021). Digital transformation and convergence toward the 2030 agenda's sustainability development goals: Evidence from Italian listed firms. *Sustainability*, 13(21), 11831.
- Cappa, F., Oriani, R., Peruffo, E., & McCarthy, I. (2021). Big data for creating and capturing value in the digitalized environment: Unpacking the effects of volume, variety, and veracity on firm performance. *Journal of Product Innovation Management*, 38(1), Article 1.
- Cf, O. (2015). Transforming our world: The 2030 Agenda for Sustainable Development. *United Nations: New York, NY, USA*.
- Denicolai, S., Zucchella, A., & Magnani, G. (2021). Internationalization, digitalization, and sustainability: Are SMEs ready? A survey on synergies and substituting effects among growth paths. *Technological Forecasting and Social Change*, 166, 120650.
- Eller, R., Alford, P., Kallmünzer, A., & Peters, M. (2020). Antecedents, consequences, and challenges of small and medium-sized enterprise digitalization. *Journal of Business Research*, 112, 119–127.
- Esposito De Falco, S., Scandurra, G., & Thomas, A. (2021). How stakeholders affect the pursuit of the Environmental, Social, and Governance. Evidence from innovative small and medium enterprises. *Corporate Social Responsibility and Environmental Management*, 28(5), 1528–1539. <https://doi.org/10.1002/csr.2183>
- Fang, M., Nie, H., & Shen, X. (2023). Can enterprise digitization improve ESG performance? *Economic Modelling*, 118, 106101. <https://doi.org/10.1016/j.econmod.2022.106101>
- Feng, J., Goodell, J. W., & Shen, D. (2022). ESG rating and stock price crash risk: Evidence from China. *Finance Research Letters*, 46, 102476. <https://doi.org/10.1016/j.frl.2021.102476>

- Flyverbom, M., Deibert, R., & Matten, D. (2019). The Governance of Digital Technology, Big Data, and the Internet: New Roles and Responsibilities for Business. *Business & Society*, 58(1), 3–19. <https://doi.org/10.1177/0007650317727540>
- Flyverbom, M., Madsen, A. K., & Rasche, A. (2017). Big data as governmentality in international development: Digital traces, algorithms, and altered visibilities. *The Information Society*, 33(1), 35–42. <https://doi.org/10.1080/01972243.2016.1248611>
- Friede, G., Busch, T., & Bassen, A. (2015). ESG and financial performance: Aggregated evidence from more than 2000 empirical studies. *Journal of Sustainable Finance & Investment*, 5(4), 210–233. <https://doi.org/10.1080/20430795.2015.1118917>
- Garcia, A. S., Mendes-Da-Silva, W., & Orsato, R. J. (2017a). Sensitive industries produce better ESG performance: Evidence from emerging markets. *Journal of Cleaner Production*, 150, 135–147. <https://doi.org/10.1016/j.jclepro.2017.02.180>
- Garcia, A. S., Mendes-Da-Silva, W., & Orsato, R. J. (2017b). Sensitive industries produce better ESG performance: Evidence from emerging markets. *Journal of Cleaner Production*, 150, 135–147. <https://doi.org/10.1016/j.jclepro.2017.02.180>
- Girón, A., Kazemikhasragh, A., Cicchiello, A. F., & Panetti, E. (2021). Sustainability Reporting and Firms' Economic Performance: Evidence from Asia and Africa. *Journal of the Knowledge Economy*, 12(4), 1741–1759. <https://doi.org/10.1007/s13132-020-00693-7>
- Gupta, J., & Vegelin, C. (2016). Sustainable development goals and inclusive development. *International Environmental Agreements: Politics, Law and Economics*, 16(3), 433–448. <https://doi.org/10.1007/s10784-016-9323-z>
- Harrmann, L. K., Eggert, A., & Böhm, E. (2023). Digital technology usage as a driver of servitization paths in manufacturing industries. *European Journal of Marketing*, 57(3), 834–857. <https://doi.org/10.1108/EJM-11-2021-0914>
- Hinings, B., Gegenhuber, T., & Greenwood, R. (2018). Digital innovation and transformation: An institutional perspective. *Information and Organization*, 28(1), 52–61. <https://doi.org/10.1016/j.infoandorg.2018.02.004>
- Huang, D. Z. X. (2021). Environmental, social and governance (ESG) activity and firm performance: A review and consolidation. *Accounting & Finance*, 61(1), 335–360. <https://doi.org/10.1111/acfi.12569>
- Huang, J., Zhao, J., & Cao, J. (2021). Environmental regulation and corporate R&D investment—Evidence from a quasi-natural experiment. *International Review of Economics & Finance*, 72, 154–174. <https://doi.org/10.1016/j.iref.2020.11.018>
- Huang, Q., Xu, C., Xue, X., & Zhu, H. (2023). Can digital innovation improve firm performance: Evidence from digital patents of Chinese listed firms. *International Review of Financial Analysis*, 89, 102810. <https://doi.org/10.1016/j.irfa.2023.102810>

- Kyaw, K., Olugbode, M., & Petracci, B. (2017). Can board gender diversity promote corporate social performance? *Corporate Governance (Bingley)*, 17(5), 789–802. Scopus.
<https://doi.org/10.1108/CG-09-2016-0183>
- Lee, S.-Y. (2021). Sustainable supply chain management, digital-based supply chain integration, and firm performance: A cross-country empirical comparison between south korea and vietnam. *Sustainability (Switzerland)*, 13(13). <https://doi.org/10.3390/su13137315>
- Lozano, R. (2011a). Addressing stakeholders and better contributing to sustainability through game theory. *Journal of Corporate Citizenship*, 43, 45–62.
- Lozano, R. (2011b). Addressing stakeholders and better contributing to sustainability through game theory. *Journal of Corporate Citizenship*, 43, Article 43.
- LSEG Annual Report—2023 _ Partnering to transform.pdf*. (n.d.).
- Masocha, R. (2018). Does environmental sustainability impact innovation, ecological and social measures of firm performance of SMEs? Evidence from South Africa. *Sustainability (Switzerland)*, 10(11).
<https://doi.org/10.3390/su10113855>
- Montero Guerra, J. M., Danvila-del-Valle, I., & Méndez-Suárez, M. (2023). The impact of digital transformation on talent management. *Technological Forecasting and Social Change*, 188, 122291. <https://doi.org/10.1016/j.techfore.2022.122291>
- Muhammad, H., & Migliori, S. (2023). Effects of board gender diversity and sustainability committees on environmental performance: A quantile regression approach. *Journal of Management & Organization*, 29(6), 1051–1076. <https://doi.org/10.1017/jmo.2022.8>
- Muhammad, H., Migliori, S., & Mohsni, S. (2022). Corporate governance and R&D investment: The role of debt financing. *Industrial and Corporate Change*, 31(3), 628–653.
<https://doi.org/10.1093/icc/dtab056>
- Nirino, N., Santoro, G., Miglietta, N., & Quaglia, R. (2021). Corporate controversies and company's financial performance: Exploring the moderating role of ESG practices. *Technological Forecasting and Social Change*, 162, 120341. <https://doi.org/10.1016/j.techfore.2020.120341>
- Nollet, J., Filis, G., & Mitrokostas, E. (2016). Corporate social responsibility and financial performance: A non-linear and disaggregated approach. *Economic Modelling*, 52, 400–407.
<https://doi.org/10.1016/j.econmod.2015.09.019>
- Peng, Y., & Tao, C. (2022). Can digital transformation promote enterprise performance? —From the perspective of public policy and innovation. *Journal of Innovation & Knowledge*, 7(3), 100198.
<https://doi.org/10.1016/j.jik.2022.100198>
- Qin, X., Wu, H., & Li, R. (2022). Digital finance and household carbon emissions in China. *China Economic Review*, 76, 101872. <https://doi.org/10.1016/j.chieco.2022.101872>
- Rauf, F., Wanqiu, W., Naveed, K., Qadri, S. U., & Ali, M. S. e. (2024). How ESG reporting is effected by sustainable finance and green innovation: Moderating role of sales growth. *Environmental Science and Pollution Research*, 31(5), 7246–7263. <https://doi.org/10.1007/s11356-023-31479-4>

- Ren, X., Zeng, G., & Zhao, Y. (2023). Digital finance and corporate ESG performance: Empirical evidence from listed companies in China. *Pacific-Basin Finance Journal*, 79, 102019. <https://doi.org/10.1016/j.pacfin.2023.102019>
- Ribeiro-Navarrete, S., Botella-Carrubi, D., Palacios-Marqués, D., & Orero-Blat, M. (2021). The effect of digitalization on business performance: An applied study of KIBS. *Journal of Business Research*, 126, 319–326. <https://doi.org/10.1016/j.jbusres.2020.12.065>
- Sardana, D., Gupta, N., Kumar, V., & Terziovski, M. (2020). CSR ‘sustainability’ practices and firm performance in an emerging economy. *Journal of Cleaner Production*, 258. <https://doi.org/10.1016/j.jclepro.2020.120766>
- Sila, V., Gonzalez, A., & Hagendorff, J. (2016). Women on board: Does boardroom gender diversity affect firm risk? *Journal of Corporate Finance*, 36, 26–53. <https://doi.org/10.1016/j.jcorpfin.2015.10.003>
- Tan, Y., & Zhu, Z. (2022). The effect of ESG rating events on corporate green innovation in China: The mediating role of financial constraints and managers’ environmental awareness. *Technology in Society*, 68, 101906. <https://doi.org/10.1016/j.techsoc.2022.101906>
- Tremblay, D.-G., Yagoubi, A., & Psyché, V. (2022). Digital Transformation: An Analysis of the Role of Technology Service Providers in Montreal’s Emerging AI Business Ecosystem. In M. Ratajczak-Mrozek & P. Marszałek (Eds.), *Digitalization and Firm Performance: Examining the Strategic Impact* (pp. 17–44). Springer International Publishing. https://doi.org/10.1007/978-3-030-83360-2_2
- Wu, K., & Lu, Y. (2023). Corporate digital transformation and financialization: Evidence from Chinese listed firms. *Finance Research Letters*, 57, 104229. <https://doi.org/10.1016/j.frl.2023.104229>
- Zeng, H., Ran, H., Zhou, Q., Jin, Y., & Cheng, X. (2022). The financial effect of firm digitalization: Evidence from China. *Technological Forecasting and Social Change*, 183. <https://doi.org/10.1016/j.techfore.2022.121951>
- Zhou, D., Kautonen, M., Dai, W., & Zhang, H. (2021). Exploring how digitalization influences incumbents in financial services: The role of entrepreneurial orientation, firm assets, and organizational legitimacy. *Technological Forecasting and Social Change*, 173, 121120.

PART II: PAPERS

9. PAPER 1:

When Digitalization Meets Sustainability: Insights from a Bibliometric and Systematic Literature Review of its impacts on firm performance.

Muhammad Haseeb

Department of Advanced Technologies and Medicine & Dentistry (*DITM&O*). Center for Advanced Studies and Technology (CAST). G. D'Annunzio University of Chieti–Pescara (Italy).

Stefania Migliori

Department of Management and Business Administration. G. D'Annunzio University of Chieti–Pescara, Italy.

Maria Josefina Figueroa

Department of Management Society and Communications (MSC). CBS Sustainability – Center for Business and Development Studies. Copenhagen Business School, Denmark.

Submitted to:

Journal of Meditari Accountancy Research (In-Review)

Presented at:

Journal of Management Studies Professional Development Workshop, sponsored by the Journal of Management Studies and the Society for the Advancement of Management Studies, held at the University of Edinburgh, UK, on Monday, March 4th, 2024.

Department of Management Society and Communication (MSC), CBS–Sustainability Center, Copenhagen Business School, Denmark, on Thursday, November 8th, 2023, under the title “Digitalization Initiative for Sustainability.”

⁸Abstract

Purpose – In recent years, digitalization has become a critical force driving the transformation of a firm's operational strategies, enhancing process efficiency and improving overall performance. Beyond operational improvements, digitalization provides organizations with significant opportunities to address the challenges aligned with the United Nation's 2030 Sustainable Development Goals (SDGs). This study aims to provide a comprehensive and up-to-date review of how digitalization influences sustainability initiatives and their impact on firm performance. Additionally, it synthesizes the existing body of knowledge into an integrated framework, simplifying the complexities of this subject and providing clarity and structure to its key concepts.

Design/Methodology/Approach – This research utilizes a systematic literature review combined with a comprehensive bibliometric approach (B-SLR) to examine the relationship between the digitalization-sustainability nexus and the performance of firms. Data was collected from SCOPUS and Web of Science (WOS), resulting in 305 English-language publications from 2013 to 2023. The study provides an in-depth examination of the current research landscape, highlighting the intersection of these critical areas.

Findings – The bibliometric analysis part is divided into two primary sections. The first section focuses on performance analysis, covering aspects such as; the number of studies published over time, leading publications sources and journals, top publication countries, geographical distribution of countries, and the key authors and their most cited works. The second section presents a science mapping analysis, which includes countries' collaborations, co-authorship analysis, co-citation trends, keywords of co-occurrence, and density analysis. These analysis provides valuable insights into the fundamental characteristics of research in this field. Additionally, Content analysis highlights four thematic clusters: (1) digitalization's impact on sustainable firm performance, (2) sustainable corporate performance and green practices, (3) integrating industry 4.0 technologies in sustainable supply chain management, and (4) digitalization as the driver of circular economy business models.

Originality/Value – This paper concludes by discussing the most prominent emerging research themes, identifying key trends in the literature, and suggesting areas that should be prioritized in future research agendas. The findings offer valuable guidance for scholars and practitioners seeking to understand the

⁸ **Abbreviations:** SDGs – Sustainable Development Goals; SLR – Systematic Literature Review; CSR – Corporate Social Responsibility; CE – Circular Economy; SSCM – Sustainable Supply Chain Management. WOS – Web of Science.

relationship between digitalization, sustainability and firm performance, while also informing future studies in this increasingly relevant area.

Research Limitations/Implications – This study acknowledges several limitations. The reliance on SCOPUS and Web of Science databases may narrow the scope of the review, potentially omitting relevant studies from other sources. Furthermore, the exclusion of book chapters, conference papers, reports, and non-English publications may result in the omission of important contributions. The VOS-Viewer tool was used for data analysis; however, the use of alternative software might have provided additional insights and a more comprehensive perspective.

Keywords – Digitalization, Sustainability Initiatives, Firm Performance, Bibliometric Analysis, SLR

Paper Type – Literature Review

9.1. Introduction

Digitalization is the powerful engine that drives economic development and growth worldwide. In a fast-growing and transforming environment, organizations are obliged to adopt and utilize digital technologies (solutions), which are resulting in structural and reversible changes in business processes. In 2018, digitally transformed firms represented 13.5 billion US dollars of global GDP by the end of 2023, and they are expected to be 53.3 billion US dollars, over half of the general nominal GDP (Statista, 2023). The term “Digital Transformation” stems from the concept of “Digitalization,” which refers to leveraging digital technologies to innovate business models, open up new revenue streams, and unlock valuable opportunities for growth (Kohtamäki et al., 2019; Parida et al., 2019). According to (Bloomberg, 2018) digitalization is a process of application of digital technologies and describes how social interactions are increasingly restructured through digital communication. It also explains the transition process from analogue to digital operations and how this shift shapes our lives.

Digital technologies include Industry 4.0 (I4.0), the Internet of Things (IoT), Big data analytics (BDA), Blockchain technology, Artificial intelligence (AI), Cloud computing, Cyber-physical systems (CPS), Machine learning, Virtual and augmented reality (VR/AR), Automation robotics, and so on (Sony & Naik, 2020). Incorporating these technologies into the (digital) transformation process presents an opportunity for real-time data availability and improved connectivity. By doing so, organizations can proactively identify potential issues which improve the decision-making process. This proactive stance allows for timely adjustments in response to disruptions and ongoing challenges, fostering greater responsiveness, resilience, and sustainability in the operations (Ogrea et al., 2024). Therefore, companies must seize the initiatives and nurture specific capabilities at various organizational and operational levels of their business model to achieve the benefits of successful digital transformation adoption (Battistella et al., 2017; Eller et al., 2020a).

In today’s socio-economic landscape, businesses are confronted with considerable challenges. Therefore, pursuing innovative (digital) strategies and more effective methods for enhancing competitiveness and increasing value is vital. Companies can achieve sustainable performance and excel in the current market by coordinating financial, environmental, and social requirements (Bota-Avram, 2023). However, industrialization (transformation) has brought not only great advances but also serious environmental problems (Hizarci-Payne et al., 2021; López Pérez et al., 2024). Although, the business world and society are increasingly aware that our planet has limited (scarce) resources and that we are pushing the Earth hard to reach its limits. As a result, consumer preferences and pressure groups are changing, leading to the search for balanced economic growth combined with sustainable practices (Tang et al., 2018; Nandi et al., 2021; López Pérez et al., 2024).

According to the Brundtland Commission report in 1987; Sustainable development is defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” This definition focuses on the needs of both current and future generations. It qualifies as a widely accepted definition of sustainable development in a universal sense. However, it is required to define this concept in a specific context. (Goyal et al., 2013) defined business sustainability as “Adopting business strategies and activities that meet the needs of the enterprises and its stakeholders (such as shareholders, employees, clients, pressure groups and communities) today while protecting, sustaining and enhancing the human and natural resources that will be needed in future.” Furthermore, Elkington (1998), introduced the “triple bottom line (TBL)” concept, which revolutionized the way organizations operates. Instead of maximizing profits, organizations must prioritize TBL principles that address corporate earnings, environmental responsibility, and social initiatives. Based on this discourse, scholars have varying opinions on the meanings of corporate social responsibility and corporate sustainability.

However, it has been seen in the literature that the discourse on the performance of firms in relation to digitalization and sustainability initiatives has evolved organically across multiple disciplines. (Witschel et al., 2022) demonstrated that business model innovation is crucial for maintaining competitiveness in the digital era. Similarly, (Wen et al., 2022) asserted that manufacturing firms with higher viability are more adaptable to digital technologies and tend to implement differentiated competitive strategies. Consequently, they concluded that incentivizing innovation (digitally) has a greater impact on more viable firms. Additionally, (Korte et al., 2021) identified the Internet of Things (IoT) as a pivotal component of Industry 4.0, enhancing manufacturing efficiency by reducing errors and costs. (Somohano-Rodríguez et al., 2022) found that strategic planning and the integration of digital technologies and advanced robotics are essential for SME’s innovation in Industry 4.0. (Bhatia & Kumar, 2022) highlighted “data governance” as the most critical success factor for Industry 4.0. Also, (Kurniawan et al., 2022) elucidated that digital technologies in the waste sector promote the recovery of non-biodegradable waste for a circular economy, enabling online transactions of recycled goods. Industrial reports indicate that digitalization under Industry 4.0 offers economic benefits, such as cost savings and improved performance. However, while adopting Industry 4.0 poses challenges for firms, integrating it within the sustainability sector is even more complex (Dalenogare et al., 2018; Verma et al., 2022).

Besides these, numerous studies have also examined the nexus between firm performance and sustainability (reporting) performance, where ESG (environmental, social, and governance) parameters are used to measure sustainability reporting, and the performance of firms was operationalized through financial market and operating performance metrics. Typically, these studies measure performance in terms of return on equity (ROE) and return on assets (ROA) can be categorized into three groups.

The first group, comprising studies such as (Hamman et al., 2010; Han et al., 2016; Bernardi & Stark, 2018; Aboud & Diab, 2018; Brooks & Oikonomou, 2018; Gupta & Gupta, 2020) align with the value creation theory and stakeholder theory, suggesting a positive impact of sustainability reporting on firm performance. Further studies, such as (López et al., 2007; Agyemang & Ansong, 2017; Ikram et al., 2019) also documented a positive impact on the performance of firms, but they operationalized through employee commitment and corporate reputation. The second group indicates studies by (González-Benito & González-Benito, 2005; Brammer et al., 2006; López et al., 2007; Nakamura, 2015) showed a negative/adverse association between sustainability reporting and performance metrics consistent with the cost of capital reduction theory. Additionally, some researchers (Tuppura et al., 2016) have investigated the bidirectional impact of aggregate sustainability (ESG) on the financial performance of firms. Some studies (Barnea & Rubin, 2010; Fauzi et al., 2009; Siew et al., 2013) found no statistically significant relationship between sustainability reporting and firm performance.

The existing literature on corporate sustainability and firm performance has predominantly focused on literature reviews (van Beurden & Gössling, 2008; Goyal et al., 2013). Although some studies have been examined through systematic literature reviews and bibliometric analysis, these have been limited to areas such as eco-innovation and corporate environmental performance (Chowdhury et al., 2023; López Pérez et al., 2024) and meta-analyses (Orlitzky & Benjamin, 2001; Q. Wang et al., 2016). Additionally, bibliometric analyses have been conducted on sustainable firm performance and corporate performance (Bota-Avram, 2023; Kumari & Joshi, 2023). Several studies have also investigated the integration of sustainability and digitalization in business model innovation, as well as corporate social responsibility (CSR) and business management (Calderon-Monge & Ribeiro-Soriano, 2024; Ogorean et al., 2024). Other areas of focus include digital capabilities (Annarelli et al., 2021) and Industry 4.0 (I4.0) in the supply chain (Jetty & Afshan, 2024). The nexus between sustainability and (Gupta & Gupta, 2020; Hongming et al., 2020; Bansal et al., 2021; Bodhanwala & Bodhanwala, 2021), CSR in the sustainability domain (Linnenluecke & Griffiths, 2013) and the firm performance relationship in SMEs (Bartolacci et al., 2020) have also been explored in the literature.

Despite the growing interest in this study area, proper classification research is still missing. The main objective of this study is to provide a better understanding of the existing literature on a single platform by providing the future scope of research in this field of investigation. In this context, to better understand the interplay between digitalization (transformation), sustainability (initiatives), and the performance of firms, it is essential to establish a knowledge or theoretical framework based on bibliometric and systematic literature review (B-SLR onwards), both conceptual and empirical that guides researchers in understanding the direction of the literature as well as being of great use to business leaders who wish to apply/implement sustainable strategies and practices within the organization. Establishing a knowledge framework will

provide relevant information to understand the lack of consensus between authors and thus explain the various factors that impact this field of investigation.

Furthermore, a series of pre-defined research questions must be answered to establish a solid knowledge framework, considering that the main objective of this study is to guide the development of a theoretical framework and identify potential future research directions.

1. Who are the prominent contributors to the literature on the interaction between digitalization, sustainability and firm performance?
2. What principal thematic areas are emerging from the current literature that could open up directions to the unexplored area of investigation in this topic?
3. How can the literature on digitalization (transformation), Sustainability (initiatives), and firm performance be advanced further?

As we have seen in the above sections, numerous studies in the literature have analyzed the impact of digital technologies (digitalization) on firm performance, reporting, eco-innovation, and corporate environmental performance (sustainability) through empirical, conceptual, and systematic literature reviews; they often lack conclusive results. These studies focused on immediate questions without considering the long-term impacts of the digitalization-sustainability nexus on firm performance. To address this research gap and answer these research questions (mentioned above), we employ a systematic literature review with a bibliometric approach (B-SLR). This methodology enables scholars to synthesize and explore existing knowledge paths by highlighting gaps and interconnections and critically assessing prior literature. Additionally, it allows researchers to expand the knowledge domain by identifying overlooked pathways and conceptual linkages through new innovative methodologies and interdisciplinary approaches (Marzi et al., 2025).

To achieve these research goals and the study's objective, we followed (Donthu et al., 2021) bibliometric analysis framework (toolbox) in **Figure 1**, which enhances methodological rigor while stimulating the author's creativity. It encourages scholars to move beyond merely systematizing prior research and offers new insights capable of explaining the scope of academic literature.

In response to **research question 1**, we performed performance analyses, including (the number of studies over time, top publication sources, countries, top authors, and cited publications) in the first phase. The second phase, Science Mapping methodology, includes (countries' collaboration, co-authorship, co-occurrence, and co-citation analysis of peer-reviewed studies) outlining the research context. We approached **research question 2** by employing enrichment techniques (network or content analysis) to outline the cluster or key thematic areas in the literature. Finally, to answer **research question 3**, we

examined key thematic articles and regions, discussed prior literature, identified gaps, and synthesized guidelines for future research agendas.

This study offers several theoretical and practical contributions: **(1)** It provides a comprehensive, up-to-date review of digitalization (transformation) impact on Sustainability (transition) and performance of firms from broader perspectives, it's also summarizing the current state of knowledge within an integrated knowledge framework. **(2)** It simplifies the complexity of the topic by offering structure and clarity. **(3)** It offers links between digitalization (role) and the relationship between sustainability and firm performance. **(4)** This literature review serves as a guide for scholars and researchers in developing novel empirical studies and proposing new directions and opportunities within this field. **(5)** It Synthesizes guidelines for identifying future research gaps and agendas in this area of study.

[Insert Figure 1; Research Methodology Framework (toolbox) Here]

9.2. Theoretical and Methodological Foundations of Review's Research/Studies

The term "review research" refers to research inquiries that employ scientific methods to analyze and synthesize prior research in order to create new knowledge frameworks for academic practices and policymaking (Kunisch et al., 2023). Indeed, the analysis of scholarly publications constitutes an opportunity to spotlight research gaps and encourage the adoption of new theoretical lenses that stimulate the introduction of new theories and also investigate underexplored areas (Alegre et al., 2023; Fan et al., 2022). Consistently, by discouraging researchers from using the same old theories and methods in a recycled and replete way, literature reviews are levers to trigger future research and new theoretical insights (Marzi et al., 2025). According to (Alegre et al., 2023) literature reviews should advance academic debates by identifying gaps, proposing new theoretical frameworks, and exploring underdeveloped research areas. Further, (Fink et al., 2019) stated that a Systematic literature review is a "Systematic, explicit comprehensive and reproducible method for identifying evaluation and synthesizing the existing body of completed and recorded works produced by researchers' scholars and practitioners."

Over the past years, we have seen in the literature academicians and researchers employing (follows) multiple approaches such as SLRs, Meta-analysis, Narrative, and Integrative review, still yet, with a sharp surge in academic production, a bibliometric literature review acquired salience due to its role in mapping knowledge in a single, coherent corpus. The primary challenge associated with bibliometric studies is crafting reviews that consistently deliver innovative links and patterns (Marzi et al., 2025). Therefore, we believe that the bibliometric methodology or approach can offer a solid and rigorous base from which review authors can then apply their creativity and problematization to advance existing

knowledge. In addition, it is essential to compare bibliometric analysis (review) with other literature reviews (meta-analysis and SLRs) in order to see the broader picture of the framework of the study. Meta-analysis estimates the overall strength and direction of effects or relationships, the across-study variance in the distribution of effect size estimation, and the factors that explain the variance (Aguinis et al., 2011). Whereas SLRs such as domain, method, and theory-based reviews encapsulate the acquisition arrangements and assessment of the extant literature using a thematic procedure (Donthu et al., 2021).

According to (Donthu et al., 2021) bibliometric and meta-analysis are able to handle large amounts of literature and provide a nuanced summary of a given field through the considered tends to be less diverse and heterogeneity of existing studies, and the existing publication bias can have an adverse effect on the validity of the results obtained via meta-analysis. In contrast, systematic literature reviews using classic methods require a narrow scope of study and thus include a lesser number of papers for review (e.g., between tens [e.g., 40] and low hundreds [e.g., 100-300] (Snyder, 2019). In that sense, systematic literature reviews are better suited for confined (e.g., social media influencer marketing). Unlike systematic literature reviews that tend to rely on qualitative techniques, which could be marred by interpretation bias from scholars across different academic backgrounds (MacCoun, 1998), bibliometric analysis and meta-analysis rely upon quantitative techniques and thus can avoid or mitigate that bias.

As we seen in the above discussion in the literature, that meta-analysis and bibliometric analysis are both quantitative in nature, the distinction between the two methods can be confusing to some scholars. To shed light on this distinction, business scholars should note that their quantitative methods are relatively different in terms of usage, though they can both handle large amounts of literature. Specifically, meta-analysis concentrates on summarizing empirical evidence by analyzing the direction and strengths of effects and relationships among variables (Carney et al., 2011). In summary, the choice of review method depends on the review's goals and the literature's magnitude and nature. These methods are complementary and offer unique advantages to scholars. In this study, we intersect bibliometric analysis and SLRs (B-SLR), combining quantitative and qualitative approaches to analyze and synthesize the existing body of knowledge on the determinants of digitalization, sustainability, and firm performance.

9.2.1. Data Collection Protocols

This step involves an initial literature review to synthesize the existing body of knowledge on the determinants of digitalization and its impact on sustainability and firm performance. This process includes a series of tasks aimed at gaining a deeper understanding of the subject area, identifying research gaps, and subsequently refining these gaps into a specific research question. Eventually, this step defines the potential theoretical contribution of the overall study. For this purpose, this study work is structured in the following phases.

a. Research questions and the boundaries of the study: Before initiating the literature review, the current status of the analyzed research field was examined (Donthu et al., 2021; Marzi et al., 2025). To this end, the most repeated keywords were noted to establish the search equation to be used later for the review. Once the current situation of the research field was analyzed, it was observed that there were gaps in terms of digitalization's impact on the sustainability and performance of firms. In this sense, this work was motivated by the need to answer the following questions [RQ1 – RQ2] that we had already mentioned in the introduction section of this study. Once the research questions were established, inclusion criteria for articles in this review process were developed.

b. Database selection: Once the research questions were defined, criteria for including articles in the review process were established. To address these questions [RQ1–RQ3], we selected two primary databases, SCOPUS and Clarivate Analytics Web of Science (WoS), to source relevant articles. According to (Marzi et al., 2025) numerous databases are available online for query extraction (e.g., ABI/Inform, Business Source Ultimate EBSCO, Dimension, Google Scholar, SCOPUS, PubMed, and WoS). However, within management studies, SCOPUS and WoS are typically preferred. Despite some differences within broader fields (social and management sciences), both databases are considered valuable for robust data extraction (Hiebl, 2023; Mongeon & Paul-Hus, 2016). They also offer significant insights and high-impact data collection and are recognized as the most reliable databases for this study type.

c. Identifying keywords of the study: To identify the articles necessary for this research and account for the most frequently recurring keywords derived from the analysis phase, we conducted a series of targeted searches in each database. These searches involved the application of specific keyword sets designed to locate documents relevant to our study. This step in the review process is crucial as a precise definition of search terms ensures that we can effectively retrieve relevant studies. To facilitate the search, we divided our topic into three core areas/parts: “Digitalization and Sustainability,” “Digitalization and Firm Performance,” and “Sustainability and Firm Performance.” By structuring the search in this manner, we were able to focus on the most pertinent literature.

A total of nine (9) search strings were employed across the SCPOUS and Web of Science (WoS) databases. The primary keywords included; “*digital transformation and SDGs*,” “*green technology innovation*,” “*firm digitalization*,” “*sustainable firm performance*,” “*digital transformation and environmental performance*,” “*sustainable business models*,” “*big data analytics*,” “*ESG*,” and “*Firm performance*.” all within the subject area of “Business and Management” due to their economic relevance. These keywords were transformed into search strings using Boolean logic, applying “*” in combination with “OR” and “AND” operators. To execute these searches, the connectors were applied with the “AND” command to ensure comprehensive and focused results.

d. Selection of articles included: By applying the same search equations across both Web of Science (WoS) and SCOPUS, we obtained a significantly enormous number of relevant articles from both databases. To eliminate duplicates, we combined the nine (9) search equations using the “OR” function in both databases, resulting in a total of 1883 articles. Analysis reveals clear trends that the majority of publications on this topic began in 2013, with the number of articles steadily increasing through 2023. Further examination showed that 98% of the articles retrieved were published in English. Based on these insights, we refined our search by applying the flowing filters:

Documents Type: Research Articles

Publication Years: 2013–2023

Documents Language: English

Subject Area: Business Management and Accounting, Environmental Science, Economics, Econometrics and Finance.

e. Data Extraction and Evaluation: For the extraction of data for bibliometric analysis, we adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocols. As outlined by (Page, McKenzie, et al., 2021; Page, Moher, et al., 2021), this protocol incorporates updated reporting guidelines that reflect advancement in the methods for identifying, selecting, evaluating, and synthesizing studies. The PRISMA protocol offers several clear advantages, including a detailed, rigorous, and well-described checklist that aids academics and researchers in enhancing the conduct of bibliometric analysis, systematic review reporting, and meta-analysis. The PRISMA protocol also provides a **Flow Diagram 2**, that guides the steps of the systematic literature review (SLR) process. The primary objective of this method is to plan, identify, and evaluate studies to extract and summarize data from the literature, as noted by (Tranfield et al., 2003). This ensures that the bibliographic research is objective, transparent, and replicable. The choice of the PRISMA protocol over other standards and guidelines is due to its clear and easily understandable analytical and methodological approach.

Following the filtering process, the initial dataset comprised a total of 1883 documents, with 1058 sourced from the Web of Science (WoS) database and 825 from the Scopus database. This represented the first phase of the systematic review process, known as **Identification**, during which the initial dataset was refined based on a series of predefined selection criteria. During the literature review, studies whose titles and abstracts contained the keywords used in the search equation but not directly related to the research objective were excluded. Consequently, 50% of the retrieved documents from both databases (Scopus & Web of Science) were eliminated due to their lack of relevance to the study’s

objectives. Specifically, 362 papers were excluded based on a title review, while an additional 579 were removed following an abstract review. As a result, a total of 941 studies were deemed irrelevant and excluded from further analysis in this literature review process.

In the second phase, **Screening**, 942 articles remained for further assessment. At this stage, additional inclusion and exclusion criteria were applied, as outlined in the previous section. As a result, 490 documents that were published in journals outside the relevant field of study were removed. Additionally, 173 duplicate studies appearing in both the WoS and Scopus databases were identified and eliminated. This refinement process left a total of 452 articles for further evaluation. During the third phase, **Eligibility**, the remaining 452 articles were further assessed for relevance. To ensure that only studies directly related to the research topic were included, each article was manually reviewed based on its title, abstract, and keywords. This rigorous examination led to the removal of an additional 147 articles that did not meet the eligibility criteria.

In the final phase, **Inclusion**, a total of 305 studies were deemed relevant for contextualizing the research and strengthening the methodological framework. These selected articles formed the final dataset for bibliometric analysis. At the conclusion of the search and selection criteria, this finalized dataset was exported in plain text and comma-separated values (CSV) file formats in accordance with the requirements of the bibliometric analysis software. The subsequent section provides a detailed explanation of the data extraction and analysis method used in this study.

[Insert Figure 2; PRISMA Protocol Diagram Here]

9.2.2. Bibliometric Analysis

Bibliometric analysis is a mathematical–statistical approach that provides insights into the current state and evolution of a specific field of knowledge. This method offers a comprehensive view of relevant literature and facilitates a deeper understanding of the most relevant (pivotal) studies, especially in dynamic research domains such as digitalization, sustainability, and firm performance. As noted by (Donthu et al., 2021), bibliometric analysis enables the summarization of vast (huge) amounts of scientific data, helping to define the intellectual landscape and identify emerging trends within a research topic.

According to (Donthu et al., 2021; Marzi et al., 2025), the growing interest in bibliometric analysis can be attributed to several factors. **(1)** the availability of advanced bibliometric software and extensive scientific databases like Web of Science (WoS), Scopus, and Dimensions, which streamline technical evaluation; **(2)** the capacity to handle large datasets, which enhances the utility of the analysis; and **(3)** the ability to detect emerging within specific research fields with greater ease. These advantages underscore

the growing influence of bibliometric analysis, which is expected to significantly shape both current and future research. Despite its increasing popularity, there is currently no universally accepted framework for conducting bibliometric analysis within Business and Economic Research. To address this gap, (Donthu et al., 2021; Marzi et al., 2025), have proposed step-by-step guidelines for properly conducting bibliometric analysis in the context of business and economic academia.

In this study, we followed (Donthu et al., 2021), guidelines for performing the bibliographic analyses, which involved applying two primary techniques.

- a. Performance Analysis:** It focuses on evaluating the contribution of various research constituents to a specific field. This descriptive form of analysis is a cornerstone of bibliometric studies. It is typically featured in most literature reviews, even those that do not engage in science mapping. Performance analysis involves presenting the performance of research entities (Such as., authors, institutions, countries, and journals), which resembles the background or profile of participants commonly presented in empirical research but in a more analytical context.
- b. Science Mapping:** On the other hand, explores the relationship between research constituents. This analysis examines the intellectual interaction in science mapping (including co-citation analysis, bibliographic coupling, co-word analysis, and co-authorship analysis). When combined with network analysis, these methods provide valuable insights into the bibliometric and intellectual structure of a research field.

For the purpose of this study, we utilized the VOS Viewer software (van Eck & Waltman, 2010), which supports three types of scientific maps: network visualization, overlay visualization, and density visualization. As highlighted by (Donthu et al., 2021; Marzi et al., 2025), VOS Viewer was chosen for its various advantages: **(1)** It is user-friendly and does not require programming expertise to set up bibliometric analysis parameters; **(2)** it effectively handles large datasets and offers superior mapping capabilities, facilitating more straightforward interpretation; and **(3)** based on a variety of adopted metrics, the software provides a clear presentation of the relationship between subjects, making its powerful tool for visualization the connections within research fields.

9.3. Results from the Bibliometric Analysis

In this section, we present the results of a comprehensive bibliometric analysis of scientific publications that explore the impact of digitalization on the sustainability and performance of firms, as outlined in the methodological section. The findings are organized according to the unit of analysis (such as., articles, authors, journals, and key conceptual research themes) within this field. The primary objective of this bibliometric analysis is to provide a holistic view of past, current, and emerging trends while

addressing the first research question (**RQ1**), which is divided into two phases: **(a)** Performance Analysis and **(b)** Science Mapping Analysis. Specifically, we aim to identify the prominent contributors to the literature examining the interaction between digitalization, sustainability, and firm performance.

9.3.1. Performance Analysis

As depicted in **Figure 2** (PRISMA Protocol), this study is based on 305 publications which focus on the intersection of digitalization, sustainability, and firm performance. These articles span multiple disciplines (such as Business management and accounting, Economics, Econometrics, Finance, and Environmental science). The performance analysis, presented through several bibliometric indicators, offers an overview of the development and distribution of research on this topic from a statistical perspective. As noted by (Donthu et al., 2021), this part of the bibliometric analysis is descriptive in nature. It includes key indicators (such as the number of studies published over time, the leading source of publications, the geographical distribution of research, key prominent authors, and frequently cited work) within the field.

9.3.1.1. No Studies Over–Time

The dataset comprises 305 articles published between 2013 and 2023. **Figure 3** illustrates the evolution of research in this field by depicting the annual publication trends over this period. Although these articles span a decade (10 years), academic interest has notably increased over the past seven years (2017–2023). The number of publications has shown a consistent upward trajectory, reaching a total of 93 in 2023. In contrast, prior to 2017, the annual publication count remained below six, with no (zero) articles published during 2014 and 2016. However, a significant shift was observed in 2019, as research in this field began to receive considerable attention, resulting in 21 published studies coming out, followed by substantial growth in subsequent years. These findings highlight the expanding scholarly focus on the role of digitalization on sustainability and the performance of firms. Given the ongoing challenges countries face in aligning financial, environmental and social objectives to enhance stakeholders' value, this research domain is expected to continue attracting academic and professional interest.

[Insert Figure 3: Studies Over Time-Period Here]

9.3.1.2. Top Publication Sources

Table 1 displays the most productive source titles in this area of study, categorized according to the number of publications. To provide a comprehensive picture of these journals and their relevance in this study field, it includes information on each journal, Number of publications in the dataset, Total number of citations, Average citation score, Journal rating, or Impact factor recorded of each journal (according to

2023) and details of publisher. The most prolific source in the dataset is the “*Journal of Cleaner Production*” (impact factor 11.1), with 53 publications and a citation score of 550, indicating that most of the publications came from these sources. Furthermore, the “*Journal of Business Research*” (impact factor 11.3) published 43 articles with a citation score of 1292, and the “*Journal of Technological Forecasting Social Change*” (impact factor 12) published 37 articles with an average citation score of 28.86, highlighting the significant impact of these journals in their respective fields. As per (*Academic-Journal-Guide-2021*), a substantial portion of the publication ranked in 3 or 3* categories, representing 44% of the total sample size. It is observed that journals with the greatest impact factors have drawn the maximum citations for their contributions in this area of research, highlighting their influence on their respective domains.

[Insert Table 1: Top Publication Sources/Journals Here]

9.3.1.3. Top Publication Countries

Table 2 lists the most productive countries in this field of research, categorized by their respective number of articles. This table provides a comprehensive overview of these countries' roles and significance within this research area. It includes information about the total number of citations count and the average citation per item.

It is observed that China is the most influential country in terms of the development and worldwide distribution of publications on this current topic of investigation, with 91 articles and a citation score of 868; Germany became a (second) place, with 47 articles and a citation score of 601; and the (third) United Kingdom, with 46 articles and citation score of 522, respectively. However, this analysis revealed an interesting pattern between countries with identical publication counts. For instance, both countries, Romania and Spain have published 28 articles, while Hungary and the United States have each published 18 articles. However, a closer examination of the citation counts reveals a divergence in their research impact. Spain’s work has garnered 205 citations, yielding an average citation score of 4.27, whereas Romania’s research has received 125 citations, resulting in an average citation score of 4.46. In a similar vein, the United States has accumulated 318 citations with an average citation score of 17.66, while Hungary’s research has been cited 320 times, leading to an average citation score of 17.77. This discrepancy in citation counts indicates that while these countries may produce a similar volume of publications, their research's influence and recognition can vary significantly, explaining the study’s fragmentation between countries.

[Insert Table 2: Top Countries with Citations Here]

Figure 4 shows the geographical distribution of these nations. Interestingly, there seems to be no (zero) study on the continents of Northern America (Canada) and Africa. However, the map reveals that the regions of Asia, Australia, Europe, and Southern America are predominant and highlight an important aspect of this research field. Research institutions in Europe, the United Nations, and universities in China actively promote cooperation with academic institutions both within and outside their institutions. This cooperation and collaboration indicate a shared interest in exploring the potential benefits of digitalization for improving sustainability and firm performance, fostering knowledge exchange, and driving innovations in these regions. Such collaborations may lead to novel insights and practices that enhance digitally driven-organizational performance and contribute to sustainable development.

[Insert Figure 4: Geographical Contributions Here]

9.3.1.4. Top Authors and Cited Publications

Table 3 provides a comprehensive overview of the key authors whose works have made notable contributions to this research area, along with the titles of their publications that have achieved the highest citation counts. The ranking is based on multiple factors, including total citation count, Average citation per year, Journal's impact factor, and Year of publication. It is vital to remember that the number of citations a publication obtains is a strong predictor of its quality and relevance to the subject.

[Insert Table 3: Top Authors and Publications Here]

According to the data, the most influential articles in this research field were authored by (Eller et al., 2020b); their work is titled *“Antecedents, consequences, and challenges of small and medium-sized enterprise digitalization.”* and published in the *“Journal of Business Research”* in 2020, received the highest citation count, 524, with an average citation score of 52.4. Following that, the second most influential article in the dataset were *“Digital technologies and firm performance: The role of digital organisational culture.”* was authored by (Martínez-Caro et al., 2020), and published in the *“Journal of Technological Forecasting and Social Change”* in the same year, it has accumulated a total of 425 citations score with 45.2 average citation count per year. It is observed that most of the articles within this field of research are published in the *“Journal of Business Research”*. For instance, the article *“The duality of digital and environmental orientations in the context of SMEs: Implications for innovation performance.”* written by (Ardito et al., 2021), was published in 2021 and had a citation score of 238. Another notable study from 2021, titled *“The effect of digitalization on business performance: An applied study of KIBS.”* was authored by (Ribeiro-Navarrete et al., 2021) and has received 197 citations. Lastly, the 2021 publication *“Stability in turbulent times? The effect of digitalization on the sustainability of competitive advantage,”* authored by (Knudsen et al., 2021), has a citation score of 153, with an average score of 15.30. Nonetheless,

given that the citation frequency of these papers is expected to rise with time, these findings do not represent all high-quality publications. Some papers published in the most recent reader will also be often quoted in the future after their work is recognized.

9.3.2. Science Mapping Analysis

The primary goal of the science mapping analysis, which constitutes the second component of the bibliometric analyses, is to provide a comprehensive overview of the bibliometric and intellectual structure of the selected research field (Donthu et al., 2021; Marzi et al., 2025). This analysis employs various techniques for science mapping (such as co-citation analysis, co-occurrence analysis, bibliographic coupling, and co-authorship analysis). These techniques, when combined with enrichment bibliometric methods, help to map out the relationship and intellectual connections within the field, offering valuable insights into the structure and evolution of research on the relationship between digitalization, sustainability, and firm performance.

9.3.2.1. Countries Collaboration Analysis

[Insert Figure 5: Countries Collaboration Here]

Figure 5 illustrates the countries with the highest number of published papers and their interrelationships based on citations received from authors in other countries. The colors of the nodes (Blue, Green, Yellow, and Purple) represent different countries, and the size of each node corresponds to the number of articles published in that country. When an article has authors from multiple countries, a partnership is formed between each pair of countries, represented by a link between the nodes. The strength of these partnerships is indicated by the thickness of the links.

The maps demonstrate that publications written by Chinese authors were primarily cited by South Korean, Pakistani, and Malaysian authors. The United Kingdom (UK) is the next most significant emerging contributor to this area of research. Most contributions in Europe came from Germany, Norway, and Finland. Although these findings show that the concepts of digitalization, sustainability, and firm performance originated in Europe, they have since spread to other nations and become a popular research topic.

9.3.2.2. Co-Authorship Analysis

The co-authorship study investigates collaboration between scholars and research institutions based on the number of articles jointly authored (Singh & Del Giudice, 2019). This type of study is becoming increasingly significant since research networks among scholars can lead to advancements in research fields

with higher clarity and more valuable findings (Khanra et al., 2021). Identifying significant author networks is critical for better understanding the literature structure on this topic of investigation.

In this context, articles having 20 or more citations within the Web of Science and Scopus databases are considered critical collaboration. As a result, 47 out of 305 contributing authors emerged in the network of co-authors, which was divided into four distinct clusters— Red, Green, Blue, and Yellow— as illustrated in **Figure 6**. Within the Red cluster, comprising eight connections/links, the authors Parida V., Wincent J., Abou-Foul, and Ruiz-Alba J. established links with an additional seven authors. The Green cluster includes Hollos D. with seven links, Rahman M. with four links, and Hughes M with three. The Blue cluster/group is spearheaded by Kristoffersen E., with six connections, followed by Hermundsdottir F., with five links, and both Gillani F. and Sadiq Jajja, with three connections each. Finally, in the Yellow group, which is considered five authors, Blomsma F. has four links, Mikalef P. has four, and Lincon G. has two prominent connections.

[Insert Figure 6: Co-Authorship Analysis Here]

9.3.2.3. Co-Citation Analysis

Co-Citation analysis is a method for determining the frequency of citations between two or more articles. If two papers appear in the same reference list in a third publication, they are deemed referenced. Co-citation analysis is used to analyze thematic similarities between publications on a certain research topic, as well as to study how literature is structured based on the publications mentioned (Farrukh et al., 2020; Khanra et al., 2021).

We set a minimum threshold of twenty citations per author for our dataset of 305 published studies, and 73 articles matched the criteria. **Figure 7** depicts the network diagram, which allows for visualization of researchers' co-citation networks in digitalization impact on sustainability and firm's performance. The four most prestigious clusters, including the 42 most relevant publications, were identified. The red cluster is the largest, containing fifteen articles, followed by the Green Cluster, which has ten articles; the Blue Cluster, which has twelve publications; and the Yellow cluster, which has five articles. **Tables 5a, 5b, 5c, and 5d** represent the details of each article corresponding to a cluster associated with critical thematic areas, which are **(a)** digitalization impact on sustainable firm performance, **(b)** Sustainable corporate performance and green practices, **(c)** integrating industry 4.0 technologies for sustainable supply chain management and **(d)** digitalization as a driver of circular economy business models.

[Insert Figure 7: Co-Citation Analysis Here]

9.3.2.4. Co-occurrence of keywords Analysis

Keyword co-occurrence analysis is a methodological approach in content analysis that measures the frequency of simultaneous appearances of two keywords within the keywords list of publications, abstracts, or titles. This technique is based on the assumption that the concepts denoted by these keywords are significantly interrelated when they appear together in a single publication (Park & Nagy, 2018).

After establishing a minimum threshold of five keyword occurrences (i.e., a keyword has to appear at least five times), we discovered that 44 out of 1044 keywords met this criterion. As a result, we were able to form four clusters, which are depicted in **Figure 8**, as Green (11 keywords), Red (12 keywords), Blue (9 keywords), and Yellow (7 keywords). The keyword “*Sustainability*” emerged as the most significant in this analysis, with 59 occurrences and having a total link strength of 89, found in the red cluster. This was followed by “*Green Innovation*” in the Green cluster (with 19 occurrences and total link strength of 16), “*Industry 4.0*” in the Blue cluster (19 occurrences and total link strength of 45), and “*Digitalization*” (62 occurrence and total link strength 106), as shown in **Table 4**. Each circle size represents the frequency of a keyword's appearance in the specified field, and the distance between the circles represents the relationship between the keywords. This table further demonstrates the strength of the relationship between the terms “Digitalization,” “Sustainability,” and “Firm performance,” which are particularly prominent. This map visually represents the most critical nodes, the connection between the terms identified by color, and their relative proximity.

[Insert Figure 8: Co-Occurrence of Keywords Here]

[Insert Table 4: Co-Occurrence of Keywords Here]

For a more comprehensive understanding of keyword co-occurrence, **Figure 9** represents a cluster density visualization of high-frequency keywords. This enhanced visualization presents the density of keywords individually for each cluster. However, it's important to note that density analysis focuses on evaluating the central importance of topics using a heat map without considering interlinkages and temporal dynamics.

[Insert Figure 9: Density Analysis Here]

9.4. Content Analysis of Thematic Areas

To address our second research question (**RQ2**), which seeks to identify the principal thematic areas emerging from the current literature that could guide future investigations, we conducted a content analysis of these thematic areas. According to (Donthu et al., 2021), clustering is an enrichment technique for

bibliometric analysis aimed at creating thematic or social clusters, depending on the type of analysis being conducted. To curating network clusters and observing their development can be instrumental in understanding how a research field evolves. For instance, thematic clusters created through co-citation analysis and bibliographic coupling illuminate the major themes underpinning the intellectual structure and development over time.

The thematic connections among studies within each cluster were meticulously examined through a comprehensive content analysis, as outlined in **Table 5a–5d**. This analysis of the most esteemed articles within each theme identified sub-themes pertaining to their respective domains. Furthermore, a thorough examination of these thematic areas (fields) enables us to identify several unexplored emerging research areas/opportunities. Therefore, we aim to bridge these gaps by suggesting significant directions for further future investigations. Specifically, with the help of content analysis, we identified four distinct thematic areas: **(1)** the impact of digitalization on firm performance, **(2)** sustainable corporate performance and green practices, **(3)** the integration of Industry 4.0 technologies for sustainable supply chain management, **(4)** digitalization as a circular economy business model.

[Insert Table of 1st Thematic Red Cluster 1; 5a Here]

[Insert Table of 2nd Thematic Green Cluster 2; 5b Here]

[Insert Table of 3rd Thematic Blue Cluster 3; 5c Here]

[Insert Table of 4th Thematic Yellow Cluster4; 5d Here]

I. Digitalization Impact on Sustainable Firm Performance

In today's dynamic manufacturing environment, key features like agility, product innovation and productivity play an important role in sustainable firm performance. Firms face multiple challenges due to the complexity and dynamic nature of production systems, and the demand from consumers for custom-made (innovative) products requires exceptional connectivity and consistency in delivery (process) channels (Fatorachian & Kazemi, 2018; Tupa et al., 2017).

Digitalization offers a transformative approach to business models through the integration of Information Communication Technologies (ICT) into their core strategies. It acts as a catalyst for sustainable firm performance through leveraging technologies (such as sensors, big data, blockchain and the Internet of things) to enhance process efficiency. These digital technologies enable firms to generate real-time data, improve information transparency (flow), and also support decentralizing and autonomous supply chain management processes. For example, digitalization can reduce carbon (CO²) emissions in

supply chain operations through intelligent routing and optimized vehicle usage for the delivery of goods (Wroblewski, 2018; L. Guo & Xu, 2021).

However, not all firms are ready and equipped to implement digitalization in their processes or operations. For instance, SMEs face multiple challenges in adopting digitization due to their limitation in financial and also human resources, including workforce technical skills (Sanchez-Riofrio et al., 2022). According to (X. Guo et al., 2023), several tools are available to assess a firm's sustainability performance, such as Life Cycle Assessment (LCA), which evaluates a product's entire life cycle, starting from raw materials to final disposal. This process is very helpful to gather data on the inputs and outputs for each phase of the life cycle processes, as well as to quantify the resources used and emissions produced at each stage. Another approach is the Eco-Efficiency approach (Rashidi & Saen, 2015), which calculates the ratio between a product or service's economic performance and environmental impact. Economic performance can be measured in terms of sales, revenue, and annual yields, while environmental impact includes resource inputs and waste output, like material consumption, energy, water, and greenhouse gas emissions (Sharma et al., 2022). Finally, a standard tool for evaluating a firm's sustainable performance is the triple bottom line model, or the "3P" model, which balances three sustainability factors. People, Planet, and profit (Sanchez-Riofrio et al., 2022; S. Li et al., 2023; Cirillo et al., 2023).

II. *Sustainable Corporate Performance and Green Practices*

Green practices are "Environmentally friendly cooperative activities between the members of an organization to address ecological concerns, reduce environmental impacts, and capture the added value that can emerge from these activities" (Russo & Fouts, 1997; Klassen & Whybark, 1999). Green practices encompass innovations in products and processes designed to mitigate negative environmental and social impacts caused by businesses. Small and medium enterprises (SMEs) are increasingly adopting proactive measures to implement sustainable initiatives aimed at reducing emissions and waste pollution. These enterprises recognize that green practices are perceived as the essential solution for advancing ecological innovation. Therefore, firms are committed to producing eco-friendly products and adopting eco-friendly materials and packaging to adhere to environmental standards throughout manufacturing (M.-J. Lee & Roh, 2023).

Green technology can be categorized into three main areas: **(a)** Green Processes, **(b)** Green Products, and **(c)** Green Management. **(a)** Green Processes focus on minimizing the use of natural resources while converting raw materials into consumable products. **(b)** Green Products include new and improved versions of existing products or services created using non-toxic, biodegradable materials or minimal nonrenewable energy resources, enhancing energy efficiency by reducing waste and disposal needs. **(c)**

Green Management involves restructuring the current management system, strategies, policies, and guidelines, implementing new regulations related to production and management processes within the organization, or transitioning towards an environmentally sustainable system (Abbas & Sağsan, 2019; L. Li, Tong, et al., 2022)..

Sustainable Corporate performances represent an opportunity for companies to enhance their effectiveness by integrating a diverse range of performance (financial and non-financial) metrics (such as profitability, growth, return on investment, return on equity, and market shares), resulting in improved productivity and performance. By adopting sustainable practices, businesses can meet stakeholders' needs, reduce negative impacts, and enhance productivity and performance (Leischnig et al., 2016). Green Practices are essential for corporate social responsibility and achieving competitive advantages, leading to better corporate performance. Firms also aim to improve productivity, quality, reputation, and product differentiation, which boosts market share and profitability (Forcadell et al., 2020; Homburg & Wielgos, 2022).

III. *Integrating Industry 4.0 Technologies for Sustainable Supply Chain Management*

Over the past decade, substantial advancements in sustainable supply chain management (S.-Y. Lee, 2021) and industry 4.0 technologies (Bhagat et al., 2022) have occurred. Digital technologies (like big data analytics, deep learning, simulation and the Internet of Things) have been utilized to meet the modern demands of supply chain operations. These demands focus on increasing productivity, reducing waste, optimizing resources both inside and outside the factory, and promoting a more sustainable production process (Denicolai et al., 2021).

According to the literature (Cappa et al., 2021; Díaz-Chao et al., 2021; Bhagat et al., 2022) contend that achieving sustainable performance is unattainable without technological innovation. The advanced and disruptive technologies introduced by Industry 4.0 are viewed as beneficial, guiding organizations towards sustainable performance in both industrial and service sectors. These technologies can enhance value addition, minimize waste generation, and improve process integration, thereby significantly boosting organizational performance. Besides, the literature also identifies factors that influence SSCM both positively and negatively. Positive aspects include information sharing, forecasting accuracy, cost savings, and resource efficiency. Conversely, pressure from stakeholders, adaptability challenges, and delayed market entry compel companies to balance environmental, social and economic considerations, leading to supply chain uncertainty (Denicolai et al., 2021).

I4.0 applications have been developed to address challenges in transforming supply chain operations and creating digital networks. This concept is especially advantageous for emerging economies,

as it presents significant employment opportunities in sectors like information technology, cybersecurity, and process engineering. However, by facilitating automation and improving human-machine interaction. I4.0 can reduce workplace accidents while simultaneously improving product quality and precision in daily tasks without compromising the safety of workers. While robots take a routine task, humans can concentrate/focus on value-addition activities, fostering a healthier work-life balanced approach. Information technologies empower firms to gain first-mover advantage by deploying IT resources ahead of their competitors effectively creating barriers for new entrants (Joensuu-Salo et al., 2018; Sharma et al., 2022; Bhagat et al., 2022). As a result, companies that leverage I4.0 technologies can achieve complementary gains that enhance their competitiveness and also contribute to sustainable performance.

IV. *Digitalization as a Driver of Circular Economy Business Model*

The systematic adoption of Circular Economy principles necessitates the development of innovative business models that enable enterprises to generate value while complying with CE guidelines. The Circular Economy framework is acknowledged as a viable alternative to the conventional “take, make, waste” model. This paradigm shift represents a novel strategy for sustainable corporate growth, addressing both environmental and societal considerations, and has significant implications for regional development (Su et al., 2013; Ghisellini et al., 2016; Urbinati et al., 2017).

According to the (Rapport_McKinsey-Towards_A_Circular_Economy, 2015), CE aims to redefine growth paradigms by focusing on societal benefits, gradually decoupling economic activities from the consumption of limited resources and eliminating waste. CE advocates for the integration of business operations with the principle of industry ecology, emphasizing the redesign of products and processes to enhance system efficiency and sustainability. From this perspective, companies are exploring opportunities to recover and reuse products and components across various industries. Although, implementation circularity within both established and emerging firms necessitates the adoption of advanced technological expertise and innovative human skills (Nayal, Kumar, et al., 2022).

According to literature (Lenka et al., 2017; Joensuu-Salo et al., 2018) highlights the significant role of digitization in facilitating circular economy (CE) business models. Digital technologies, stemming from the I4.0 concept originally developed in the manufacturing sector, offer capabilities that support CE business models. These include the ability to identify and track materials within supply chains, thereby enhancing the manufacturing process efficiency and reducing the need for product ownership in product in the product-service system. Digitalization capabilities are categorized into three types: **(a)** intelligence, **(b)** connective, and **(c)** analytical. **(a)** *Intelligence capabilities* involve upgrading essential hardware with digital components to enable data collection. **(b)** *Connective capabilities* pertain to the wireless

interconnection of products and their integration with the Internet and (c) *Analytical capabilities* focus on developing knowledge by generating insights from the extensive data collected by sensors and systems.

The existing literature on the integration of digital technologies in the circular economy (CE) business model. According to a study (Nayal, Kumar, et al., 2022), “*Supply chain firm performance in circular economy and digital era to achieve sustainable development goals*”, explores the relationship between flexibility, AI–IoT adoption, and supply chain (SC) performance within the framework of circular economy (CE) and digital transformation. The findings reveal that both information flexibility and organizational flexibility exert a significant influence on the adoption of AI–IoT technologies. Notably, organizational flexibility fully mediates the effect of AI–IoT adoption on SC performance. Furthermore, the study reveals that the circular economy moderates the relationship between organizational flexibility and AI–IoT adoption. These findings provide valuable insights for developing cross-country comparative studies and inform the creation of strategies and policies aimed at advancing AI–IoT integration within circular supply chains.

Another study on (Cappa et al., 2021), “*Big Data for Creating and Capturing Value in the Digitalized Environment: Unpacking the Effects of Volume, Variety, and Veracity on Firm Performance*”. This study investigates the impact of big data on firm performance, specifically focusing on the dimensions of volume and variety within a digitalized environment. These findings reveal that the sheer volume of big data has a detrimental effect on firm performance, suggesting that larger data sets do not inherently generate values. Additionally, the level of veracity, reflected in the extent of employee engagement in big data analysis, is positively associated with firms' ability to capture big data, thereby improving performance. These insights highlight the circumstances under which big data can be a source of value creation and capture, offering important implications for both theory and practice. Despite recognizing digital technologies as crucial for CE business models, there is limited understanding of how they drive revenue from resource flow improvements and optimize material flow and capture in real-world applications.

9.5. Future Research Directions

This bibliometric analysis conducted in this study contributes to the identification and consolidation of emerging research trends in digital transformation, sustainability initiatives, and firm performance. It also offers a framework for future research. **Table 6** provides a synthesis of key research directions, highlighting areas of growing interest among scholars. Despite the extensive body of literature on this topic of investigation, significant gaps remain exist therefore in order to understand the intersection of digitalization, sustainability, and performance of the firm we propose several future research avenues aimed

at advancing knowledge and clarifying the current state of digital transformation in the context of sustainability and firm performance as outlined in (RQ3).

[Insert Table 6: Future Research Direction Here]

9.6. Discussion and Conclusion

In this paper, we present a comprehensive overview of the role of digitalization in the sustainability and performance of firms through a systematic literature review combined with a bibliometric analysis (B-SLR) approach. We examine 305 English-language publications from 2013 to 2023 across the fields (business management, accounting, finance, and economic and environmental sciences) by using Web of Science (WoS) and Scopus databases. By analyzing journals, articles, and authors, the B-SLR approach offers important insights into the emerging field of investigation. The findings highlight key trends, challenges, and emerging (future) research directions in this area, demonstrating the growing significance of this topic within both academic and business communities. This study not only contributes to the systematization of the existing body of knowledge in this growing field but underscores its importance for future research.

In order to achieve the objectives of this study and address the research objectives/goals, we followed the bibliometric analysis framework proposed by (Donthu et al., 2021). This scientific method proves valuable for both established and emerging scholars seeking to explore and evaluate key emerging areas within business research. To answer the first research question (RQ1), *Who are the prominent contributors to the literature on the interaction between digitalization, sustainability, and firm performance?* We divided our analysis into two main sections: (a) Performance Analysis and (b) Science Mapping technique/analysis.

In the first section (a) of performance analysis we include (such as, no of studies over time, top publication sources/journals, top publication countries, geographical contributions, and top authors and cited publications). As shown in **Table 1**, top publication sources we highlight leading sources of publications in this emerging field of investigation. The most promising/notable journals are the Journal of Cleaner Production (53 studies), Journal of Business Research (43 studies), Business Strategy and the Environment (30 studies), and Journal of Technological Forecasting and Social Change (37 studies) are recognized for their higher impact factors and have accumulated the most citations in this topic. These journals are recognized for their high-impact factors and have consistently attracted the highest citation count reflecting their prominent role in advancing research in the field of digitalization, sustainability, and performance of firms. Additionally, Top publication countries in **Table 2**, offers a detailed overview of the most influential countries contributing to the global dissemination of research on this topic of investigation.

Countries like China (91 articles), Germany (47 articles), the United Kingdom (46 articles), Italy (37 articles), India (29 articles), and Romania (28 articles) have made valuable contributions to the global dissemination of this study's findings, helping to deepen our understanding of its implications and fostering a collaborative approach to understanding the topic. This trend reflects the positive impact of enhanced investments in research and development in these countries, coupled with a strong commitment to sustainability and embracing digital transformation. These efforts are paving the way for innovation and long-term goals. **Figure 4**, Geographically Contribution Patterns highlights the geographical distribution of the contributions showing majority of research originates from Europe, Asia, and Australia, while regions like Africa and Canada show comparatively fewer contributions. This distribution reflects both regional research priorities and the varying levels of research infrastructure and support available across different countries. By doing so, we can foster a more balanced global research landscape and encourage contributions from all regions.

In terms of authorship and citation impact, the study by (Eller et al., 2020b), titled “*Antecedents, consequences, and the challenges of small and medium-sized enterprise digitalization*” stands out as the most cited work, with a citation score of 524. This study addresses real-world business challenges in the context of digitalization and small to medium-sized enterprises. It highlights the positive relationship between digital transformation and the financial performance of firms, emphasizing how embracing digital strategies can lead to improved business outcomes. Following closely, the study by (Martínez-Caro et al., 2020), “*Digital technologies and firm performance: The role of digital organizational culture*,” has received 452 citations, contributing further insights into the role of digital culture in improving firm performance. Similarly, the work by (Denicolai et al., 2021), titled “*Internationalization, digitalization, and sustainability: Are SMEs ready? A survey on synergies and substituting effects among growth paths*” has garnered 339 citations further exploring the intersection between digitalization, internationalization, and sustainability in SMEs. Additionally, two studies in our dataset have each received 263 citation counts one was written by (Cappa et al., 2021), “*Big data for creating and capturing value in the digitalized environment: unpacking the effects of volume, variety, and veracity on firm performance*,” and another authored by (Ukko et al., 2019), “*Sustainability strategy as a moderator in the relationship between digital business strategy and financial performance*.” These works are widely recognized for their thorough exploration of the topic and their ability to provide valuable insights into these variables that interact and influence organizational performance. The substantial influence of these studies on the field is further demonstrated in **Table 3**, which underscores their critical role in expanding our understanding of the broader implications of digitalization and sustainability initiatives.

In the second part of the study, we employed a **(b) Science Mapping Approach**, incorporating (such as, countries collaboration analyses, co-authorship analyses, co-citation analyses, and co-occurrence of keywords) analysis. These methods are effective in uncovering the collaborative patterns within academic research, revealing how topics of digitalization, sustainability, and firm performance are widely distributed across various key communities.

In **Figure 5**, the collaboration map among countries effectively highlights the dynamics of published research (articles) and their interconnections through citations from authors in other countries. The analysis reveals a strong presence of published papers from China, which are notably cited by authors from South Korea, Pakistan, and Malaysia. Additionally, the United Kingdom (UK) is emerging as a significant contributor to this topic of investigation. Within the European (region) Germany, Norway, and Finland stand out as a key contributor, as shown in the (blue, green, yellow, and purple) nodes. Each varying size of these nodes reflects the volume of studies published in each country, offering valuable insights into global research collaboration patterns. **Figure 6**, illustrates the intellectual collaboration between scholars and institutions, based on the frequency of co-authored publications. This co-authorship analysis is essential as it not only identifies leading researchers and institutions but also highlights the degree of collaboration within the research area. By mapping out the intellectual geography of the study it offers valuable insights into how scientific ideas and innovation are exchanged and developed within the academic community. The analysis of the co-authorship network reveals an intriguing division into four distinct clusters, that are identified by colors: Red, Green, Blue, and Yellow, as illustrated in **Figure 6**. In the Red Cluster, which contains eight connections, authors such as Parida V., Wincent J., Abou-Foul, and Ruiz-Alba J. effectively established links with seven additional authors, showcasing a strong collaborative effort. The Green cluster highlights the contributions of Hollos D. with seven links, Rahman M. with four links, and Hughes M with three links, indicating a dynamic network of collaboration among these authors, The Blue cluster is notable for its leadership by Kristoffersen E., who has formed six connections. Following closely are Hermundsdottir F., with five links, and both Gillani F. and Sadiq Jajja, each with three connections, reflecting a solid foundation of collaboration. Lastly, the Yellow group, comprising five authors, demonstrates strong interconnectivity with Blomsma F. and Mikalef P. each having four links, while Lincon G. contributes with two significant connections. This structure emphasizes the collaborative landscape and potential synergies within these groups.

Figure 7, which shows the results of the co-citation analysis, evaluates the references cited by scientific publications within the selected dataset. By examining the relationship between these cited works, we can gain a deeper understanding of the foundational themes that underpin the research area regarding the role of digitalization and its impact on sustainability and firm performance and be able to identify

frequently co-cited publications and suggest significant correlations between them. In this co-citation analysis, we identified four prestigious clusters comprising a total of 42 significant publications based on our dataset. The Red cluster stands out as the largest, containing 15 articles, which highlights a robust research area. Following this, the Green Cluster offers 10 articles, showcasing important contributions, while Blue Cluster features 12 publications that add depth to the overall analysis. Lastly, the Yellow Cluster includes 5 articles that still provide valuable insights. **Tables 5a, 5b, 5c, and 5d** provide detailed information about each article within its respective cluster, highlighting critical thematic areas. In **Figure 8**, we presented a keyword co-occurrence analysis that includes an insightful examination in the form of content analysis. This analysis effectively demonstrates the frequency with which specific keywords appear together in titles, abstracts, and keyword publications lists, allowing us to identify key patterns of collaboration, core research themes, and emerging trends within this field. Through these analyses, we have successfully categorized our data into four distinct clusters: Green (11 keywords), Red (12 keywords), Blue (9 keywords), and Yellow (7 keywords). The keyword “Sustainability” stands out as the most significant term, with 59 occurrences and a total link strength of 89, positioned within the Red cluster (group). Following that closely “Green Innovation” in the Green cluster appeared 19 times with a total link strength of 16; “Industry 4.0” in the Blue cluster, also with 19 occurrences but a higher link strength of 45; and “Digitalization” which had 62 occurrence and total link strength of 106, further summarized in **Table 4**, providing a comprehensive picture of the current landscape.

In addressing the second research question (**RQ2**) of this study, which aims to identify the key thematic areas emerging from the existing body of literature, we conducted a comprehensive content analysis, as outlined in **Table 5a–5d**. This analysis focused on the most influential articles within each theme, uncovering sub-themes that are directly relevant to their corresponding fields. As a result, we identified four distinct thematic areas for further that merit further investigation: **(1)** the impact of digitalization on sustainable firm performance, **(2)** sustainable corporate performance and green practices, **(3)** the integration of industry 4.0 technologies for sustainable supply chain management, and **(4)** digitalization as a circular economy business model.

The first thematic area we address the **(1)** impact of digitalization on sustainable firm performance. In the context of today’s rapidly evolving manufacturing landscape, digitalization plays an important role in advancing sustainable firm performance by improving responsiveness, innovation, and productivity. As consumer demand for customized products rises, firms face increasing challenges in maintaining efficient and consistent delivery systems. The integration of information communication technologies (ICT), including big data, blockchain, and the Internet of Things, provides firms with opportunities to optimize operations. These technologies enable real-time data flow, improve transparency, and support decentralized

supply chain management (such as., reducing carbon emissions) through optimized routing and vehicle usage (Wroblewski, 2018; L. Guo & Xu, 2021). However, the path to digitalization is not without challenges, especially for SMEs, which often lack the financial and technical resources required for implementation (Sanchez-Riofrio et al., 2022). To assess sustainability performance, firms commonly use frameworks like life cycle assessment (LCA), eco-efficiency, and triple bottom line models. LCA evaluates environmental impacts throughout a product's life cycle, while eco-efficiency measures the balance between economic performance and environmental impact (Rashidi & Saen, 2015) + (Sharma et al., 2022), and the triple bottom line model evaluates sustainability across three pillars: people, planet, and profit (Sanchez-Riofrio et al., 2022; S. Li et al., 2023; Cirillo et al., 2023).

The second thematic area we focus on the, **(2)** sustainable corporate performance and green practices. Green practices, which focus on reducing ecological impacts through environmentally friendly actions within organizations are critical to sustainable corporate performance. These practices involve product and process innovations that minimize environmental damage. Small and medium enterprises (SMEs) are increasingly adopting sustainable initiatives, such as reducing emissions, minimizing waste, and using eco-friendly materials and packaging (M.-J. Lee & Roh, 2023). Green technologies can be divided into three categories: **(a)** Green Processes, **(b)** Green Products, and **(c)** Green Management. Green Processes aim to use limited natural resources, while Green Products focus on creating environmentally friendly goods and services. Green Management involves updating company policies and strategies to support sustainability (Abbas & Sağsan, 2019; L. Li, Tong, et al., 2022). By adopting sustainable practices, companies can improve both financial and non-financial performance metrics (like profitability, growth, and market shares). These practices help businesses meet stakeholder expectations and enhance productivity, quality, and reputation leading to increased competitiveness and profitability (Leischnig et al., 2016) + (Forcadell et al., 2020; Homburg & Wielgos, 2022).

The third thematic area we focus on the, **(3)** integration of industry 4.0 technologies for effective supply chain management. In the past decade, significant advancements have been made in both sustainable supply chain management (S.-Y. Lee, 2021) and Industry 4.0 technologies (Bhagat et al., 2022). Digital technologies (like big data analytics, deep learning, simulation, and the Internet of Things) have become essential in addressing the evolving demands of modern supply chain operations. These demands emphasize the need to increase productivity, reduce waste, optimize resources both within and outside the factory, and promise more sustainable production processes (Denicolai et al., 2021). The literature suggests that achieving sustainable performance is closely tied to technological innovation (Cappa et al., 2021; Díaz-Chao et al., 2021; Bhagat et al., 2022). Industry 4.0 technologies viewed as disruptive yet highly valuable, guide organizations toward sustainable outcomes across both industrial and service sectors. These

technologies enable value creation, waste reduction, and process integration, all of which significantly enhance organizational performance. Additionally, while there are numerous advantages, the literature also highlights challenges that impact sustainable supply chain management, including issues related to information sharing, forecasting accuracy, cost efficiency, and resource optimization.

The fourth thematic area **(4)** explores digitalization as a circular economy business model. The adoption of Circular Economy (CE) principles requires the development of innovative business models that create value while promoting sustainability. CE presents a shift from the traditional “take, make, waste” model, offering a more sustainable approach to growth that addresses both environmental and social challenges. This paradigm shift not only supports corporate sustainability but also drives regional development (Su et al., 2013; Ghisellini et al., 2016; Urbinati et al., 2017). At its core CE seeks to decouple economic activities from the consumption of finite resources while minimizing waste. By integrating principles of industrial ecology, CE encourages companies to redesign products and processes for greater efficiency and sustainability. However successful implementation of circularity requires the adoption of advanced technologies and specialized skills, highlighting the critical role of digital innovation (Nayal, Kumar, et al., 2022). Digital technologies particularly those emerging from Industry 4.0 (I4.0) framework, are pivotal in advancing CE business models. These technologies enable more efficient material tracking across supply chains, reducing the need for product ownership and facilitating a shift toward product and service (Lenka et al., 2017; Joensuu-Salo et al., 2018). The capabilities of digitalization (such as., intelligence, connectivity, and analytics) boost decision-making processes by providing real-time insights which are essential for optimizing resource use and supporting circular practices. While the potential of digital technologies in driving Circular Economy business models is well-recognized, further research is needed to understand how these technologies can optimize resource flow and material capture in real-world applications.

To address the final **(3)** research question—“How can the literature on digitalization, sustainability, and firm performance be expanded?” — we present a summary of key research (future) directions in **Table 6**, identifying twenty emerging themes derived from the four main thematic areas in **Section 5**. These thematic areas also provide a clear direction for future studies.

This bibliometric systematic literature review (B-SLR), provides an overview of current knowledge in the areas of digitalization, sustainability, and performance of firms. This overview can guide future research efforts and encourage the development of innovative methodologies. However, we also see in the literature that smaller firms often face greater difficulties in adopting sustainable strategies compared to the (big) larger firms due to limited resource availability. The effectiveness of sustainability initiatives on firm performance can differ (varies) between developed and developing regions (Lenka et al., 2017) + (Y. Li et

al., 2020). Larger organizations/firms with more substantial resources tend to invest more in digitalization, often with less emphasis on short-term financial returns. These findings contribute to the ongoing debate in the literature regarding the link between digitalization and sustainability on firm performance.

9.6.1. Theoretical Implications

This study integrates a systematic literature review with a bibliometric analysis (B-SLR) to establish a comprehensive framework that guides researchers in understanding the current state of knowledge in this field. The theoretical contributions of this study are outlined as follows:

First, this study provides a comprehensive synthesis of the existing body of literature on digitalization, sustainability, and firm performance. The performance section includes (no of studies over time, top publication sources/journals, top publication countries, geographical contributions, and top authors and cited publications), and the science mapping further explores the (such as countries' collaboration analyses, co-authorship analyses, co-citation analyses, and co-occurrence of keywords) analysis.

Second, the study describes the knowledge map of Digitalization (transformation), Sustainability (initiatives), and firm performance literature by identifying four thematic areas emerging from the current literature that could guide further investigation, through content analysis. Specifically, with the help of content analysis, we identified four distinct thematic areas: (1) the impact of digitalization on firm performance, (2) sustainable corporate performance and green practices, (3) the integration of Industry 4.0 technologies for sustainable supply chain management, (4) digitalization as a circular economy business model.

Third, through in-depth content analysis within these thematic areas, this study offers valuable recommendations for future research directions. The contextual framework provided helps address existing challenges in the field and offers a structured approach to navigating the fragmented literature. This contribution enriches the current body of knowledge by synthesizing previous research and presenting a robust foundation for advancing studies on the intersection of digitalization, sustainability, and firm performance.

9.6.2. Practical Implications

This paper also provides several important practical insights in the context of digitalization's role in sustainability and the performance of firms. The practical implications of this study area as outlined as follows:

Firstly, this study emphasizes the value of integrating (corporate) sustainability across all areas of businesses and its potential to deliver significant economic benefits. The growing body of research in this field of investigation highlights that sustainability (especially) when combined with digital technologies can be a major driver for (profitability) performance. Therefore, In today's competitive landscape, investment in sustainability practices especially backed by digital technologies is an essential determinant of a firm's profitability.

Secondly, B-SLR presents a clear framework for stakeholders, guiding companies/firms to understand how sustainable practices (supported by digital strategies) impact the overall profitability of firms. It also provides guidance on managing the potential challenges that arise when balancing sustainability with performance objectives, especially in an era of rapid digital transformation.

Thirdly, the publication (patterns) related to this topic of study (investigation) identifies leading authors, countries, and institutions that are making notable contributions to this study field. It further guides business leaders/practitioners (in that region) to take the lead and implement these practices in their operations.

Fourth, this study shows that companies engaging in digital (transformation) efforts tend to experience performance improvement. Digital platforms are crucial for engaging stakeholders and influencing market reactions. Therefore, businesses should carefully manage their digital presence to create value for stakeholders, enhancing both financial and non-financial performance.

9.6.3. Limitations and Future Research Agenda

This study acknowledges several limitations that should be considered when interpreting the findings. This B-SLR primarily relied on data from the SCOPUS and Web of Science databases. Future research intends to broaden the scope by incorporating additional (others) databases such as ABI/Inform, Business Source, Ultimate (EBSCO), Dimension, Google Scholar, PubMed, Ei Compendex, and Inpec. The inclusion of these databases could provide a more comprehensive set of insights as well. While SCOPUS and Web of Science are widely acknowledged as reputable sources for literature review and bibliometric analysis, their exclusivity may limit the comprehensibility of the review potentially omitting influential studies that are not indexed in these (two) databases. Although it is observed that the bibliometric part of this study, is a popular and established method for analyzing trends and growth in scientific research, it is not without limitations, like time required for citation accumulations.

To ensure methodological consistency, in this study we excluded book chapters, conference papers, and reports. Additionally, our search strategy exclusively focused on the author's keywords, which may

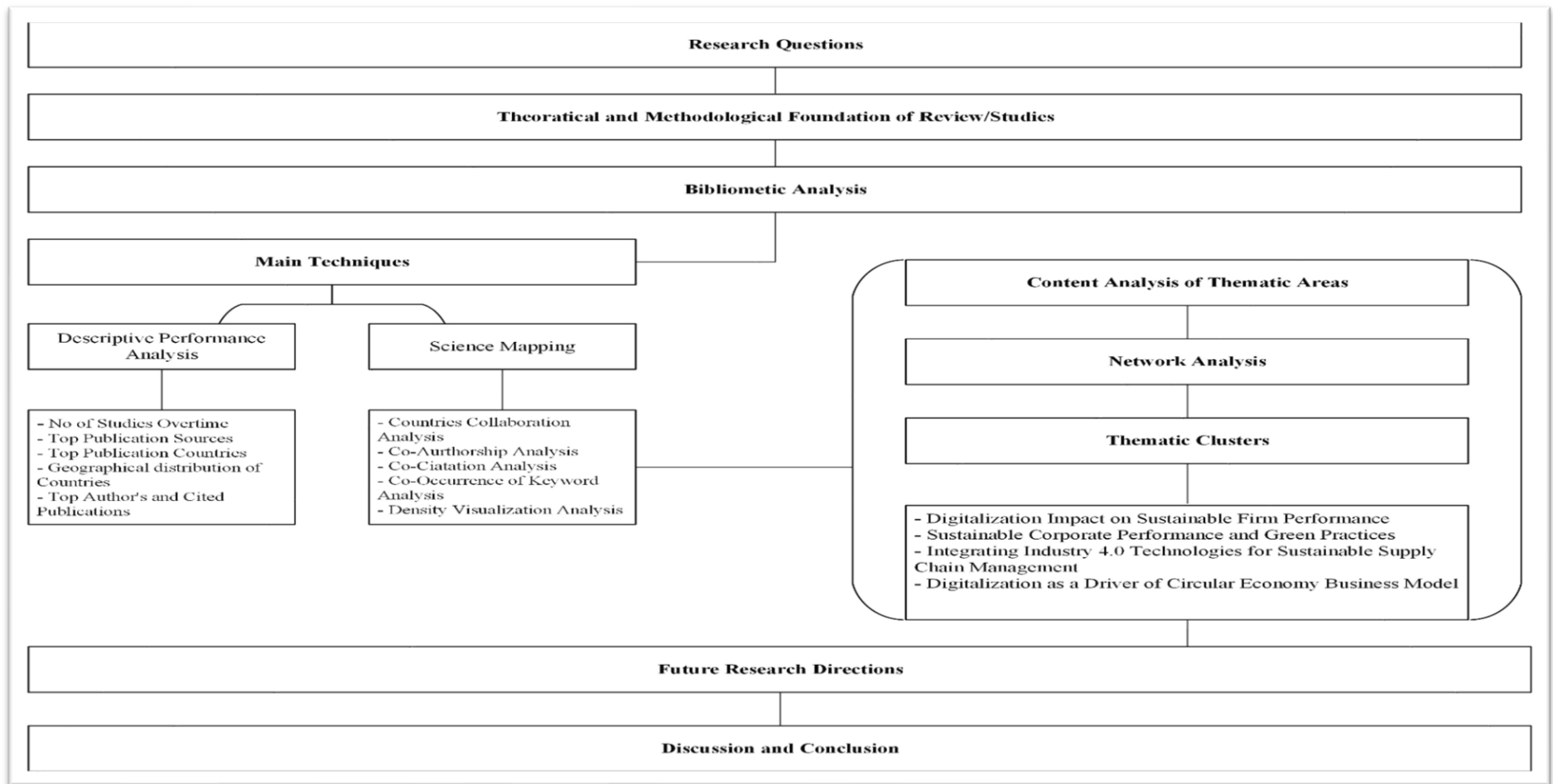
have resulted in the omission of some relevant studies/publications. The criteria for study selection also potentially excluded significant research published in languages other than English or across different time periods from 2013-2023. The analysis was conducted using VOS-Viewer, a widely utilized tool in the academic community; however, alternative software (such as., Bibliometrix, CitNetExplorer, CiteSpace, and VisualBib) could have provided a more detailed or nuanced analysis.

9.6.4. Additional Data File

Haseeb, M. (2024). Supplementary/Additional data file for the manuscript titled: *When Digitalization Meets Sustainability: Insights from a Bibliometric and Systematic Literature Review of its Impacts on Firm Performance*. <https://doi.org/10.5281/zenodo.13305800>

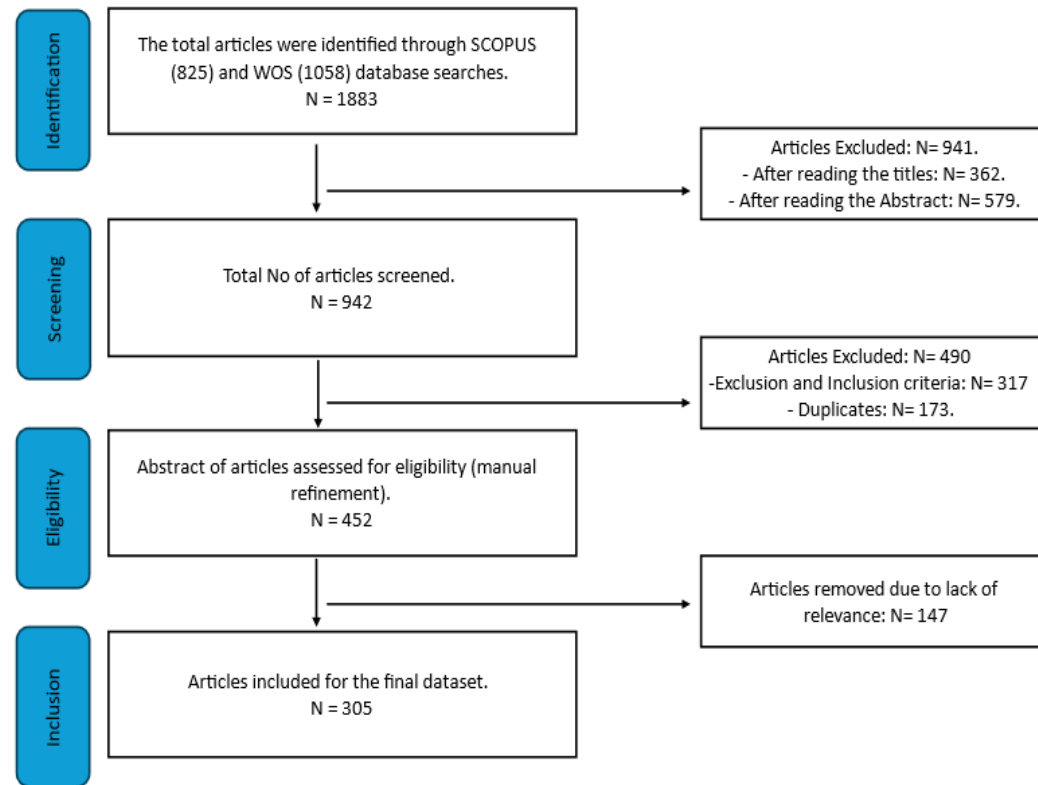
9.7. FIGURES OF THE PAPER 1.

9.7.1. ⁹Figure 1. Research Methodology Framework (Toolbox)



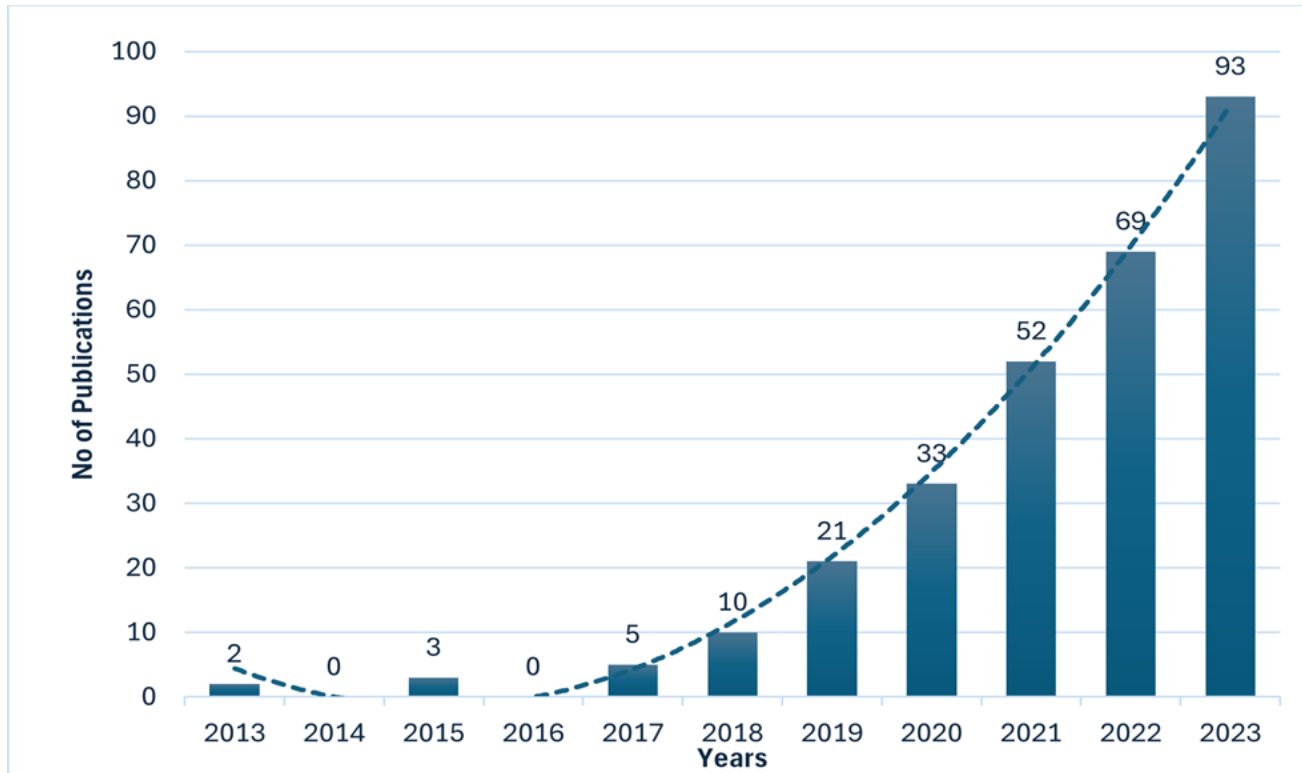
⁹ Research Methodology Framework (Toolbox); Adapted by (Donthu et al., 2021).

9.7.2. ¹⁰Figure 2. Prisma Study Protocols



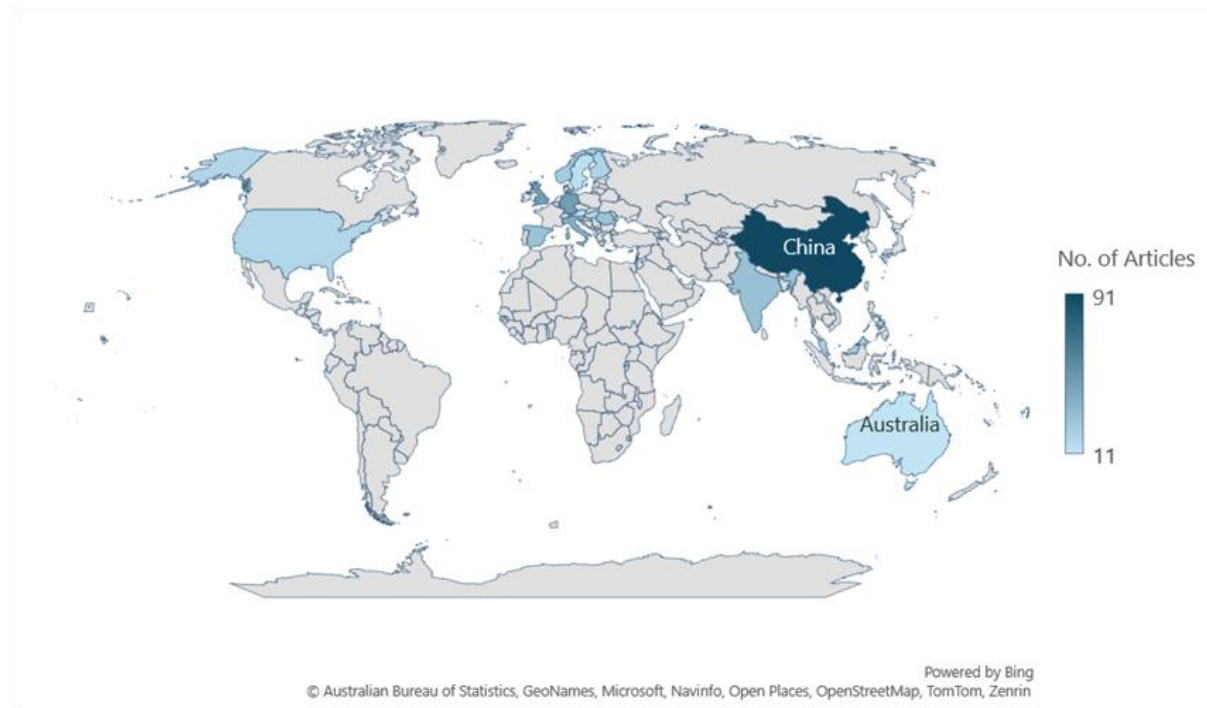
¹⁰ Prisma protocol (flowchart) diagram.

9.7.3. ¹¹Figure 3: Studies over a period.



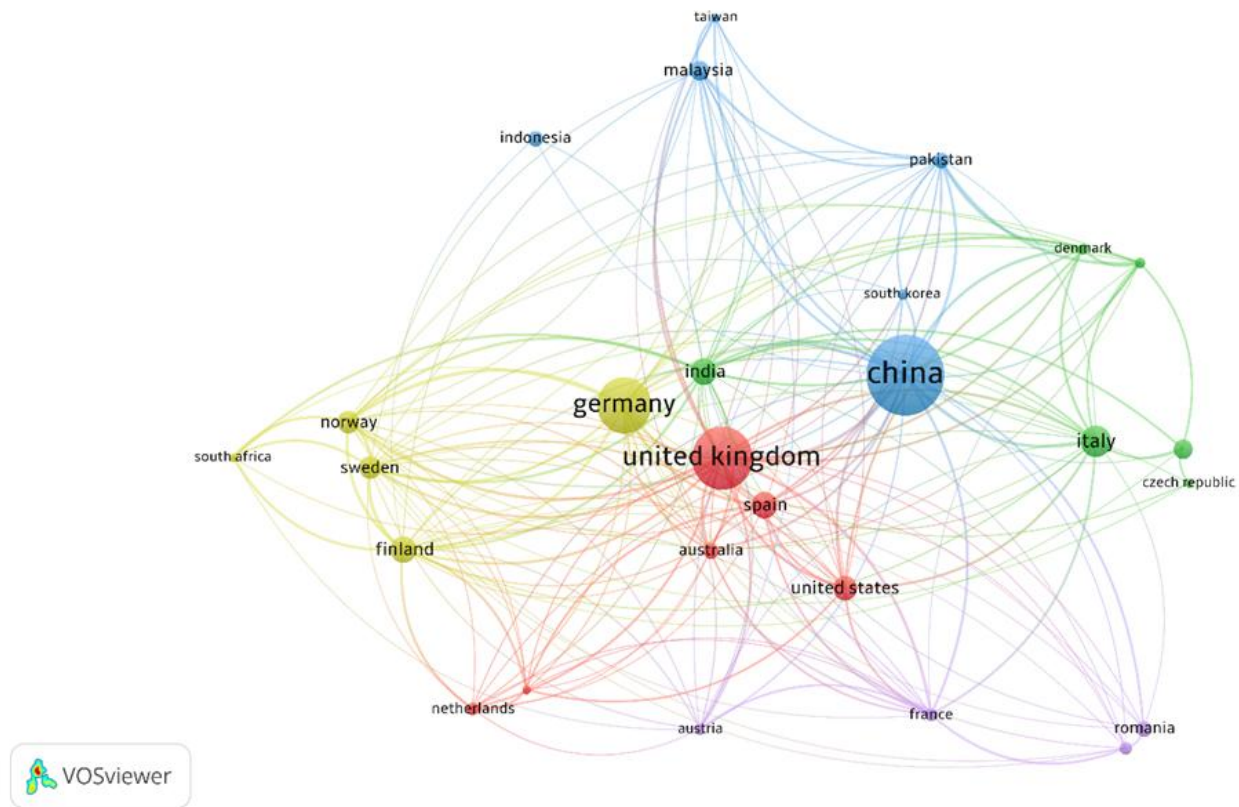
¹¹ Evolution of number of articles published overtime (2013–2023)

9.7.4. ¹²Figure 4. Geographical Contributions



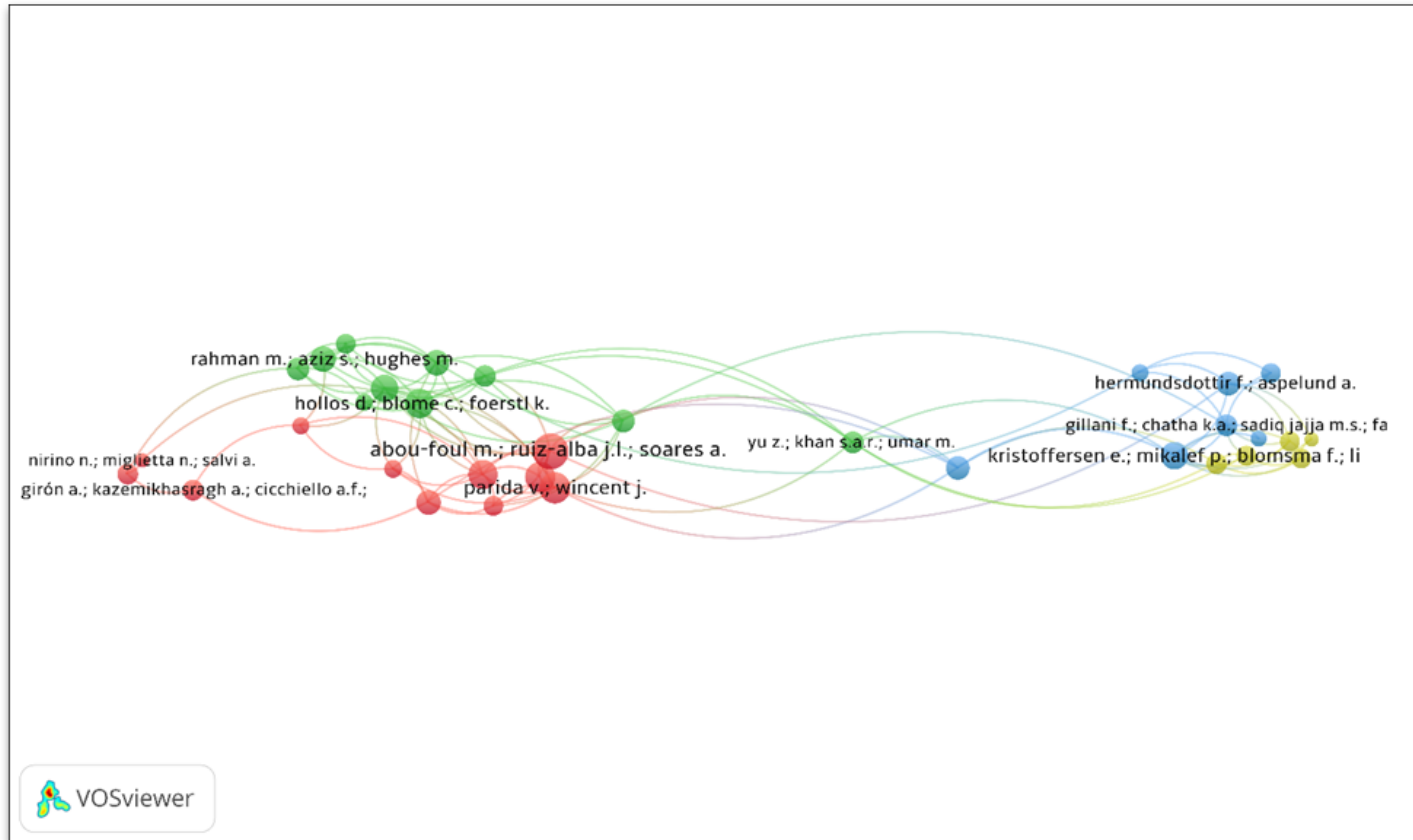
¹² Choropleth Map of geographical contribution of studies

9.7.5. ¹³Figure 5. Countries Collaboration Analysis.



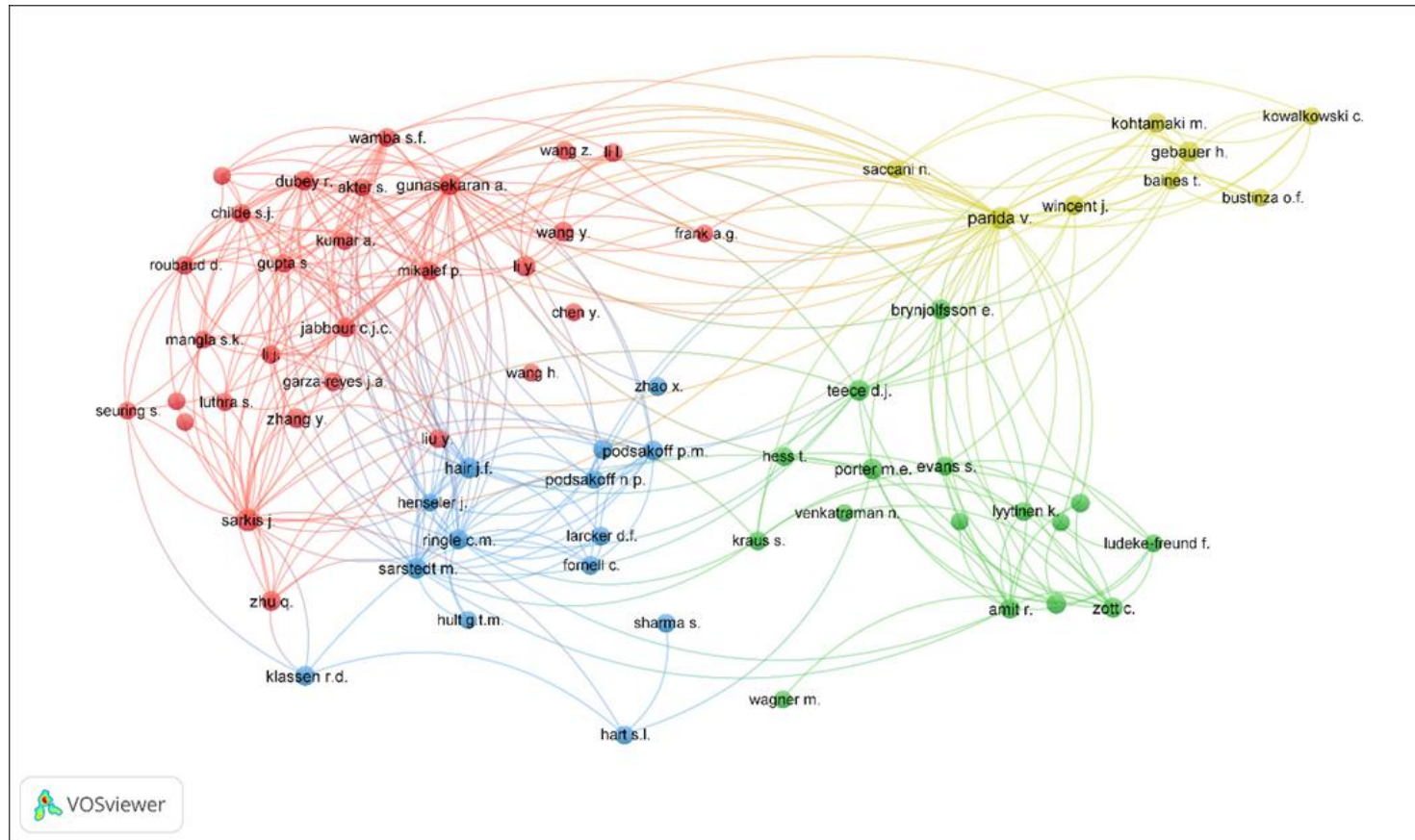
¹³ Countries Collaboration Map with VOS-viewer. Full Fraction Counting with a Minimum number of publications 05

9.7.6. ¹⁴Figure 6. Co-Authorship Analysis.



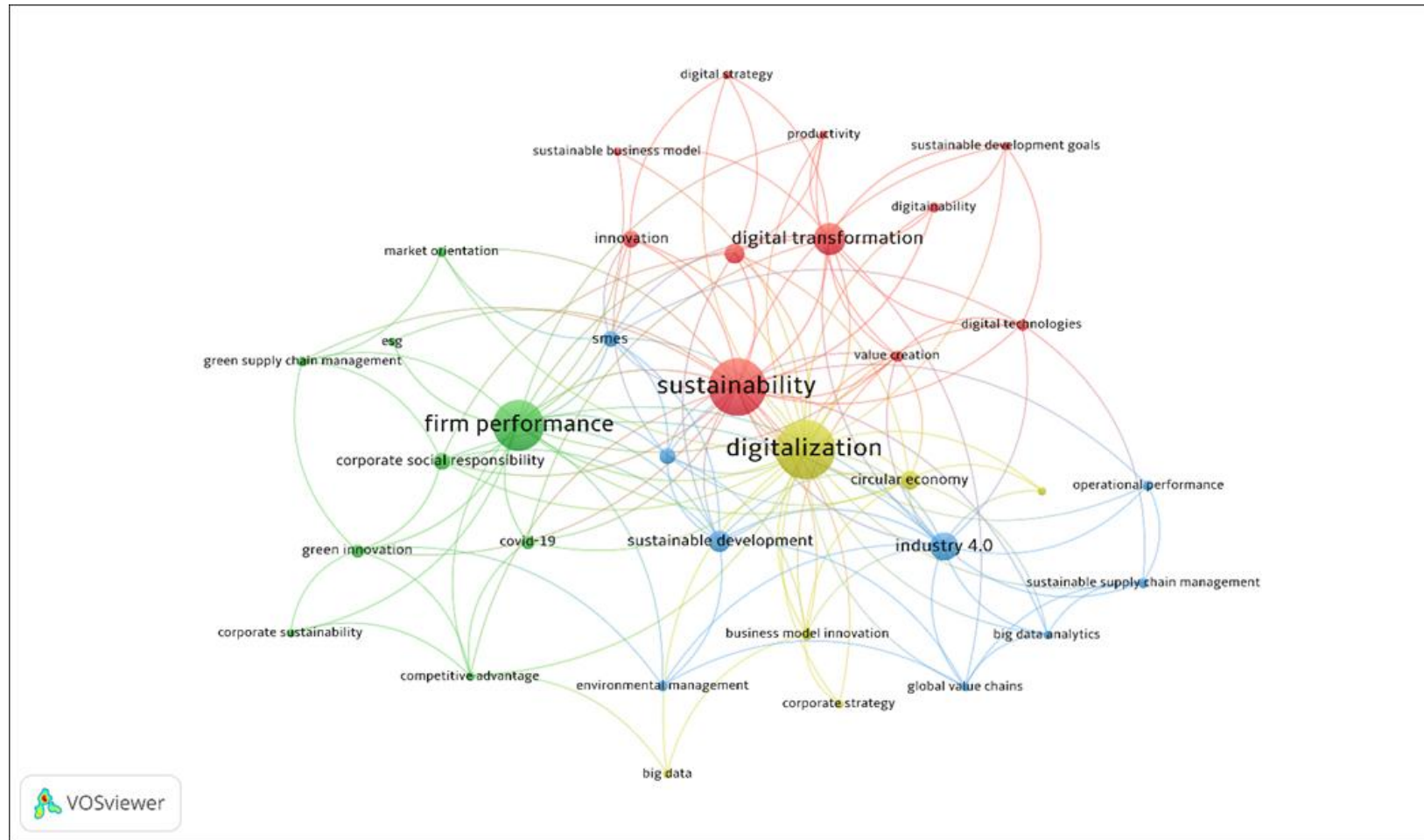
¹⁴ Network of authors from-authorship analysis using VOS-viewer. Full Fraction Counting with a Minimum number of publications 03 with 20 or more citations count.

9.7.7. ¹⁵Figure 7. Co-Citation Analysis.



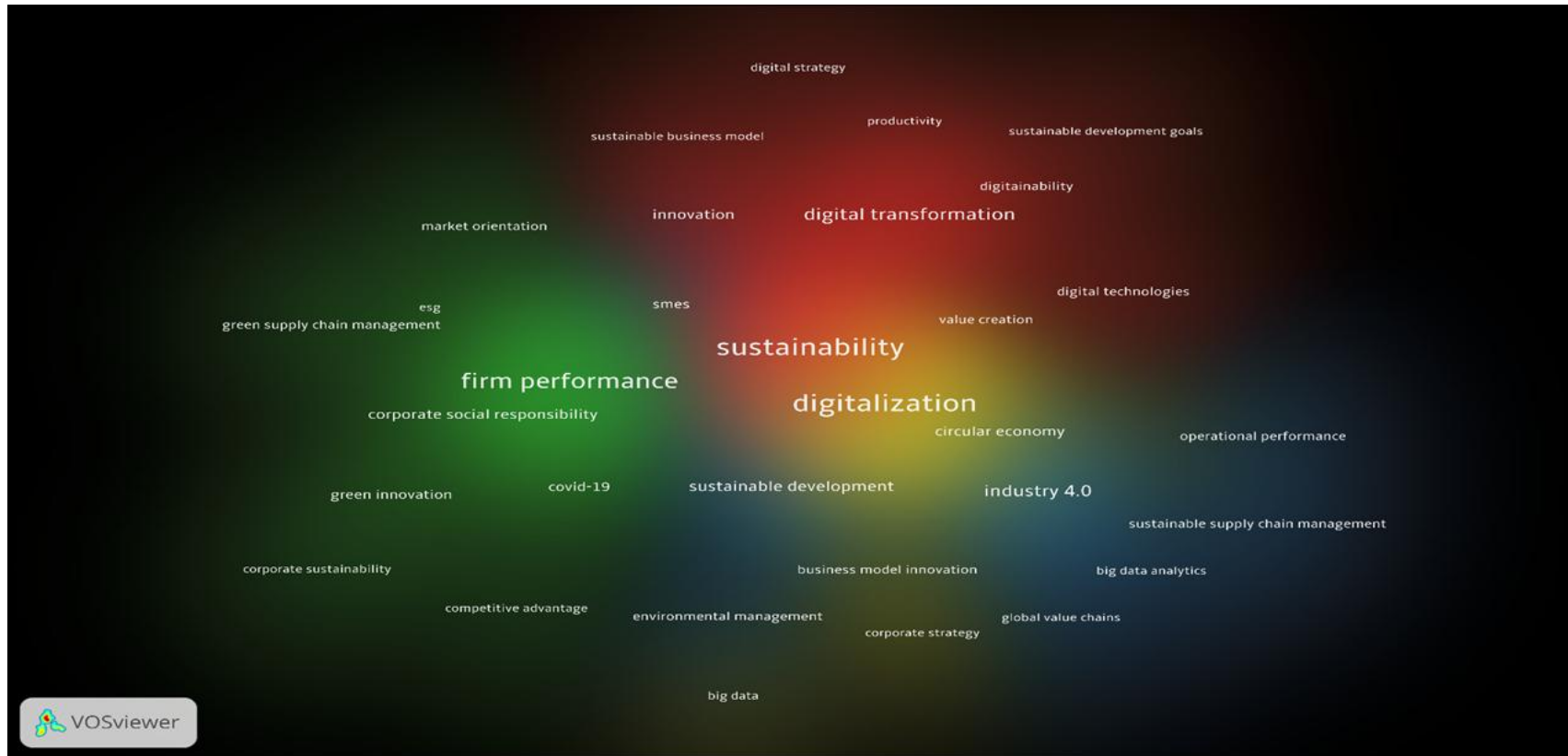
¹⁵ Co-Citation Map with VOS-viewer. Full Fraction Counting with a Minimum number of 20 citations per author

9.7.8. ¹⁶Figure 8. Co-Occurrence of Keywords.



¹⁶ Co-occurrence of author keyword's map with VOS-viewer. Full Fraction Counting method with a threshold 05 co-occurrence.

9.7.9. ¹⁷Figure 9. Density Analysis.



¹⁷ Density map with VOS-viewer. Full Fraction Counting method with a threshold 05 co-occurrence.

9.8. LIST OF TABLES OF PAPER 1.

9.8.1. ¹⁸Table 1.

Top Publications Sources/Journals

Sr. No	Title of Source	No. of Articles	Total Citations	Average citations	Impact Factor (2023)	Publisher
1	Journal of Cleaner Production	53	550	10.37	11.1	Elsevier
2	Journal of Business Research	43	1292	30.04	11.3	Elsevier
3	Technological Forecasting and Social Change	37	1068	28.86	12	Elsevier
4	Business Strategy and the Environment	30	300	10	13.4	Wiley Online Library
5	Sustainability	27	432	16	3.9	MDPI
6	Production Planning & Control	15	273	18.2	8.3	Taylor & Francis
7	Journal of Innovation & Knowledge	13	299	23	18.1	Elsevier
8	Administrative sciences	7	185	26.42	2.2	MDPI
9	Technology Analysis & Strategic Management	6	133	22.16	3.4	Taylor & Francis
10	Business Process Management Journal	6	123	20.5	3.46	Emerald Publishing Limited
11	Industrial Marketing Management	5	172	34.4	10.3	Elsevier
12	Technology in Society	4	247	61.75	2.1	Elsevier
13	Journal of Product Innovation Management	3	263	87.66	10.5	Wiley Online Library
14	European Journal of Information Systems	3	210	70	9.5	Taylor & Francis
15	Global Policy	1	86	86	1.9	Wiley Online Library

¹⁸ Source: Author's Calculation

9.8.2. ¹⁹Table 2.

Top Countries with Citations

Sr. No	Countries	Number of Articles	Total citations count	Average citation count per Items
1	China	91	868	9.5
2	Germany	47	601	12.7
3	UK	46	522	11.34
4	Italy	37	186	5.02
5	India	29	212	7.31
6	Romania	28	125	4.46
7	Spain	28	205	4.27
8	Norway	23	280	12.17
9	Malaysia	22	195	8.86
10	Finland	19	756	39.78
11	Hungary	18	320	17.77
12	USA	18	318	17.66
13	Austria	13	175	13.46
14	Sweden	13	62	4.76
15	Australia	11	38	3.45

¹⁹ Source: Author's Calculation

9.8.3. ²⁰Table 3.

Top Authors and Publications

Sr. No	Authors	Title	Journal Name	Year of Publication	Total No of citations	Average citations per year	Publisher
1	(Eller et al., 2020b)	Antecedents, consequences, and challenges of small and medium-sized enterprise digitalization	Journal of Business Research	2020	524	52.4	Elsevier
2	(Martínez-Caro et al., 2020)	Digital technologies and firm performance: The role of digital organisational culture	Technological Forecasting and Social Change	2020	452	45.2	Elsevier
3	(Denicolai et al., 2021)	Internationalization, digitalization, and sustainability: Are SMEs ready? A survey on synergies and substituting effects among growth paths	Technological Forecasting and Social Change	2021	339	33.9	Elsevier
4	(Cappa et al., 2021)	Big data for creating and capturing value in the digitalized environment: unpacking the effects of volume, variety, and veracity on firm performance	Journal of Product Innovation Management	2021	263	26.3	Wiley Online Library
5	(Ukko et al., 2019)	Sustainability strategy as a moderator in the relationship between digital business strategy and financial performance	Journal of Cleaner Production	2019	263	26.3	Elsevier
6	(Zhai et al., 2022)	Does digital transformation enhance a firm's performance? Evidence from China	Technology in Society	2022	247	24.7	Elsevier
7	(Martín-Peña et al., 2019)	Servitization and digitalization in manufacturing: the influence on firm performance	Journal of Business & Industrial Marketing	2019	244	24.4	Emerald Publishing Limited
8	(Ardito et al., 2021)	The duality of digital and environmental orientations in the context of SMEs: Implications for innovation performance	Journal of Business Research	2021	238	23.8	Elsevier
9	(Hanelt et al., 2021)	Digital M&A, digital innovation, and firm performance: an empirical investigation	European Journal of Information Systems	2021	210	21	Taylor & Francis
10	(Heredia et al., 2022)	How do digital capabilities affect firm performance? The mediating role of technological capabilities in the “new normal”	Journal of Innovation & Knowledge	2022	198	19.8	Elsevier

²⁰ Source Author's Calculation

11	(Ribeiro-Navarrete et al., 2021)	The effect of digitalization on business performance: An applied study of KIBS	Journal of business research	2021	197	19.7	Elsevier
12	(Abou-Foul et al., 2021)	The impact of digitalization and servitization on the financial performance of a firm: an empirical analysis	Production Planning & Control	2021	189	18.9	Taylor & Francis
13	(L. Li, 2022)	Digital transformation and sustainable performance: The moderating role of market turbulence	Industrial Marketing Management	2022	172	17.2	Elsevier
14	(Knudsen et al., 2021)	Stability in turbulent times? The effect of digitalization on the sustainability of competitive advantage	Journal of Business Research	2021	153	15.3	Elsevier
15	(Nayal, Raut, et al., 2022)	The impact of sustainable development strategy on sustainable supply chain firm performance in the digital transformation era	Business Strategy and the Environment	2022	119	11.9	Wiley Online Library

9.8.4. ²¹Table 4.

Co-occurrence of Keywords

Clusters	Items	Keywords	Co-occurrence	Total link strength	Topic
Red (Cluster1)	11	Sustainability	59	89	Digitalization's impact on sustainable firm performance
		Firm Performance	48	65	
		Value Creation	25	14	
		Digital Transformation	24	34	
		Innovation	19	18	
		Digital Technologies	15	10	
		Digitainability	14	13	
		Sustainable Development Goals	14	7	
		Digital Strategy	13	16	
		Productivity	13	7	
		Sustainable Business Models	13	15	
Green (Cluster 2)	9	Corporate Social Responsibility	19	16	Sustainable Corporate Performance and Green Practices
		Green Innovation	16	13	
		Green Supply Chain Management	14	17	
		Competitive Advantages	13	8	
		Financial Performance	11	14	
		Covid-19	6	10	
		Market Orientations	4	5	
		Corporate Sustainability	3	4	
		ESG	3	17	
Blue (Cluster 3)	9	Industry 4.0	19	45	Integrating Industry 4.0 technologies for sustainable supply chain management
		Environmental Sustainability	18	16	
		Environmental Management	14	8	

²¹ Source Author's Calculation

		Big Data Analytics	13	10	
		Sustainable Development	13	26	
		SME's	12	17	
		Global Values Chains	8	10	
		Operational Performance	4	5	
		Sustainable Supply Chain Management	4	9	
Yellow (Cluster 4)	6	Digitalization	62	106	Digitalization as a driver of the circular economy business model
		Business Model Innovation	15	14	
		Big Data	13	15	
		Circular Economy	10	24	
		Corporate Strategy	3	7	
		Sustainable Production	3	8	

9.8.4.a. ²²Table 5a

Top articles in Red Cluster 1.

Cluster	Topic	Authors	Total link Strength
Red (Cluster1)	Digitalization Impact on Sustainable Firm Performance	(Broccardo et al., 2023)	0.089
		(Yang & Yee, 2022)	0.065
		(M.-J. Lee & Roh, 2023)	0.014
		(L. Guo & Xu, 2021)	0.034
		(Wroblewski, 2018)	0.018
		(Heredia et al., 2022)	0.01
		(Ionaşcu et al., 2022)	0.013
		(Jung & Shegai, 2023)	0.007
		(Sanchez-Riofrio et al., 2022)	0.016
		(X. Guo et al., 2023)	0.007
		(Hanelt et al., 2021)	0.015
		(Cirillo et al., 2023)	0.006
		(Zhai et al., 2022)	0.014
		(Oduro et al., 2023)	0.017
		(S. Li et al., 2023)	0.057

²² Source: Author's Calculation

9.8.4.b. ²³Table 5b.

Top articles in Green Cluster 2

Cluster	Topic	Authors	Total link Strength
Green (Cluster 2)	Sustainable Corporate Performance and Green Practices	(Abou-Foul et al., 2021)	0.016
		(Ricci et al., 2020)	0.013
		(Forcadell et al., 2020)	0.017
		(L. Li, Tong, et al., 2022)	0.008
		(Knudsen et al., 2021)	0.014
		(Xu et al., 2023)	0.018
		(Ukko et al., 2019)	0.005
		(Martins, 2023)	0.004
		(Z. Wang et al., 2023)	0.017
		(Leischnig et al., 2016)	0.012

²³ Source: Author's Calculation

9.8.4.c. ²⁴Table 5c.

Top articles in Blue Cluster 3

Cluster	Topic	Authors	Total link Strength
Blue (Cluster 3)	Integrating Industry 4.0 Technologies for Sustainable Supply Chain Management	(Nayal, Raut, et al., 2022)	0.045
		(Bhagat et al., 2022)	0.016
		(Joensuu-Salo et al., 2018)	0.008
		(S.-Y. Lee, 2021)	0.01
		(AlMulhim, 2021)	0.026
		(Cappa et al., 2021)	0.017
		(L. Li, Ye, et al., 2022)	0.01
		(Denicolai et al., 2021)	0.005
		(Díaz-Chao et al., 2021)	0.009
		(Reza et al., 2021)	0.007
		(Ardito et al., 2021)	0.003
		(Sharma et al., 2022)	0.005

²⁴ Source: Author's Calculation

9.8.4.d. ²⁵Table 5d.

Top articles in Yellow Cluster 4

Cluster	Topic	Authors	Total link Strength
Yellow (Cluster 4)	Digitalization as a Driver of Circular Economy Business Model	(Nayal, Kumar, et al., 2022)	0.106
		(Eller et al., 2020b)	0.014
		(Homburg & Wielgos, 2022)	0.015
		(Martín-Peña et al., 2019)	0.024
		(Hautala-Kankaanpää, 2022)	0.007

²⁵ Source: Author's Calculation

9.8.5. ²⁶Table 6.

Future Research Directions

Thematic Areas	Future Research Themes	Exemplary References
Digitalization Impact on Sustainable Firm Performance	How does the digital culture within organizations impact the association between digital platforms and supply chain capabilities, and how does this influence operational performance?	(Haq & Huo, 2023)
	What mechanisms enable digital strategy to enhance digital capabilities and drive sustainable competitive performance in SMEs, particularly within manufacturing sectors?	(Yang & Yee, 2022)
	What is the mediating role of exploratory and exploitative green-tech innovation in the relationship concerning corporate digitalization and sustainability, particularly relating to the sustainable aspects of entrepreneurial business performance?	(Denicolai et al., 2021)
	How does digital transformation relate to sustainable business performance, with a focus on the sustainable aspects of entrepreneurial business performance?	(Broccardo et al., 2023)
Sustainable Corporate Performance and Green Practices	What are the essential green practices that substantially improve the corporate performance of enterprises across various industries and organizational settings?	(Ryoo & Koo, 2013)
	When it comes to financial performance, operational effectiveness, innovation, and competitiveness in the market, how do green practices affect these aspects of company performance?	(Bhagat et al., 2022)
	Exploring the drivers and barriers behind the adoption and implementation of environmentally friendly practices within organizations. Additionally, delving into the way in which these factors exert influence on the long-term performance and outcomes of corporations?	(Nguyen et al., 2018)
	What important roles do leadership, stakeholder involvement, and organizational culture play in encouraging and maintaining the integration of sustainable practices to boost business performance?	(Shahzad et al., 2020)
Integrating Industry 4.0 Technologies for Sustainable Supply Chain Management.	How do different frameworks for measuring and evaluating sustainable practices and firm performance capture the multifaceted nature of sustainability and effectively analyze its impact on business outcomes?	(Le et al., 2022)
	More in-depth investigation is required to identify strategies that enable SMEs to embrace sustainable and ethical business practices through integration of Industry 4.0 technologies.	

²⁶ Sources Author's Calculation (Future Research Directions)

	It is essential to investigate the analysis of the disruptive technology's characteristics of I4.0, which concerns factors integral to SSC integration. Such studies provide valuable support for reducing waste and boosting remanufacturing activities	(Karmaker et al., 2023)
	Develop a conceptual framework model to improve understanding of I4.0 and SSCM across various industrial sectors.	(Mastos et al., 2020)
	While previous studies have developed various frameworks for circular economy and industry 4.0 technologies, there is a need for a guidelines framework that details the application of digital technologies at different stages of SSCM implementation to achieve SBP?	(Singh & Del Giudice, 2019)
	What challenges are associated with the intersection of SSCM and I4.0 in the context of digitalization, and how can suitable modelling techniques be used to understand adoption strategies?	(Kunkel et al., 2022)
Digitalization as a Driver of Circular Economy Business Models.	Investigating digital technologies and strategies that facilitate the transition to a CE and assess their impact on various dimensions of business models.	(Ranta et al., 2021)
	Examine organizations' barriers and challenges in adopting and implementing digital solutions to support circular economy principles within business operations and identify strategies for overcoming these challenges.	(Agrawal et al., 2021)
	Analyze digital transformation's economic, environmental, and social effects on the CE and develop methodologies for organizations to measure and evaluate these impacts effectively.	(Chiaroni et al., 2021)
	Determining how an organization can strategically adopt business model innovation to create, deliver and capture value through digital channels.	
	Exploring pioneering technologies and business models that facilitate a smooth shift towards a circular and sustainable economy is crucial.	
	Assess whether developing an infrastructure plan to address digitalization adoption challenges could be a viable solution for achieving growth within the circular economy.	

9.9. References

- Abbas, J., & Sağsan, M. (2019). Impact of knowledge management practices on green innovation and corporate sustainable development: A structural analysis. *Journal of Cleaner Production*, 229, 611–620. <https://doi.org/10.1016/j.jclepro.2019.05.024>
- Aboud, A., & Diab, A. (2018). The impact of social, environmental and corporate governance disclosures on firm value: Evidence from Egypt. *Journal of Accounting in Emerging Economies*, 8(4), 442–458. <https://doi.org/10.1108/JAEE-08-2017-0079>
- Abou-Foul, M., Ruiz-Alba, J. L., & Soares, A. (2021). The impact of digitalization and servitization on the financial performance of a firm: An empirical analysis. *Production Planning & Control*, 32(12), 975–989.
- Academic-journal-guide-2021-methodology-final.pdf*. (n.d.). Retrieved 2 July 2024, from <https://d1sqxrh4fb2al3.cloudfront.net/academic-journal-guide-2021-methodology-final.pdf>
- Agrawal, R., Wankhede, V. A., Kumar, A., Upadhyay, A., & Garza-Reyes, J. A. (2021). Nexus of circular economy and sustainable business performance in the era of digitalization. *International Journal of Productivity and Performance Management*, 71(3), 748–774. <https://doi.org/10.1108/IJPPM-12-2020-0676>
- Aguinis, H., Pierce, C. A., Bosco, F. A., Dalton, D. R., & Dalton, C. M. (2011). Debunking Myths and Urban Legends About Meta-Analysis. *Organizational Research Methods*, 14(2), 306–331. <https://doi.org/10.1177/1094428110375720>
- Agyemang, O. S., & Ansong, A. (2017). Corporate social responsibility and firm performance of Ghanaian SMEs: Mediating role of access to capital and firm reputation. *Journal of Global Responsibility*, 8(1), 47–62. <https://doi.org/10.1108/JGR-03-2016-0007>
- Alegre, J., Callahan, J., & Iszatt-White, M. (2023). Innovative conceptual contributions—Raising the game for theory-driven reviews. *International Journal of Management Reviews*, 25(2), 233–239. <https://doi.org/10.1111/ijmr.12333>
- AlMulhim, A. F. (2021). Smart supply chain and firm performance: The role of digital technologies. *Business Process Management Journal*, 27(5), 1353–1372.
- Annarelli, A., Battistella, C., Nonino, F., Parida, V., & Pessot, E. (2021). Literature review on digitalization capabilities: Co-citation analysis of antecedents, conceptualization and consequences. *Technological Forecasting and Social Change*, 166, 120635. <https://doi.org/10.1016/j.techfore.2021.120635>
- Ardito, L., Raby, S., Albino, V., & Bertoldi, B. (2021). The duality of digital and environmental orientations in the context of SMEs: Implications for innovation performance. *Journal of Business Research*, 123, 44–56.

- ARE, F. O. for S. D. (n.d.). 1987: *Brundtland Report*. Retrieved 19 February 2025, from <https://www.are.admin.ch/are/en/home/medien-und-publikationen/publikationen/nachhaltige-entwicklung/brundtland-report.html>
- Bansal, M., Samad, T. A., & Bashir, H. A. (2021). The sustainability reporting-firm performance nexus: Evidence from a threshold model. *Journal of Global Responsibility*, 12(4), 491–512. <https://doi.org/10.1108/JGR-05-2021-0049>
- Barnea, A., & Rubin, A. (2010). Corporate Social Responsibility as a Conflict Between Shareholders. *Journal of Business Ethics*, 97(1), 71–86. <https://doi.org/10.1007/s10551-010-0496-z>
- Bartolacci, F., Caputo, A., & Soverchia, M. (2020). Sustainability and financial performance of small and medium sized enterprises: A bibliometric and systematic literature review. *Business Strategy and the Environment*, 29(3), 1297–1309. <https://doi.org/10.1002/bse.2434>
- Battistella, C., De Toni, A. F., De Zan, G., & Pessot, E. (2017). Cultivating business model agility through focused capabilities: A multiple case study. *Journal of Business Research*, 73, 65–82. <https://doi.org/10.1016/j.jbusres.2016.12.007>
- Bernardi, C., & Stark, A. W. (2018). On the value relevance of information on environmental and social activities and performance – Some evidence from the UK stock market. *Journal of Accounting and Public Policy*, 37(4), 282–299. <https://doi.org/10.1016/j.jaccpubpol.2018.07.001>
- Bhagat, P. R., Naz, F., & Magda, R. (2022). Role of Industry 4.0 Technologies in enhancing sustainable firm performance and green practices. *Acta Polytechnica Hungarica*, 19(8), 229–248.
- Bhatia, M. S., & Kumar, S. (2022). Critical Success Factors of Industry 4.0 in Automotive Manufacturing Industry. *IEEE Transactions on Engineering Management*, 69(5), 2439–2453. *IEEE Transactions on Engineering Management*. <https://doi.org/10.1109/TEM.2020.3017004>
- Bodhanwala, S., & Bodhanwala, R. (2021). Exploring relationship between sustainability and firm performance in travel and tourism industry: A global evidence. *Social Responsibility Journal*, 18(7), 1251–1269. <https://doi.org/10.1108/SRJ-09-2020-0360>
- Bota-Avram, C. (2023). Bibliometric analysis of sustainable business performance: Where are we going? A science map of the field. *Economic Research-Ekonomska Istraživanja*, 36(1), 2137–2176. <https://doi.org/10.1080/1331677X.2022.2096094>
- Brammer, S., Brooks, C., & Pavelin, S. (2006). Corporate Social Performance and Stock Returns: UK Evidence from Disaggregate Measures. *Financial Management*, 35(3), 97–116. <https://doi.org/10.1111/j.1755-053X.2006.tb00149.x>
- Broccardo, L., Truant, E., & Dana, L.-P. (2023). The interlink between digitalization, sustainability, and performance: An Italian context. *Journal of Business Research*, 158, 113621.

- Brooks, C., & Oikonomou, I. (2018). The effects of environmental, social and governance disclosures and performance on firm value: A review of the literature in accounting and finance. *The British Accounting Review*, 50(1), 1–15. <https://doi.org/10.1016/j.bar.2017.11.005>
- Calderon-Monge, E., & Ribeiro-Soriano, D. (2024). The role of digitalization in business and management: A systematic literature review. *Review of Managerial Science*, 18(2), 449–491. <https://doi.org/10.1007/s11846-023-00647-8>
- Cappa, F., Oriani, R., Peruffo, E., & McCarthy, I. (2021). Big data for creating and capturing value in the digitalized environment: Unpacking the effects of volume, variety, and veracity on firm performance. *Journal of Product Innovation Management*, 38(1), 49–67.
- Carney, M., Gedajlovic, E. R., Heugens, P. P. M. A. R., Van Essen, M., & Van Oosterhout, J. (2011). Business group affiliation, performance, context, and strategy: A meta-analysis. *Academy of Management Journal*, 54(3), 437–460. Scopus. <https://doi.org/10.5465/AMJ.2011.61967812>
- Chiaroni, D., Vecchio, P. D., Peck, D., Urbinati, A., & Vrontis, D. (2021). “Digital technologies in the business model transition towards a circular economy”. *Resources, Conservation and Recycling*, 168, 105286. <https://doi.org/10.1016/j.resconrec.2020.105286>
- Chowdhury, S. B., DasGupta, R., Choudhury, B. K., & Sen, N. (2023). Evolving alliance between corporate environmental performance and financial performance: A bibliometric analysis and systematic literature review. *Business and Society Review*, 128(1), 95–131. <https://doi.org/10.1111/basr.12301>
- Cirillo, V., Fanti, L., Mina, A., & Ricci, A. (2023). New digital technologies and firm performance in the Italian economy. *Industry and Innovation*, 30(1), 159–188.
- Conducting Research Literature Reviews*. (2025, February 5). SAGE Publications Inc. <https://us.sagepub.com/en-us/nam/conducting-research-literature-reviews/book259191>
- Dalenogare, L. S., Benitez, G. B., Ayala, N. F., & Frank, A. G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. *International Journal of Production Economics*, 204, 383–394. <https://doi.org/10.1016/j.ijpe.2018.08.019>
- Denicolai, S., Zucchella, A., & Magnani, G. (2021). Internationalization, digitalization, and sustainability: Are SMEs ready? A survey on synergies and substituting effects among growth paths. *Technological Forecasting and Social Change*, 166, 120650.
- Díaz-Chao, Á., Ficapal-Cusí, P., & Torrent-Sellens, J. (2021). Environmental assets, industry 4.0 technologies and firm performance in Spain: A dynamic capabilities path to reward sustainability. *Journal of Cleaner Production*, 281, 125264.
- Digitization, Digitalization, Digital Transformation, and Beyond*. (n.d.). ResearchGate. Retrieved 19 February 2025, from

- https://www.researchgate.net/publication/382069117_Digitization_Digitalization_Digital_Transformation_and_Beyond
- Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, 133, 285–296. <https://doi.org/10.1016/j.jbusres.2021.04.070>
- Elkington, J. (1998). Partnerships from cannibals with forks: The triple bottom line of 21st-century business. *Environmental Quality Management*, 8(1), 37–51. <https://doi.org/10.1002/tqem.3310080106>
- Eller, R., Alford, P., Kallmünzer, A., & Peters, M. (2020a). Antecedents, consequences, and challenges of small and medium-sized enterprise digitalization. *Journal of Business Research*, 112, 119–127. <https://doi.org/10.1016/j.jbusres.2020.03.004>
- Eller, R., Alford, P., Kallmünzer, A., & Peters, M. (2020b). Antecedents, consequences, and challenges of small and medium-sized enterprise digitalization. *Journal of Business Research*, 112, 119–127.
- Fan, D., Breslin, D., Callahan, J. L., & Iszatt-White, M. (2022). Advancing literature review methodology through rigour, generativity, scope and transparency. *International Journal of Management Reviews*, 24(2), 171–180. <https://doi.org/10.1111/ijmr.12291>
- Farrukh, M., Meng, F., Wu, Y., & Nawaz, K. (2020). Twenty-eight years of business strategy and the environment research: A bibliometric analysis. *Business Strategy and the Environment*, 29(6), 2572–2582. <https://doi.org/10.1002/bse.2521>
- Fatorachian, H., & Kazemi, H. (2018). A critical investigation of Industry 4.0 in manufacturing: Theoretical operationalisation framework. *Production Planning & Control*, 29(8), 633–644. <https://doi.org/10.1080/09537287.2018.1424960>
- Fauzi, H., Mahoney, L. S., & Abdul Rahman, A. (2009). *The Link between Corporate Social Performance and Financial Performance: Evidence from Indonesian Companies* (SSRN Scholarly Paper No. 1489181). Social Science Research Network. <https://papers.ssrn.com/abstract=1489181>
- Forcadell, F. J., Aracil, E., & Úbeda, F. (2020). The impact of corporate sustainability and digitalization on international banks' performance. *Global Policy*, 11, 18–27.
- GDP driven by digital transformation 2018-2023*. (n.d.). Statista. Retrieved 19 February 2025, from <https://www.statista.com/statistics/1134766/nominal-gdp-driven-by-digitally-transformed-enterprises/>
- Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, 114, 11–32. <https://doi.org/10.1016/j.jclepro.2015.09.007>

- González-Benito, J., & González-Benito, Ó. (2005). Environmental proactivity and business performance: An empirical analysis. *Omega*, 33(1), 1–15. <https://doi.org/10.1016/j.omega.2004.03.002>
- Goyal, P., Rahman, Z., & Kazmi, A. A. (2013). Corporate sustainability performance and firm performance research. *Management Decision*, 51(2), 361–379. <https://doi.org/10.1108/00251741311301867>
- Guo, L., & Xu, L. (2021). The effects of digital transformation on firm performance: Evidence from China's manufacturing sector. *Sustainability*, 13(22), 12844.
- Guo, X., Li, M., Wang, Y., & Mardani, A. (2023). Does digital transformation improve the firm's performance? From the perspective of digitalization paradox and managerial myopia. *Journal of Business Research*, 163, 113868.
- Gupta, A. K., & Gupta, N. (2020). Effect of corporate environmental sustainability on dimensions of firm performance – Towards sustainable development: Evidence from India. *Journal of Cleaner Production*, 253, 119948. <https://doi.org/10.1016/j.jclepro.2019.119948>
- Hamman, J. R., Loewenstein, G., & Weber, R. A. (2010). Self-Interest through Delegation: An Additional Rationale for the Principal-Agent Relationship. *American Economic Review*, 100(4), 1826–1846. <https://doi.org/10.1257/aer.100.4.1826>
- Han, J.-J., Kim, H. J., & Yu, J. (2016). Empirical study on relationship between corporate social responsibility and financial performance in Korea. *Asian Journal of Sustainability and Social Responsibility*, 1(1), 61–76. <https://doi.org/10.1186/s41180-016-0002-3>
- Hanelt, A., Firk, S., Hildebrandt, B., & Kolbe, L. M. (2021). Digital M&A, digital innovation, and firm performance: An empirical investigation. *European Journal of Information Systems*, 30(1), 3–26.
- Haq, I. U., & Huo, C. (2023). Digital strategy and environmental performance: The mediating role of digitalization in SMEs. *Digital Economy and Sustainable Development*, 1(1), 9. <https://doi.org/10.1007/s44265-023-00010-5>
- Hautala-Kankaanpää, T. (2022). The impact of digitalization on firm performance: Examining the role of digital culture and the effect of supply chain capability. *Business Process Management Journal*, 28(8), 90–109.
- Heredia, J., Castillo-Vergara, M., Geldes, C., Gamarra, F. M. C., Flores, A., & Heredia, W. (2022). How do digital capabilities affect firm performance? The mediating role of technological capabilities in the “new normal”. *Journal of Innovation & Knowledge*, 7(2), 100171.
- Hiebl, M. R. W. (2023). Sample Selection in Systematic Literature Reviews of Management Research. *Organizational Research Methods*, 26(2), 229–261. <https://doi.org/10.1177/1094428120986851>

- Hizarci-Payne, A. K., İpek, İ., & Kurt Gümüş, G. (2021). How environmental innovation influences firm performance: A meta-analytic review. *Business Strategy and the Environment*, 30(2), 1174–1190. <https://doi.org/10.1002/bse.2678>
- Homburg, C., & Wielgos, D. M. (2022). The value relevance of digital marketing capabilities to firm performance. *Journal of the Academy of Marketing Science*, 50(4), 666–688.
- 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), 2158244020953180. <https://doi.org/10.1177/2158244020953180>
- Ikram, M., Sroufe, R., Mohsin, M., Solangi, Y. A., Shah, S. Z. A., & Shahzad, F. (2019). Does CSR influence firm performance? A longitudinal study of SME sectors of Pakistan. *Journal of Global Responsibility*, 11(1), 27–53. <https://doi.org/10.1108/JGR-12-2018-0088>
- Ionaşcu, I., Ionaşcu, M., Nechita, E., Săcărin, M., & Minu, M. (2022). Digital transformation, financial performance and sustainability: Evidence for European Union listed companies. *Amfiteatru Economic*, 24(59), 94–109.
- Jetty, S., & Afshan, N. (2024). A bibliometric analysis and systematic literature review of industry 4.0 implementation in supply chain. *Journal of Science and Technology Policy Management*, ahead-of-print(ahead-of-print). <https://doi.org/10.1108/JSTPM-07-2023-0112>
- Joensuu-Salo, S., Sorama, K., Viljamaa, A., & Varamäki, E. (2018). Firm performance among internationalized SMEs: The interplay of market orientation, marketing capability and digitalization. *Administrative Sciences*, 8(3), 31.
- Jung, S.-U., & Shegai, V. (2023). The impact of digital marketing innovation on firm performance: Mediation by marketing capability and moderation by firm size. *Sustainability*, 15(7), 5711.
- Karmaker, C. L., Al Aziz, R., Ahmed, T., Misbaudhin, S. M., & Moktadir, M. A. (2023). Impact of industry 4.0 technologies on sustainable supply chain performance: The mediating role of green supply chain management practices and circular economy. *Journal of Cleaner Production*, 419, 138249.
- Khanra, S., Dhir, A., Kaur, P., & Mäntymäki, M. (2021). Bibliometric analysis and literature review of ecotourism: Toward sustainable development. *Tourism Management Perspectives*, 37, 100777. <https://doi.org/10.1016/j.tmp.2020.100777>
- Klassen, R. D., & Whybark, D. C. (1999). The Impact of Environmental Technologies on Manufacturing Performance. *The Academy of Management Journal*, 42(6), 599–615. <https://doi.org/10.2307/256982>

- Knudsen, E. S., Lien, L. B., Timmermans, B., Belik, I., & Pandey, S. (2021). Stability in turbulent times? The effect of digitalization on the sustainability of competitive advantage. *Journal of Business Research*, 128, 360–369.
- Kohtamäki, M., Parida, V., Oghazi, P., Gebauer, H., & Baines, T. (2019). Digital servitization business models in ecosystems: A theory of the firm. *Journal of Business Research*, 104, 380–392. <https://doi.org/10.1016/j.jbusres.2019.06.027>
- Korte, A., Tiberius, V., & Brem, A. (2021). Internet of Things (IoT) Technology Research in Business and Management Literature: Results from a Co-Citation Analysis. *Journal of Theoretical and Applied Electronic Commerce Research*, 16(6), Article 6. <https://doi.org/10.3390/jtaer16060116>
- Kumari, G., & Joshi, Y. (2023). Corporate sustainability performance and firm performance: The state-of-the-art and future research agenda. *Benchmarking: An International Journal*, 31(9), 3398–3427. <https://doi.org/10.1108/BIJ-03-2023-0195>
- Kunisch, S., Denyer, D., Bartunek, J. M., Menz, M., & Cardinal, L. B. (2023). Review Research as Scientific Inquiry. *Organizational Research Methods*, 26(1), 3–45. <https://doi.org/10.1177/10944281221127292>
- Kunkel, S., Matthess, M., Xue, B., & Beier, G. (2022). Industry 4.0 in sustainable supply chain collaboration: Insights from an interview study with international buying firms and Chinese suppliers in the electronics industry. *Resources, Conservation and Recycling*, 182, 106274. <https://doi.org/10.1016/j.resconrec.2022.106274>
- Kurniawan, T. A., Dzarfan Othman, M. H., Hwang, G. H., & Gikas, P. (2022). Unlocking digital technologies for waste recycling in Industry 4.0 era: A transformation towards a digitalization-based circular economy in Indonesia. *Journal of Cleaner Production*, 357, 131911. <https://doi.org/10.1016/j.jclepro.2022.131911>
- Le, T. T., Vo, X. V., & Venkatesh, V. G. (2022). Role of green innovation and supply chain management in driving sustainable corporate performance. *Journal of Cleaner Production*, 374, 133875. <https://doi.org/10.1016/j.jclepro.2022.133875>
- Lee, M.-J., & Roh, T. (2023). Unpacking the sustainable performance in the business ecosystem: Coopetition strategy, open innovation, and digitalization capability. *Journal of Cleaner Production*, 412, 137433.
- Lee, S.-Y. (2021). Sustainable supply chain management, digital-based supply chain integration, and firm performance: A cross-country empirical comparison between South Korea and Vietnam. *Sustainability*, 13(13), 7315.
- Leischnig, A., Woelfl, S., & Ivens, B. (2016). *When does digital business strategy matter to market performance?*

- Lenka, S., Parida, V., & Wincent, J. (2017). Digitalization Capabilities as Enablers of Value Co-Creation in Servitizing Firms. *Psychology & Marketing*, 34(1), 92–100. <https://doi.org/10.1002/mar.20975>
- Li, L. (2022). Digital transformation and sustainable performance: The moderating role of market turbulence. *Industrial Marketing Management*, 104, 28–37.
- Li, L., Tong, Y., Wei, L., & Yang, S. (2022). Digital technology-enabled dynamic capabilities and their impacts on firm performance: Evidence from the COVID-19 pandemic. *Information & Management*, 59(8), 103689.
- Li, L., Ye, F., Zhan, Y., Kumar, A., Schiavone, F., & Li, Y. (2022). Unraveling the performance puzzle of digitalization: Evidence from manufacturing firms. *Journal of Business Research*, 149, 54–64.
- Li, S., Gao, L., Han, C., Gupta, B., Alhalabi, W., & Almakdi, S. (2023). Exploring the effect of digital transformation on Firms' innovation performance. *Journal of Innovation & Knowledge*, 8(1), 100317.
- Li, Y., Dai, J., & Cui, L. (2020). The impact of digital technologies on economic and environmental performance in the context of industry 4.0: A moderated mediation model. *International Journal of Production Economics*, 229, 107777.
- Linnenluecke, M. K., & Griffiths, A. (2013). Firms and sustainability: Mapping the intellectual origins and structure of the corporate sustainability field. *Global Environmental Change*, 23(1), 382–391. <https://doi.org/10.1016/j.gloenvcha.2012.07.007>
- López, M. V., Garcia, A., & Rodriguez, L. (2007). Sustainable Development and Corporate Performance: A Study Based on the Dow Jones Sustainability Index. *Journal of Business Ethics*, 75(3), 285–300. <https://doi.org/10.1007/s10551-006-9253-8>
- López Pérez, G., García Sánchez, I. M., & Zafra Gómez, J. L. (2024). A systematic literature review and bibliometric analysis of eco-innovation on financial performance: Identifying barriers and drivers. *Business Strategy and the Environment*, 33(2), 1321–1340. <https://doi.org/10.1002/bse.3550>
- MacCoun, R. J. (1998). Biases in the interpretation and use of research results. *Annual Review of Psychology*, 49, 259–287. Scopus. <https://doi.org/10.1146/annurev.psych.49.1.259>
- Martínez-Caro, E., Cegarra-Navarro, J. G., & Alfonso-Ruiz, F. J. (2020). Digital technologies and firm performance: The role of digital organisational culture. *Technological Forecasting and Social Change*, 154, 119962.
- Martín-Peña, M.-L., Sánchez-López, J.-M., & Díaz-Garrido, E. (2019). Servitization and digitalization in manufacturing: The influence on firm performance. *Journal of Business & Industrial Marketing*, 35(3), 564–574.
- Martins, A. (2023). Dynamic capabilities and SME performance in the COVID-19 era: The moderating effect of digitalization. *Asia-Pacific Journal of Business Administration*, 15(2), 188–202.

- Marzi, G., Balzano, M., Caputo, A., & Pellegrini, M. M. (2025). Guidelines for Bibliometric-Systematic Literature Reviews: 10 steps to combine analysis, synthesis and theory development. *International Journal of Management Reviews*, 27(1), 81–103. <https://doi.org/10.1111/ijmr.12381>
- Mastos, T. D., Nizam, A., Vafeiadis, T., Alexopoulos, N., Ntinas, C., Gkourtis, D., Papadopoulos, A., Ioannidis, D., & Tzovaras, D. (2020). Industry 4.0 sustainable supply chains: An application of an IoT enabled scrap metal management solution. *Journal of Cleaner Production*, 269, 122377. <https://doi.org/10.1016/j.jclepro.2020.122377>
- Mongeon, P., & Paul-Hus, A. (2016). The journal coverage of Web of Science and Scopus: A comparative analysis. *Scientometrics*, 106(1), 213–228. <https://doi.org/10.1007/s11192-015-1765-5>
- Nakamura, E. (2015). The bidirectional CSR investment – economic performance relationship. *Journal of Global Responsibility*, 6(1), 128–144. <https://doi.org/10.1108/JGR-05-2014-0021>
- Nandi, S., Sarkis, J., Hervani, A. A., & Helms, M. M. (2021). Redesigning Supply Chains using Blockchain-Enabled Circular Economy and COVID-19 Experiences. *Sustainable Production and Consumption*, 27, 10–22. <https://doi.org/10.1016/j.spc.2020.10.019>
- Nayal, K., Kumar, S., Raut, R. D., Queiroz, M. M., Priyadarshinee, P., & Narkhede, B. E. (2022). Supply chain firm performance in circular economy and digital era to achieve sustainable development goals. *Business Strategy and the Environment*, 31(3), 1058–1073.
- Nayal, K., Raut, R. D., Yadav, V. S., Priyadarshinee, P., & Narkhede, B. E. (2022). The impact of sustainable development strategy on sustainable supply chain firm performance in the digital transformation era. *Business Strategy and the Environment*, 31(3), 845–859.
- Nguyen, M., Bensemann, J., & Kelly, S. (2018). Corporate social responsibility (CSR) in Vietnam: A conceptual framework. *International Journal of Corporate Social Responsibility*, 3(1), 9. <https://doi.org/10.1186/s40991-018-0032-5>
- Oduro, S., De Nisco, A., & Mainolfi, G. (2023). Do digital technologies pay off? A meta-analytic review of the digital technologies/firm performance nexus. *Technovation*, 128, 102836.
- Ogrean, C., Herciu, M., & Tichindelean, M. (2024). Integrating Sustainability and Digitalization in Business Model Innovation. A Bibliometric Study. *Studies in Business and Economics*, 19(2), 307–331. <https://doi.org/10.2478/sbe-2024-0040>
- Orlitzky, M., & Benjamin, J. D. (2001). Corporate Social Performance and Firm Risk: A Meta-Analytic Review. *Business & Society*, 40(4), 369–396. <https://doi.org/10.1177/000765030104000402>
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... Moher, D. (2021). The

- PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, 372, n71. <https://doi.org/10.1136/bmj.n71>
- Page, M. J., Moher, D., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... McKenzie, J. E. (2021). PRISMA 2020 explanation and elaboration: Updated guidance and exemplars for reporting systematic reviews. *BMJ*, 372, n160. <https://doi.org/10.1136/bmj.n160>
- Parida, V., Sjödin, D., & Reim, W. (2019). Reviewing Literature on Digitalization, Business Model Innovation, and Sustainable Industry: Past Achievements and Future Promises. *Sustainability*, 11(2), Article 2. <https://doi.org/10.3390/su11020391>
- Park, J. Y., & Nagy, Z. (2018). Data on the interaction between thermal comfort and building control research. *Data in Brief*, 17, 529–532. <https://doi.org/10.1016/j.dib.2018.01.033>
- Ranta, V., Aarikka-Stenroos, L., & Väisänen, J.-M. (2021). Digital technologies catalyzing business model innovation for circular economy—Multiple case study. *Resources, Conservation and Recycling*, 164, 105155. <https://doi.org/10.1016/j.resconrec.2020.105155>
- Rapport_McKinsey-Towards_A_Circular_Economy.pdf*. (n.d.). Retrieved 2 July 2024, from https://www.werktrends.nl/app/uploads/2015/06/Rapport_McKinsey-Towards_A_Circular_Economy.pdf
- Rashidi, K., & Saen, R. F. (2015). Measuring eco-efficiency based on green indicators and potentials in energy saving and undesirable output abatement. *Energy Economics*, 50, 18–26.
- Reza, M. N. H., Malarvizhi, C. A. N., Jayashree, S., & Mohiuddin, M. (2021). *Industry 4.0–technological revolution and sustainable firm performance*. 1–6.
- Ribeiro-Navarrete, S., Botella-Carrubi, D., Palacios-Marqués, D., & Orero-Blat, M. (2021). The effect of digitalization on business performance: An applied study of KIBS. *Journal of Business Research*, 126, 319–326.
- Ricci, F., Scafarto, V., Ferri, S., & Tron, A. (2020). Value relevance of digitalization: The moderating role of corporate sustainability. An empirical study of Italian listed companies. *Journal of Cleaner Production*, 276, 123282.
- Russo, M. V., & Fouts, P. A. (1997). A Resource-Based Perspective on Corporate Environmental Performance and Profitability. *The Academy of Management Journal*, 40(3), 534–559. <https://doi.org/10.2307/257052>
- Ryoo, S. Y., & Koo, C. (2013). Green practices-IS alignment and environmental performance: The mediating effects of coordination. *Information Systems Frontiers*, 15(5), 799–814. <https://doi.org/10.1007/s10796-013-9422-0>

- Sanchez-Riofrio, A. M., Lupton, N. C., & Rodríguez-Vásquez, J. G. (2022). Does market digitalization always benefit firms? The Latin American case. *Management Decision*, 60(7), 1905–1921.
- Shahzad, M., Qu, Y., Zafar, A. U., Rehman, S. U., & Islam, T. (2020). Exploring the influence of knowledge management process on corporate sustainable performance through green innovation. *Journal of Knowledge Management*, 24(9), 2079–2106. <https://doi.org/10.1108/JKM-11-2019-0624>
- Sharma, M., Kumar, A., Luthra, S., Joshi, S., & Upadhyay, A. (2022). The impact of environmental dynamism on low-carbon practices and digital supply chain networks to enhance sustainable performance: An empirical analysis. *Business Strategy and the Environment*, 31(4), 1776–1788.
- Siew, R. Y. J., Balatbat, M. C. A., & Carmichael, D. G. (2013). The relationship between sustainability practices and financial performance of construction companies. *Smart and Sustainable Built Environment*, 2(1), 6–27. <https://doi.org/10.1108/20466091311325827>
- Singh, S. K., & Del Giudice, M. (2019). Big data analytics, dynamic capabilities and firm performance. *Management Decision*, 57(8), 1729–1733.
- Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, 104, 333–339.
- Somohano-Rodríguez, F. M., Madrid-Guijarro, A., & López-Fernández, J. M. (2022). Does Industry 4.0 really matter for SME innovation? *Journal of Small Business Management*, 60(4), 1001–1028. <https://doi.org/10.1080/00472778.2020.1780728>
- Sony, M., & Naik, S. (2020). Industry 4.0 integration with socio-technical systems theory: A systematic review and proposed theoretical model. *Technology in Society*, 61, 101248. <https://doi.org/10.1016/j.techsoc.2020.101248>
- Su, B., Heshmati, A., Geng, Y., & Yu, X. (2013). A review of the circular economy in China: Moving from rhetoric to implementation. *Journal of Cleaner Production*, 42, 215–227. <https://doi.org/10.1016/j.jclepro.2012.11.020>
- Tang, M., Walsh, G., Lerner, D., Fitza, M. A., & Li, Q. (2018). Green Innovation, Managerial Concern and Firm Performance: An Empirical Study. *Business Strategy and the Environment*, 27(1), 39–51. <https://doi.org/10.1002/bse.1981>
- Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review. *British Journal of Management*, 14(3), 207–222. <https://doi.org/10.1111/1467-8551.00375>
- Tupa, J., Simota, J., & Steiner, F. (2017). Aspects of risk management implementation for Industry 4.0. *Procedia Manufacturing*, 11, 1223–1230.

- Tuppura, A., Arminen, H., Pätäri, S., & Jantunen, A. (2016). Corporate social and financial performance in different industry contexts: The chicken or the egg? *Social Responsibility Journal*, 12(4), 672–686. <https://doi.org/10.1108/SRJ-12-2015-0181>
- Ukko, J., Nasiri, M., Saunila, M., & Rantala, T. (2019). Sustainability strategy as a moderator in the relationship between digital business strategy and financial performance. *Journal of Cleaner Production*, 236, 117626.
- Urbinati, A., Chiaroni, D., & Chiesa, V. (2017). Towards a new taxonomy of circular economy business models. *Journal of Cleaner Production*, 168, 487–498. <https://doi.org/10.1016/j.jclepro.2017.09.047>
- van Beurden, P., & Gössling, T. (2008). The Worth of Values – A Literature Review on the Relation Between Corporate Social and Financial Performance. *Journal of Business Ethics*, 82(2), 407–424. <https://doi.org/10.1007/s10551-008-9894-x>
- van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, 84(2), 523–538. <https://doi.org/10.1007/s11192-009-0146-3>
- Verma, P., Kumar, V., Daim, T., Sharma, N. K., & Mittal, A. (2022). Identifying and prioritizing impediments of industry 4.0 to sustainable digital manufacturing: A mixed method approach. *Journal of Cleaner Production*, 356, 131639. <https://doi.org/10.1016/j.jclepro.2022.131639>
- Wang, Q., Dou, J., & Jia, S. (2016). A Meta-Analytic Review of Corporate Social Responsibility and Corporate Financial Performance: The Moderating Effect of Contextual Factors. *Business & Society*, 55(8), 1083–1121. <https://doi.org/10.1177/0007650315584317>
- Wang, Z., Lin, S., Chen, Y., Lyulyov, O., & Pimonenko, T. (2023). Digitalization effect on business performance: Role of business model innovation. *Sustainability*, 15(11), 9020.
- Wen, H., Zhong, Q., & Lee, C.-C. (2022). Digitalization, competition strategy and corporate innovation: Evidence from Chinese manufacturing listed companies. *International Review of Financial Analysis*, 82, 102166. <https://doi.org/10.1016/j.irfa.2022.102166>
- Witschel, D., Baumann, D., & Voigt, K.-I. (2022). How manufacturing firms navigate through stormy waters of digitalization: The role of dynamic capabilities, organizational factors and environmental turbulence for business model innovation. *Journal of Management & Organization*, 28(3), 681–714. <https://doi.org/10.1017/jmo.2022.44>
- Wroblewski, J. (2018). *Digitalization and firm performance: Are digitally mature firms outperforming their peers?*
- Xu, J., Yu, Y., Zhang, M., & Zhang, J. Z. (2023). Impacts of digital transformation on eco-innovation and sustainable performance: Evidence from Chinese manufacturing companies. *Journal of Cleaner Production*, 393, 136278.

- Yang, Y., & Yee, R. W. (2022). The effect of process digitalization initiative on firm performance: A dynamic capability development perspective. *International Journal of Production Economics*, 254, 108654.
- Zhai, H., Yang, M., & Chan, K. C. (2022). Does digital transformation enhance a firm's performance? Evidence from China. *Technology in Society*, 68, 101841.

10. PAPER 2:

Exploring the Nexus Between Digitalization and Firm's ESG Performance: An Empirical Study of Danish Listed Firms.

Muhammad Haseeb

Department of Advanced Technologies and Medicine & Dentistry (*DITM&O*). Center for Advanced Studies and Technology (CAST). G. D'Annunzio University of Chieti–Pescara (Italy).

Maria Josefina Figueroa

Department of Management Society and Communications (MSC). CBS Sustainability – Center for Business and Development Studies. Copenhagen Business School, Denmark.

Stefania Migliori

Department of Management and Business Administration. G. D'Annunzio University of Chieti–Pescara, Italy.

Submitted to:

Journal of the Research in International Business and Finance (Under-Review)

Presented at:

Department of Management Society and Communication (MSC), CBS–Sustainability Center, Copenhagen Business School, Denmark.

²⁷**Abstract**

The integration of digitalization and the implementation of ESG (Environmental, Social, and Governance) practices can significantly transform business operations and improve a company's financial performance. This study empirically investigates digitalization's role on firms' ESG performance, incorporating longitudinal panel data from sixty-seven publicly listed Danish companies over an eight-year timespan (2015-2022). It also examines the moderating role of digitalization in the relationship between stock market valuation and firm ESG performance (Pillar scores).

To test the hypothesis of our study, we employed Ordinary Least Square (OLS), Random Effects (RE), and Fixed Effects (FE) multiple linear regression models on panel data retrieved from the Refinitiv Eikon™ database. For robustness and to address heterogeneity concerns, the Generalized Method of Moments (GMM) was also employed. The findings indicate that digitalization improves firms' ESG dimensions performance. Furthermore, the relationship between stock market valuation and ESG performance, as well as the environment performance (pillar score), are positively moderated by digitalization. However, digitalization has been observed to have a moderately adverse effect on the relationships from Social and Governance perspectives.

This study's contribution is threefold: First, it sheds light on the role of digitalization in enhancing firms' ESG performance (including pillar scores). Second, it explores the moderation impact of digitalization on the relationship between stock market valuation (companies' values according to the financial market) and firms' ESG performance. Finally, it provides policy implications, offering insights into the coordination of digitalization and ESG strategies for informed decision-making

Keywords: Digitalization, Digital Transformation, Environmental, Social and Governance (ESG) Performance, Firm Performance, Listed Firms.

²⁷ **Abbreviations:** ESG – Environment, Social, and Governance; OLS – Ordinary Least Square; RE – Random Effect; FE – Fixed Effect; GMM – Generalized Methods of Moments; CSR – Corporate Social Responsibility. CEO – Chief Executive Officer.

10.1. Introduction

In today's business environment, the rise of digital technologies signifies a major shift in the way that firms can fulfil their diverse responsibilities within the wider social and ecological context (Boukattaya et al., 2022). The rapid development of emerging technologies, such as cloud computing, blockchain, and artificial intelligence, has emphasized the significance of digital technology as a key tool for economic growth and a potential contribution to ecological sustainability (Andersen et al., 2022; Montero Guerra et al., 2023; W. Wang et al., 2023). As per data from the United Nations Conference on Trade and Development 2021, digital economy's value-added size in 47 countries globally was approximately \$38.1 trillion in 2021, contributing to nearly 45.0% of the worldwide Gross Domestic Product (GDP). The United States' digital economy is the most substantial, valued at \$15.3 trillion, with China trailing in the second position at \$7.1 trillion.

ESG key performance indicators are essential strategies for ensuring the sustainable development of companies and their driving forces (Lu et al., 2024). These metrics are crucial when organizations implement corporate social responsibility (CSR) measures and serve as the criteria and techniques investors use to evaluate corporate conduct and predict future financial performance (Eccles et al., 2013; Kuo et al., 2021; T.-T. Li et al., 2021). With the advancement and application of digital technology, companies leverage digital resources and consistently engage in technological innovation activities (Bohnsack et al., 2022). Firms aspire to achieve high goals by leveraging digitalization, such as optimizing resource utilization, enhancing energy efficiency, and contributing to social development by generating employment opportunities, alleviating poverty, bridging the urban-rural divide, promoting sustainable development, boosting exports, and fostering technological and green innovations (Nasiri et al., 2020; Schiavone et al., 2022).

Firms' ESG performance offers investors and researchers valuable insights into how to meet their commitment to green development and sustainable practices (Y. Li et al., 2018). The significance of ESG performance extends beyond cost reduction and profit enhancement; it also strengthens collaborative production, operational efficiency, and management oversight mechanisms (B. Lin & Ma, 2022). Companies that exhibit greater ESG performance are likely to experience higher corporate value growth (Aouadi & Marsat, 2018), improved internal controls (Harasheh & Provasi, 2023), more economical financing costs (Cheng et al., 2014), increased profitability (Eliwa et al., 2021), better stock market performance (G.-F. Feng et al., 2022) and a greater capacity to navigate volatile markets and manage systemic risks (Broadstock et al., 2021). From the production standpoint, ESG performance is intricately linked to a company's carbon footprint (Haque, 2017), greenhouse gas emissions (Tan & Zhu, 2022), brand image (Yang & Han, 2023a), and social benefits (Koh et al., 2022), whether in terms of government benefits,

business management, or investor relations. ESG has been acknowledged as a significant metric for organizations to uphold their sustainable commitments (T.-T. Li et al., 2021).

Most studies indicate that researchers, academic practitioners, and policymakers will be interested in discussing the factors that influence the firm's ESG performance (Fang et al., 2023a; Hu et al., 2023). For example, a powerful CEO is positively correlated with ESG, considering that organizations gain more from the ESG rating system than smaller firms, leading to increased firm value and size (Y. Li et al., 2018; Drempetic et al., 2020). Most of the studies highlight that better ESG performance and or making disclosures positively influenced a firm's financial performance (Kölbel et al., 2017; H.-M. Chen et al., 2022). Companies have adopted various contingency measures to address uncertain ESG risks (Aureli et al., 2020). These measures encompass minimizing waste emissions, utilizing low-carbon energy, collaborating with eco-friendly supply chain entities, enhancing employee health and safety protocols, and maintaining human and labor standards (Brogi & Lagasio, 2019; Kim & Li, 2021). These significant changes have improved ESG indicator ratings (Zhao et al., 2018) and have also impacted financial performance to some extent. Despite these, organizations still need to gain a complete analytical understanding of whether such measures increase operational costs and decrease revenue or return on assets during decision-making.

Digitalization has emerged as one of the most transformative technological innovations. It involves the adoption of digital technologies, including artificial intelligence, big data, blockchain, and cloud computing, by firms or organizations to reduce transaction costs, enhance productivity, and create additional value for customers and stakeholders (Tremblay et al., 2022). By adopting new technologies and processes, companies have enhanced their competitiveness in terms of quality, efficiency, and cost (Goldfarb & Tucker, 2019; Fang et al., 2023a). Existing literature indicates that digitalization has significantly boosted total factor productivity (F. Wang & Sun, 2022) within organizations by fostering innovation capabilities (Wen et al., 2022) and optimizing human capital and management structures (Sima et al., 2020). In response to new and stringent environmental regulations, digitalization is a vital tool for enhancing corporate ecological regulations; it is also an essential tool for strengthening corporate environmental governance performance and improving information disclosure quality and internal corporate governance, leading to improved CSR Performance (Zheng et al., 2023). Digitalization brings forth transformative opportunities, but it also presents a range of challenges that can hinder its potential to add value to a firm (Bannier et al., 2019; Sebastian et al., 2020). For instance, offering digitally mediated services may encounter the “liability of newness” as customers may be hesitant to trust unfamiliar organizational forms (Freeman et al., 1983). Furthermore, digitalization raises concerns about privacy and security due to the vast data collection enabled by firms. In addition, there is a potential for significant employment impact, with a notable study

indicating that 47 % of current jobs in the United States of America could be at risk of computerization (Forcadell et al., 2020; Tremblay et al., 2022).

Digitalization has redefined the dynamic business environment, offering companies new opportunities for development (Ancillai et al., 2022; Tremblay et al., 2022), and the integration of digitalization with ESG performance can be crucial for fostering sustainable and ethical business practices (Marcysiak & Pleskacz, 2021). Extant literature has examined the relationship between digitalization and ESG performance or firm performance from multiple perspectives, including market dynamics (S. Wang & Esperança, 2023), corporate governance (Eliwa et al., 2021; Meng et al., 2022), and leadership qualities (Mo et al., 2023), and also has provided insights into solving these challenges (Marszałek & Ratajczak-Mrozek, 2022). However, there is a notable gap in the literature regarding the influence of digitalization on ESG (Environmental, Social, and Governance) performance, particularly in relation to individual sub-themes (pillars) scores. This study seeks to address this gap by examining the impact of digitalization on ESG performance at the sub-theme level. Moreover, it explores how digitalization moderates the relationship between a firm's stock market valuation and its ESG sub-theme performance. To test these relationships, we collect longitudinal panel data and annual reports of 67 listed public Danish firms from 2015 to 2022, retrieved from the Refinitiv Eikon™ database, previously known as Thomson Reuters ASSET4 ESG.

We analyze our proposed model through a multivariate regression model approach, incorporating Ordinary Least Square (OLS), Random Effect (RE), and Fixed Effect (FE) regression models. Our primary objective is to provide researchers with a comprehensive methodology for generating reliable estimates and drawing valid inferences when working with longitudinal panel data. To address concerns regarding robustness and heterogeneity, we utilize a dynamic Generalized Method of Moments (GMM) model for this longitudinal panel data.

This study contributes to the existing literature by firstly shedding light on the role of digitalization on firms' ESG sub-themes performance or pillar score, confirming that improvements in these sub-themes by digitalization create further opportunities for companies to grow in the long run. Secondly, examining the moderation role of digitalization in the association between firm stock market valuations and ESG (including sub-themes) performance. Lastly, relevant policy implications should be provided to decision-makers so that they can coordinate and formulate effective ESG strategies.

The subsequent sections are organized as follows: **Section 2** encompasses the literature review and the hypothesis development. **Section 3** details the data collection process, measurement of variables, model specifications, and the overall model framework. **Section 4** presents the results of the multivariate

regression analysis. **Section 5** discusses the moderation effects and additional factors pertinent to the study. **Section 6** provides the empirical results of the robustness test and heterogeneity analysis. Finally, **Section 7** offers a discussion of the conclusions and policy recommendations.

10.2. Literature Review and Hypothesis Development

10.2.1. Digitalization Impact on Environmental, Social and Governance (ESG)

Performance

ESG criteria can serve as a critical performance indicator for assessing the stability and integrity of organizations (Lu et al., 2024; Garcia et al., 2017). ESG serves as an evolving metric for evaluating sustainable development that emerged as one of the foremost global concerns (Q.-J. Wang et al., 2023). Environmental indicators refer to better environmental practices, including considering biodiversity, formulating ecological guidelines, implementing pollution control measures, and disclosing carbon emission risks (Y. Li et al., 2018). Social indicators encompass the development of health and safety policies, promotion of equal employment opportunities, and activities related to various stakeholders, including employees, customers, supplier communities, and governments (Fang et al., 2023b). Governance indicators refer to enhanced corporate governance practices, including board gender diversity, the individual CEOs and chairperson roles, and policies concerning shareholders rights (Adedeji et al., 2020). The literature sees digitalization with ESG performance from three perspectives.

From an environmental standpoint, the complexity of ecological issues, governance actions, and performance is influenced by a multitude of factors (Adger, 2006a). The digital empowerment of environmental governance is perceived not merely as a straightforward application of technology but as a creative and positive process of integrating and utilizing data resources (George et al., 2021). For instance, the implementation of digital technologies within the corporate sector helps mitigate the impact of carbon emissions on products and services through economies of scale. It also can enhance public awareness of environmental protection and promote a transition towards a low-carbon consumption model (Busch & Schnippering, 2022; Qin et al., 2022). The digital economy and finance have enhanced resource allocation efficiency, increased capabilities for information integration and sharing, and fostered organizational green innovation (Guo et al., 2023). Green innovation encompasses the development of processes, technologies, or products that mitigate environmental pollution and enhance energy and resource efficiency. Companies that utilize advanced technologies to optimize production processes, refine research design, and strengthen product manufacturing heavily depend on big data, artificial intelligence, and other technologies to manage carbon emissions accurately. Consequently, digital transformation within organizations or businesses can

bolster their green innovation capabilities and environmental responsibilities, leading to improved environmental performance (B. Lin & Ma, 2022; W. Wang et al., 2023; Guo et al., 2023).

From a Social perspective, digitization has profoundly impacted the dynamics of company-customer relationships. The rapid advancement of digitalization has transformed customers from passive recipients of corporate decisions into active participants capable of influencing these decisions through extensive personal data (Cheng et al., 2014; Busch & Schnippering, 2022). Companies leverage digital channels to establish unparalleled interaction capabilities with customers, thereby enhancing brand influence (Fang et al., 2023c). Digital native firms can swiftly respond to market changes and adopt digital technologies. Conversely, other enterprises are encouraged to enhance customer perceptions and integrate resources to capitalize on transient market opportunities (Aragón-Correa, 1998). E-commerce research indicates that online rating systems provided by organizations help establish trust relationships through long-distance transactions. Additionally, compared to offline settings, online feedback systems not only reduce verification costs but also facilitate market transactions more efficiently over the internet (Schultz et al., 2013). Social media platforms play a crucial role in enhancing stakeholders' engagement by enabling direct and reciprocal communication between firms and stakeholders, thereby improving the company's reputation in the corporate world. The literature concurs that firms can more effectively communicate their achievements in environmental protection, philanthropy, and poverty alleviation to communities and governments through digital communication tools (such as websites and social media platforms), resulting in increased goodwill and higher social pillar scores (Bannier et al., 2019).

In the Governance realm, scholars and academic practitioners have had strong debates about various precise governance indicators. The composition and function of the board of directors, along with the efficacy of audit oversight, are particularly significant. The widespread adoption of digital technology enables the board to efficiently gather critical information and corporate data, facilitating reliable judgments. Concurrently, digital transformation has diminished the information gap and asymmetry between stakeholders and the board, thereby enhancing efficiency and decision-making capabilities (Bloom et al., 2014; Nollet et al., 2016; Bhattacharya & Sharma, 2019). Firms benefit from the application of digital technologies in the auditing process, which strengthens risk management and identification processes, ultimately improving audit and supervisory quality at each stage (Harasheh & Provasi, 2023). For example, the integration of information storage and processing software, such as an Enterprise Resource Planning system, significantly enhances data collection and streamlines workflows, ultimately improving employee productivity. Furthermore, the use of computer-aided manufacturing software lowers coordination costs for managers while also contributing to the efficiency and accuracy of auditing process (Fang et al., 2023a; McElheran, 2014). In summary, digitalization can help mitigate information asymmetries between

managers and employees, external investors, and boards of directors, thereby improving corporate governance and ultimately increasing enterprise governance scores. Based on the theoretical analysis of the aforementioned channels, we propose the following hypothesis.

H₁. *Digitalization will enhance firm's ESG performance.*

Considering the breakdown of the ESG Performance proxy, hypothesis **H_{1a}**, **H_{2b}**, and **H_{3c}** are formulated as components of H₁:

H_{1a}. *A significant (either positive or negative) relation between digitalization and a firm's level of environmental performance.*

H_{1b}. *A significant (either positive or negative) relationship between digitalization and a firm's level of social performance.*

H_{1c}. *A significant (either positive or negative) relation between digitalization and a firm's level of governance performance*

10.2.2. The moderating influence of digitalization on the relationship between stock market valuation and ESG performance.

To fully harness digital technology's benefits, it is imperative to integrate its value through the transformation of business processes. A series of digital management activities are essential prerequisites for firms to reap the rewards of digitalization (Marszałek & Ratajczak-Mrozek, 2022; Poncibò, 2022). By leveraging digital technology, organizations can facilitate seamless information exchange with their partners, resulting in real-time communication and improved efficiency (Truant et al., 2021).

Since organizations are placing more emphasis on ESG performance indicators, academics and industry experts have conducted extensive studies on how these indicators relate to financial performance and responses in capital or stock markets (Clark et al., 2015). Current literature shows that digitalization has increased firm stock market performance by increasing equity financing, increasing business credits, and extending subsidies (T.-T. Li et al., 2021). The digitalization of production and operational activities within organizations enables corporations to benefit from government subsidies and preferential policies offered by financial institutions. This digital transformation creates favourable conditions for financial institutions and investors to accurately and efficiently identify companies with valuable market investments, thereby reducing overall systematic risk in the market (Friede et al., 2015; Hauke-Lopes et al., 2022). An early study, based on 90% of the reviewed evidence, concluded that there is a non-negative relationship between ESG performance indicators and companies' financial performance (Friede et al., 2015).

Moreover, the positive correlation between these variables increased over time before stabilizing (Drempetic et al., 2020). Another study identified a nonlinear U-shaped relationship between ESG performance pillar score indicators and firm financial performance. However, these indicators were analyzed individually, with only governance performance indicators demonstrating a U-shaped relationship with firm financial performance (Nollet et al., 2016).

Most of the studies Research (Nollet et al., 2016; Garcia et al., 2017; Kuo et al., 2021; Harasheh & Provasi, 2023) have shown that 88% of companies experienced improved financial performance following the implementation of ESG performance indicators disclosures. Greater transparency in disclosing ESG performance indicators reduces information asymmetry and enhances trust with stakeholders. Lending institutions placed equal emphasis on ESG performance and disclosure, integrating ESG information into their leadership decisions. This focus was due to the lower cost of debt associated with companies that had better ESG performance disclosures (Eliwa et al., 2021). Incorporating ESG performance increased investment returns and reduced risk for institutional investors, while the overall and individual performance of ESG indicators enhanced corporate creditworthiness (Bhattacharya & Sharma, 2019). However, a negative relationship between ESG indicators and stock price crash risk was identified (Sherwood & Pollard, 2018; Elamer & Boulhaga, 2024). Furthermore, ESG performance indicators, including environmental, social, and governance metrics, exhibited an inverted U-shaped relationship with growth (Nollet et al., 2016). Based on these findings, stakeholders utilize digitalization and ESG performance indicators to assess the soundness of a company's financial performance, leading to the proposed hypotheses.

H₂: *The relationship between Stock market valuation and corporate ESG performance is moderated by the level of digitalization.*

In light of the disaggregation of the ESG performance proxy, the subsequent hypotheses **H_{2a}**, **H_{2b}**, and **H_{2c}** are put forward.

H_{2a}: *Digitalization (either positively or negatively) moderates the relationship between stock market valuation and Environmental Performance.*

H_{2b}: *Digitalization (either positively or negatively) moderates the relationship between stock market valuation and Social Performance.*

H_{2c}: *Digitalization (either positively or negatively) moderates the relationship between stock market valuation and Governance Performance.*

10.3. Research Methodology

10.3.1. Conceptual Framework of Study

This conceptual framework illustrates the relationship between digitalization and firm ESG, including sub-themes performance. Also, it examines the moderating role in the relationship between firms' stock market valuation and ESG performance. This model shows the two primary hypotheses, each with three sub-hypotheses, as shown in **Figure 1**. The first scenario (H_1) describes how digitalization directly impacts a firm's ESG performance. In this scenario (H_1), digitalization acts as an independent variable (IV), while overall ESG performance (including environmental pillar score H_{1a} , social pillar Score H_{1b} , and governance pillar score H_{1c}) is the dependent variable (DV). Additionally, control variables (Firm Size, Growth, Leverage, Asset Turnover and Return on Assets) also have a direct influence on overall firm ESG performance.

In the second scenario (H_2), Stock market valuation (Independent variable) influences the overall ESG performance (Dependent variable). Digitalization moderates the strength and direction of this relationship, whereas control variables are constant. This means that the level of digitalization influences the role of stock market valuation on ESG performance (Hu et al., 2023). This drives firms to improve their ESG performance to attract investors, reduce costs, manage risks and gain a competitive edge, highlighting digitalization's role in moderating the relationship between stock market valuation and ESG performance. Control variables help to isolate the specific effects of digitalization and stock market valuation on ESG performance. Both viewpoints are crucial for comprehending the impact of digital transformation on a firm's market competitiveness and ESG performance.

[Insert Figure 1, Research Model Diagram Here]

10.3.2. Sample and Data Collection

We use data from publicly listed Danish companies sourced from the Refinitiv Eikon™ database (previously known as Thomson Reuters ASSET4 ESG), which contains eight years from 2015 to 2022, with a total number of 536 longitudinal observations. The sample distribution, excluding the financial sector, is categorized into seven different segments as follows: biotechnology and medical research (22%); construction and engineering (19%), construction supplies and fixtures (16%), Information Technology services and consulting (15%), marine freight and logistics (11.5%), medical equipment, supplies and distribution (9%) and pharmaceuticals (7.5%). We excluded companies with special treatment, where ESG score values are missing, or companies that do not issue ESG reports annually.

The ²⁸Refinitiv Eikon™ database offers an ESG performance rating system, providing a comprehensive platform for creating customizable benchmarks, such as sectors and countries, to assess companies' performance. Annually, the database compiles 400 data points, which are used in a default equal-weighted framework to calculate 70 key performance indicators (KPIs). These KPIs are further categorized into 18 sub-categories within three pillar scores: (I) Environmental pillar score, encompassing resource utilization, emissions and innovations. (II) Social pillar score, divided into labor, human rights, community, and product responsibility; and (III) Governance pillar score, which included management, shareholders and CSR strategies.

10.3.3. Evaluating ESG Performance

This paper uses the four dependent variables at a firm's level. The primary variable is the overall ESG performance, divided into three sub-categories: environmental, social, and governance pillar scores, reflecting the extent of firms' involvement in ESG activities. Globally, there are over 600 ESG rating agencies. These agencies have created ESG rating data products, established evaluation standards, and developed supporting solutions by integrating resources both horizontally and vertically. However, from the user's perspective, the quality and practicality of these ESG rating standards can vary significantly. These performance variables data come from the ²⁹Refinitiv Eikon™ database.

It is acknowledged that some firms may strategically manipulate ESG reports by exaggerating or concealing information. However, it is believed that Danish publicly listed companies are unlikely to systematically falsify or distort their ESG or Corporate Sustainability Reporting standards. This assumption is primarily based on the mixed or inconclusive evidence in the literature regarding the relationship between ESG practices and Financial Performance. Consequently, falsifying ESG reports does not necessarily result in improved financial outcomes. Additionally, since the disclosure of ESG reports is voluntary for Danish-listed companies, the incentive to engage in such practices is further reduced.

10.3.4. Assessing Digitalization.

The level of digitalization of companies serves as a predictor variable in this study. Digitalization is essential for the transformation process within firms, which involves changes in organizational structure, sales systems and internal management. However, assessing the level of digitalization as a financial metric for Danish publicly listed companies presents a unique set of challenges. Despite these challenges,

²⁸ Appendix A, table A2, for additional details regarding the ESG rating system.

²⁹ LSEG Annual Report 2021

companies are keen to highlight their digitalization progress in their annual reports to attract investors. As a result, these reports are valuable tools for measuring the digitalization levels of listed companies.

To develop the digitalization index for firms, we employed the following four-step methodology followed by in the literature (Garcia et al., 2017; Ratajczak-Mrozek & Marszałek, 2022):

a. Thesaurus Construction:

We constructed a thesaurus by extracting relevant terms from representative publications related to digitalization as outlined in (Kotarba, 2017) study. This thesaurus of digitalization contains approximately 100 keywords, including terms such as big data, artificial intelligence, e-commerce, cloud computing, internet marketing, etc. After that, we reviewed the annual reports of all sixty-seven listed companies for each industry sector to ensure that our keywords listed in **Appendix A, Table A1**, comprehensively cover the main aspects of digitalization within companies.

b. Data collection:

In this Phase, we developed a Python-based web crawler to gather annual reports from the companies in our dataset. Using regular expressions, we extracted “Management Discussion and Analysis” section from each report. This section contains executives’ analyses of annual performance and a description of events and management decisions that impact operations.

c. Text Analysis:

During this stage, we employed both manual and automated word segmentation algorithms in Python to identify references to digitalization within the annual reports of the listed companies.

d. Index Calculation:

Finally, we calculated the frequency of keywords based on a digitized thesaurus. We derived a digitalization index for each firm-year by dividing the number of occurrences of the digitized thesaurus keywords by the total number of 100 keywords.

10.3.5. Other Variables and Measures

To describe digitalization's impact more rigorously on the relationship between stock market valuation and overall ESG performance, we refer to current literature (Karathanassis & Spilioti, 2003; Ricci et al., 2020) and incorporate two additional predictor variables to verify digitalization's moderation role in this association. At the level of firm financial parameters, the book value per share (BVPS) is calculated by

dividing the total equity at the end of the fiscal year by the basic weighted average shares outstanding for the same period. Earnings per share (EPS) is determined by subtracting preferred dividends from net income and then dividing the result by the average number of outstanding shares of the listed Danish firms in the dataset.

We include several control variables to ensure a thorough analysis. Among these variables, Firm Size (FS) indicate that larger companies generally have more resources available for investment in digitalization and ESG initiatives. Company Growth (Growth) is also considered, as it influences a firm's ability to adapt to digital changes; Firm Leverage (LEV) reflects the firm's debt levels and their impact on financial flexibility. The total asset turnover ratio (ATO) measures the efficiency with which a firm utilises its assets to generate sales, while return on assets (ROA) indicates overall profitability. The year's dummy and industry sectors (IND) are also included to control for time-specific and industry-specific effects, respectively. Definitions and descriptions of each specific variable are provided in **Table A3 in Appendix A**. These variables provide more detailed insights into the firm's governance structure and financial health.

10.3.6. Economic Modelling

The multivariate panel regression model was constructed (Garcia et al., 2017), to investigate the role of digitalization on ESG performance, including sub-categories of Danish listed firms' environmental, social, and governance pillar scores. This model's advantage is that it allows an estimate of the relationship between two or more independent variables with one or more (multiple) dependent variables.

This paper first sets the dependent variables merged into the following model:

ESG Performance Score $_{i,t}$

$$= \alpha_0 + \alpha_1 ESG\ Performance_{i,t} + \alpha_2 Enviromental\ Performance_{i,t} \\ + \alpha_3 Social\ Performance_{i,t} + \alpha_4 Governance\ Performance_{i,t} + \varepsilon_{i,t}$$

(1)

In specification (1), *ESG Performance Score* $_{i,t}$ represents the overall performance of Danish listed firms, including sub-theme performance scores. The coefficient of α_0 specifies the degree of influence of lagged ESG performance on the remaining three sub-categories pillar scores. Whereas as i - n th firms in the t - n th years, and ε_{it} is the error term.

A. Direct Effect

To assess the impact of digitalization on firm ESG performance, we employed a panel data regression model framework. This model is to be tested in equation (2), based on the selected variables and includes a sample size of $N = 536$ observations over a $T = 8$ -year period.

$$i = 1, \dots, N,$$

$$t = 1, \dots, T,$$

$$\begin{aligned} ESG\ Performance\ Score_{i,t} &= \alpha_0 + \beta_1 Digi_{i,t} + \beta_2 BVPS_{i,t} + \beta_3 EPS_{i,t} + \beta_4 FS_{i,t} + \beta_5 Growth_{i,t} + \beta_6 Lev_{i,t} \\ &+ \beta_7 ATO_{i,t} + \beta_8 ROA_{i,t} + Years_{i,t} + \sum_{j=1}^k \delta_j CV_{ji} + \varepsilon_{i,t} \end{aligned} \quad (2)$$

Whereas the value of i - nth firms in t - nth years. $Performance_{i,t}$ is influenced by K exogenous variables ($X_{1it} \dots \dots, X_{Kit}$), which vary across firms and over time. The error term ε_{it} is assumed to be an independent and identically distributed (*IID*) random variable with a mean of zero and variance σ_μ^2 , Independent of ($X_{1i} \dots \dots, X_{it}$), represents the effects of the omitted variables specific to the firms and the study period.

Besides these $Digi_{i,t}$ signifies the level of digitalization within firms. $BVPS_{i,t}$ representing the book value per share and $EPS_{i,t}$ denotes earnings per share, which are critical financial metrics. $FS_{i,t}$ indicates the size of companies. $Growth_{i,t}$ and $Lev_{i,t}$ reflecting the ratios of a company's growth size and leverage. $ATO_{i,t}$ evaluates the assets turnover ratio while $ROA_{i,t}$ provides insights into how effectively a company uses its assets to generate profits, as mentioned in **Model 2**.

B. Moderation Effect

We examined the moderation effect in **Model 3** by utilizing the interaction terms $BVPS_{i,t} \times Digi_{i,t}$ representing the interaction between digitalization and IV1, and $EPS_{i,t} \times Digi_{i,t}$ representing the interaction between digitalization and IV2. These terms serve as proxies to measure the moderation effect of digitalization on the association between stock market valuation and ESG performance.

$$\begin{aligned}
ESG\ Performance\ Score_{i,t} &= \alpha_0 + \beta_1 Digi_{i,t} + \beta_2 BVPS_{i,t} + \beta_3 BVPS_{i,t} \times Digi_{i,t} + \beta_4 EPS_{i,t} + \beta_5 EPS_{i,t} \times Digi_{i,t} \\
&+ \beta_6 FS_{i,t} + \beta_7 Growth_{i,t} + \beta_8 Lev_{i,t} + \beta_9 ATO_{i,t} + \beta_{10} ROA_{i,t} + Years_{i,t} + \sum_{j=1}^k \delta_j CV_{ji} \\
&+ \varepsilon_{i,t}
\end{aligned}
\tag{3}$$

We use multiple linear regression models with panel data. Three distinct approaches or methods were employed for estimating models: OLS or pooled regression model, random effect, and fixed effect regression model. The Ordinary Least Square (OLS) or pooled regression model is a standard regression technique that does not account for cross-sectional or time effects. Fixed-effect regression analysis estimates a single effect (exogenous) that is assumed to be common to every study. In contrast, the Random-effect model estimates a means of a distribution of effects, in other words (endogenous). This suggests the non-existence of heterogeneity problems.

10.4. Empirical Results

We conducted a descriptive statistical and bivariate correlation analysis to test the sample data.

10.4.1. Descriptive Statistics

Table 1 provides a detailed summary of the descriptive statistics for each variable examined in this study. The average value and standard deviation of the ESG performance score are 3.749 and 0.55, respectively. Further, the average value of the other three performance pillar scores is 3.286 for environmental performance, with a standard deviation score of 1.20; the social pillar score is 3.784, with a standard deviation score of 0.69; and the governance pillar score is 3.766, with a standard deviation score of 0.53, indicating the most of listed Danish firms achieved B grade in implementation of overall ESG practices in their business operation. However, some firms in the dataset have prioritized and implemented ESG practices with the highest priority, resulting in an A+ rating. It is observed that the average environmental pillar score is lower than the other three ESG, Social and Governance pillar scores, suggesting significant variability in sustainability reporting standards between companies.

Digitalization experienced higher volatility, and the average value and standard deviation score were 2.858 and 0.98, respectively. This shows that digitalization influences firms to improve productivity, lower operational costs, and add sources of competitive advantage. The high mean values of both earnings per share (EPS) and book value per share (BVPS) are 2.979 and 1.958, respectively, with standard deviation scores of 1.00 and 1.50 each. This suggests that investors should take into account this variability when

making an investment decision. These metrics indicate better profitability and a stronger financial position for the firms, making them potentially more attractive for investments (C.-S. Lin et al., 2015).

For the control variables, the mean firm growth rate is 2.836, with a standard deviation of 1.32. This company's growth rate indicates an expansion in product sales and market share, signaling promising growth prospects in the future. The asset turnover ratio (ATO) has a mean value of 0.089, with a standard deviation of 0.31. This indicates that most companies need to improve their asset turnover. The lowest (Min) value is -2.41, which reflects the negative annual sales and asset utilization situation of certain companies. On the other hand, the highest (Max) value is 0.93, suggesting strong sales abilities and high resource utilization by some companies.

[Insert Table 1 Descriptive Statistical Here]

10.4.2. Correlation Matrix

Table 2 represents the results of the correlation analysis, which indicates the relationship between variables employed in this study. Correlation analysis enables us to evaluate the degree of multicollinearity between predictors. According to (Serafeim, 2015), multicollinearity becomes a significant concern only when the correlation between predictors exceeds 0.9. In our analysis, none of the pairwise correlation coefficients among the independent variables surpass this threshold, indicating that multicollinearity is not an issue in the dataset.

The ESG overall performance has a positive and significant correlation with the other three aspects: environmental ($r = 0.789$, $p < 0.001$), social ($r = 0.895$, $p < 0.001$), and governance pillar scores ($r = 0.757$, $p < 0.001$), indicating that the integrate ESG practices into companies' core operations leads to constant improvements in each of all dimensions. However, digitalization was found to have a highly positive correlation with book value per share ($r = 0.170$, $p < 0.001$) and a moderate but positive correlation with firm size ($r = 0.154$, $p < 0.01$), showing companies that the adoption of digitalization led to higher valuations and larger market capitalization. The Asset turnover ($r = 0.254$, $p < 0.001$) and return on assets ($r = 0.275$, $p < 0.001$) are positively correlated with ESG performance. This suggests that efficient resource use and higher returns are associated with better ESG performance. The findings also highlight the multiple factors that influence each sub-theme of ESG, the role of digitalization in improving sustainability in the business world, and the complex relationship between financial performance and ESG outcomes.

This bivariate correlation analysis provides some preliminary insights into the relationships between the variables used in this study. However, correlation does not imply causation, and there may be

other factors affecting the variables. Therefore, we conduct a multilevel regression analysis to test our proposed hypothesis and control for the confounding effects of the other variables.

[Insert Table 2 Correlation Analysis Here]

10.5. Multi-variate Regression Model

In this section, we investigate how digitalization, as a predictor variable, impacts overall ESG performance, serving as an outcome variable in **Model 2**. We also explore digitalization's moderating effect on the relationship between stock market valuation and ESG overall and sub-themes pillar scores performance in **Model 3**. We employed a panel data econometric model approach using three different regression models: Ordinary least Square (OLS) or Pooled regression model, Random Effect, and Fixed Effect model.

To determine the most suitable estimation methods for each model, the following tests (Petersen, 2009; Hsiao, 2022) were employed: the Breusch-Pagan test, which assesses heteroskedasticity in linear regression models; the Hausman test, which distinguishes between fixed Effect (FE) and Random Effect (RE) models in panel analysis; and the F-test, applied when the FE adjustment exhibited robust standard errors. The panel data methodology allows for the control of unobservable constant heterogeneity across firms attributed to time-invariant characteristics.

10.5.1. Digitalization with Overall ESG Performance

Examining the H_1 in our study, we see that digitalization influences the firm's overall ESG performance. **Table 3** shows the results derived for the dependent variable's overall ESG performance.

Considering the dependent variable's overall ESG performance (α_1), **Table 3** indicates that firms adopting digitalization or digital transformation seem to achieve better growth and have seen more substantial socio-environmental impacts. The model I employed is an OLS regression model that shows the coefficient of digitalization has a significant positive ($\beta_1 = 5.242$; $p < 0.01$) associated with firms' overall ESG performance. This means adopting digital technologies increases a firm's overall ESG performance, which reflects the efficient use of resource utilization and the creation of new products and services in an assembly line, which takes to better market positions and adds a customer loyalty factor (Lu et al., 2024). However, the coefficient of earnings per share ($\beta_3 = 0.448$; $p < 0.1$). and book value per share ($\beta_2 = 0.196$; $p < 0.01$). are positively correlated with overall ESG performance. This indicates that a 0.448 and 0.169 unit increase in ESG overall performance led to a one-unit increase in each variable in the dataset, holding other variables constant. This reflects the pattern where companies are experiencing a rise in revenue

alongside a cost reduction. Keeping the control variable constant in the model I, the coefficient of growth ($\beta_5 = 0.105$; $p < 0.05$) has a positive and significant correlation with outcome variables, although the coefficient of firm size ($\beta_4 = -7.525$; $p < 0.01$) negative and significant associated with ESG performance score, indicating that with digitalization, companies achieve better growth due to better efficiency and productivity, through automation with data analytics. However, the coefficient of firm size demonstrates a negative significant relation with ESG performance. This suggests that digitalization, on the one hand, increased growth but, on the other hand, led to a reduction in firm size due to increased employee job losses. Companies need proactive policies to mitigate the adverse effects (Elamer & Boulhaga, 2024), of digitalization on employment, such as investment in skills programs, social security benefits, etc.

When we observe the results obtained from random effect (Model II) and fixed effect (Model III), the coefficient value of digitalization ($\beta_1 = 0.864$; $P < 0.05$) is positively associated with the overall score of ESG performance. It means that one unit increase in digitalization is associated with a 0.864 unit increase in ESG performance, although in model III, the value of the coefficient is slightly smaller ($\beta_1 = 0.596$; $t = 2.37$), which reflects a non-significant relation with firm's ESG scores. However, the coefficient of the control variable of firm size shows a positive and significant relationship in both model I and model II, compared to model I, which is negative but significant. Parallel, the value of the coefficient of ROA in model II ($\beta_8 = -0.955$; $P < 0.1$) and model III ($\beta_8 = -0.839$; $t = 1.67$) are negative and insignificant, implying the one unit increase in ROA is associated with a -0.839 unit decrease in overall ESG performance. Therefore, based on the results Breusch-Pagan's test results (11.38; $p > 0.05$) and Hausman's test results ($r = 30.804$; $p > 0.05$) indicate that the OLS model or pooled regression is more appropriate than the fixed effect and random effect models. In model I, ROA coefficient values are positive and have a significant association between digitalization and the Overall ESG performance of firms, keeping other control variables constant. Hence, H_1 cannot be rejected (and confirmed by the estimation model by OLS with robustness standard error); the conclusion is that there is a strong positive statistically significant association between digitalization and a firm's overall ESG performance.

[Insert Table 3 Overall ESG Performance Analysis Here]

10.5.2. The role of digitalization on a firm's Environmental performance

Table 4 outlines the results where environmental performance is considered a dependent variable (α_{1a}), presenting the coefficients estimation results using OLS or pooled regression in model IV. Controlling the dummy variable (Years), digitalization significantly increases the firm's environmental score ($\beta_1 = 5.085$; $p < 0.01$), indicating one unit increase in digitalization is associated with a 5.085 unit increase in the firm environmental pillar score. Furthermore, the coefficient values of book value per share ($\beta_2 = 0.498$; p

< 0.01) and earnings per share ($\beta_3 = 0.037$; $p < 0.05$) are statistically significant and have a positive impact on the firm's environmental pillar score. It suggests that companies involved in ecological practices improve their credibility and reputation among stakeholders, e.g., customers, investors, and regulators. This will lead to increased sales, better access to capital, and better financial performance (P. Chen & Hao, 2022; Liang et al., 2022).

Similarly, the random effect (Model V) and fixed effect (Model VI) results indicate a modest positive association with digitalization. In model V, the coefficient of digitalization ($\beta_1 = 0.449$; $p < 0.05$) suggests that one unit increase in a firm's digitalization is associated with a 0.449 unit increase in environmental pillar score. In contrast, in the fixed effect estimations, the coefficient value of digitalization is ($\beta_1 = 0.167$; $t = 2.29$), which is 0.282 units (or 28%) lower than model V and is statistically insignificant. It is observed that the coefficient of the control variable, firm size, remains negative or adversely associated with the environmental pillar score across all three models. Notably, in model IV, the OLS estimation results are more significant ($\beta_4 = -5.939$; $p < 0.05$) than the other two models. Similarly, the results obtained from the coefficient of ROA in the three models show that model IV ($\beta_8 = 26.835$; $p < 0.01$) indicates a significant association with firms' environmental performance, whereas the results of model V ($\beta_8 = 0.837$; $p < 0.05$) and model VI ($\beta_8 = 0.426$; $t = 0.70$) are positively associated but less significant.

Therefore, based on the results Breusch-Pagan's test results (14.830; $p > 0.05$) and Hausman's test results ($r = 34.627$; $p > 0.05$) indicate that the OLS model or pooled regression is more appropriate than the fixed effect model (V) or random effect model (VI). Hence, H_{1a} cannot be rejected (and confirmed by the estimation model by OLS with robustness standard error), and digitalization had a positive and significant impact on firms' environmental performance.

[Insert Table 4 Environmental Performance Analysis Here]

10.5.3. Digitalization influences a firm's Social Performance.

Table 5 presents the results obtained from OLS, RE, and FE models, where social performance is the dependent variable (α_{1b}) associated with digitalization. The coefficient value of digitalization in this model has a positive and significant association with all three models (VII, VIII, and IX). Still, the magnitude of the effect varies across models. Model VII ($\beta_1 = 3.939$; $p < 0.01$) shows a higher amount of significant level, followed by model VII ($\beta_1 = 0.600$; $p < 0.05$), and model IX ($\beta_1 = 0.355$; $t = 3.89$) represents a low significance value it implies that digitalization is correlated with some unobserved factors that affect the social performance of firms that varies across individual or times. It is observed that firms with strong or high social performance prioritize social responsibilities, ecological protections, human

rights, and fair competition. Collaborating with these firms increases social reputation and brand influence and attracts innovative talents from the market (Cheng et al., 2014; Kim & Li, 2021).

The other independent variables in this study, book value per share and earnings per share show a statistically significant positive association in all models (VII, VII, and IX). However, looking at control variables in this study, firm size has a highly significant effect in model VII ($\beta_4 = 14.463$; $p < 0.01$) and model IX ($\beta_4 = 3.699$; $p < 0.05$) but shows less significance in model VII ($\beta_4 = 2.542$; $p < 0.1$) compared to other models indicating larger firms have more resources and incentives to invest in social activities. The coefficient of growth ($\beta_5 = 0.139$; $p < 0.05$) had a positive associates with social performance in model VII, but its negative and insignificant relationship in model VII ($\beta_5 = -0.029$; $t = -0.74$) and model IX ($\beta_5 = -0.219$; $t = -0.78$) similarly the coefficient value of assets turnover ratio is statistically highly positive correlated with social performance in model VII ($\beta_7 = 9.230$; $p < 0.01$) but insignificant lesser correlates in model VII ($\beta_7 = 0.763$; $t = 1.19$) and model IX ($\beta_7 = 0.511$; $t = 1.79$) respectively. It indicates that sharing technology helps to distribute expensive technologies across different organizations, making it easier for them to adopt digital tools. It also allows companies to work with a broader range of partners and seek support, contributing to public welfare. Additionally, by sharing technology, companies can cut costs, thereby allocating more time and financial resources to address social issues beyond their primary business activities. The results of Breusch-Pagan's test ($r = 11.280$; $p > 0.05$) and Hausman's test ($r = 36.799$; $p > 0.05$) suggest that model VII, OLS regression is preferable to the fixed effect model and random effect model. Therefore, H_{1b} is not rejected and is supported by the OLS estimation model with robust standard errors. This implication is that there is a significant positive relationship between digitalization and companies' social performance.

[Insert Table 5 Social Performance Analysis Here]

10.5.4. The Effect of digitalization on firm's Governance performance

Governance performance (α_{1c}), as a dependent variable in **Table 6**, reported results obtained via OLS regression analysis in model X, similar to what we observed in the dependent variables (α_1 , α_{1a} , α_{1b}), indicating that digitalization helps to improve firm's overall (ESG), environmental and social performance. In this estimation model, when we control the dummy variables (Years and Industry), digitalization significantly improves the governance pillar score ($\beta_1 = 6.713$; $p < 0.01$), which means that a one-unit increase in digitalization is associated with a 6.173-unit rise in a firm's governance pillar score. In model XI, the coefficient of digitalization ($\beta_1 = 1.453$; $p < 0.05$) indicates a weak but statistically significant association amongst the predictors and the outcome variable. However, in model XII, the coefficient ($\beta_1 = 0.933$; $t = 1.35$) suggests no significant association between the predictors and the outcome variable.

The coefficients of (independent variables) book value per share in model XI ($\beta_2 = 0.259$; $p < 0.01$) and in model XII ($\beta_1 = 0.361$; $p < 0.01$) indicate a statistically positive and high correlation with firm governance performance rather than in model X ($\beta_1 = 0.007$; $p < 0.05$) which are low associated with each other. However, it's observed that the coefficient value of earning per share (β_4) is constantly negative and shows a negative association between dependent variables in all three models (Model X, Model XI, and Model XII). It means that high EPS does not always lead to better governance pillar scores due to short-term profit focus. Talking to control variables, the firm size coefficient ($\beta_4 = 6.575$; $p < 0.01$) is more statistically associated with firm governance performance in model XII, whereas growth (β_5) remains negative in both model XI and model XII ($\beta_5 = -0.005$; $t = -0.13$), ($\beta_5 = -0.011$; $t = -0.31$), respectively it is poorly and negative associated with each other, but positive correlated in model X, ($\beta_5 = 0.151$; $p < 0.05$). However, model X coefficient values assets turnover ratio ($\beta_7 = 7.727$; $p < 0.05$) has a moderate positive association with the organization's governance pillar score. These findings suggest that digitalization enhances internal governance capabilities and reduces costs while also enabling organizations to manage large volumes of internal information more efficiently. According to (Cai et al., 2012; C.-S. Lin et al., 2015) Implementing digital software tools, like (CAD) can reduce managerial coordination costs and increase stakeholder value

Based on the Breusch-Pagan's test ($r = 41.279$; $p < 0.05$) and Hausman's test ($r = 47.352$; $p > 0.05$) suggests that the model XI, random effect is preferable to the fixed effect and OLS or pooled regression. Therefore, H_{1c} is not rejected and is supported by the random effect estimation model with robust standard errors. This implication is that there is a significant positive relationship between digitalization and companies' governance performance.

[Insert Table 6 Governance Performance Analysis Here]

10.6. The moderating effect of digitalization on the association between stock market valuation and a firm's ESG (Environmental, Social, and Governance) Performance.

To test the second hypothesis (H_2) in our study, we examine how digitalization moderates the relationship between stock market valuation (companies' value according to financial markets) and a firm's ESG performance in sub-themes pillar scores; we use BVPS and EPS as proxies to measure the firm's market valuations and make interaction with digitalization scores of firms to capture the moderation effect of these variables as mentioned in **Model 3**. Using the multivariate regression model (OLS, FE, and RE), **Table 7** represents the results of the moderation effect.

[Insert Table 7 Moderation Effect Results Here]

Digitalization shows a strong positive impact on a firm's ESG performance in model I ($\beta_1 = 5.806$; $p < 0.01$) but is a less significant relationship in model II ($\beta_1 = 0.932$; $p < 0.05$) and model III ($\beta_1 = 0.656$; $t = 2.17$). This Positive association of the coefficient of digitalization on ESG performance indicates that firms' ability to manage and report ESG standards effectively, resulting in an improved transparency score, facilitates a better decision-making process and overall improved ESG outcomes. The coefficient values of BVPS and EPS positively affect ESG performance across all three models, but it is observed that model III ($\beta_2 = 0.230$; $p < 0.01$) and model I ($\beta_4 = 7.130$; $p < 0.01$) have the strongest association with ESG performance score. The consistent positive effect of BVPS and EPS across all models suggests that firms are better positioned to invest in sustainable business practices. This also supports (J. Feng et al., 2022), arguments that financially stable companies have more resources and flexibility to implement and sustain ESG initiatives, leading to better performance.

The coefficient on interaction term between the BVPS*DIGI score ($\beta_3 = 1.622$; $p < 0.5$) and EPS*DIGI score ($\beta_5 = 5.382$; $p < 0.01$) is also positive and statistically significant in model I, providing a support for H₂. This relationship reflects that higher stock market valuations are positively associated with ESG performance, and organizations with greater market values are more inclined to invest in ESG activities and disclose their ESG performance. Keeping the control variable constant, the coefficients of firm size are negatively associated with ESG performance in all three models, showing the most substantial adverse effect in model I ($\beta_6 = -5.843$; $p < 0.1$), reflecting that larger firms face challenges in implementing and managing ESG practices due to their complex business operations. Growth is a positively significant relation in Model I ($\beta_7 = 0.118$; $p < 0.05$), while the relationship of the coefficient of leverage is not significant in any model. ROA has a positive effect in model I ($\beta_{10} = 15.289$; $p < 0.05$) but a negative association in model II and model III. According to (Fang et al., 2023a; Koh et al., 2022; Kuo et al., 2021), large corporations frequently possess a diverse shareholder base that is invested in ESG activities. These corporations are more likely to utilize formal communication channels to share the results of their social activities. Additionally, they tend to be more responsive to ESG efforts due to increasing stakeholder pressure and heightened awareness of political risks. Based on the results of Breusch-Pagan's test, we accept the null hypothesis H₂ of homoskedasticity ($r = 26.67$; $p > 0.05$). Moreover, the Hausman test results ($r = 35.804$; $p > 0.05$) suggest that the OLS regressions model I is more consistent and efficient than the alternative models. Hence, we accept our H₂ that digitalization positively and significantly moderates the relationship between stock market valuation and ESG performance; therefore, H₂ is not rejected, which is confirmed by the OLS regression model with robust standard errors.

Turning our attention to H_{2a}, interestingly, the coefficient of digitalization has a significant positive effect on the firm's environmental performance in model IV ($\beta_1 = 5.096$; $p < 0.01$), suggesting a one-unit increase in digitalization leads to a 5.096 unit increase in environmental pillar score. BVPS consistently shows a positive and significant impact in all three models, with solid correlates in model V ($\beta_2 = 0.304$; $p < 0.01$), indicating that firms with higher book values better manage ecological performance. The interaction term between the BVPS*DIGI score ($\beta_3 = 2.271$; $p < 0.05$) highlights that digitalization positive influence on the environmental performance of firms, although the interaction between EPS*DIGI score shows a mixed result but more statistically significant in model IV ($\beta_5 = 6.279$; $p < 0.01$) and marginally negatively effect in model VI, ($\beta_5 = -0.310$; $p < 0.1$), this relationship may vary depending on the level of stock market valuation and other firm-specific factors.

The coefficients of firm size and leverage show varying degrees of significance. Firm size does not exert a statistically significant impact on environmental performance in any of the models, while the variable representing firm growth also lacks significance across all models. Leverage positive association on ecological performance in model IV ($\beta_8 = 0.252$; $p < 0.01$) and remains insignificant in other models. Similarly, the coefficient of ROA shows a highly positive impact in model IV ($\beta_{10} = 27.47$; $p < 0.01$), representing firms with high returns leading to a better managing environmental pillar score, although this correlation remains insignificant in model V and model VI.

These findings emphasize that smaller-scale firms, which have limited resources, produce less pollution, and face less external pressure, tend to have better environmental performance. On the other hand, larger firms, which must navigate a complex landscape of stakeholders and comply with rigorous government regulations, are required to manage diverse environmental data and allocate resources effectively (Bhattacharya & Sharma, 2019; Ma et al., 2023; H. Li et al., 2021). Based on the estimation results of all models, the Breusch-Pagan test ($r = 20.33$; $p > 0.05$) and the Hausman test ($r = 34.804$; $p > 0.05$), model IV is the most appropriate, consistent, and effective. Therefore, H_{2a} is accepted, which is supported by robust standard errors. It also indicates that digitalization positively moderates the relationship between the stock market and Environmental performance.

To test the hypothesis H_{2b} and H_{2c}, the results indicate that digitalization has a significant positive impact and enhances both social and Governance performance scores in model VII ($\beta_1 = 4.321$; $p < 0.01$) and model X ($\beta_1 = 6.813$; $p < 0.01$), while it's lesser correlates with other models. The interaction terms between digitalization and financial metrics (BVPS and EPS) show a significant adverse effect on social performance in model VII ($\beta_3 = -2.365$; $p < 0.01$) and ($\beta_5 = -5.625$; $p < 0.01$), and although these interactions also adversely correlate in other models and remain insignificant. In the same way, the interaction terms between BVPS*DIGI and EPS*DIGI in governance performance show that the coefficients of β_3 poorly

correlated in all three models and are statistically insignificant. However, the coefficient value of ($\beta_5 = -6.053$; $p < 0.01$) indicates a negative association with firm governance performance in model X and remains insignificant and has no correlation with the other two models. These findings highlight that adopting digital technologies can significantly improve the firm's overall ESG performance. Each performance or pillar score represents unique challenges for organizations to build or use targeted strategies for improvement. For instance, improving environmental performance (Q.-J. Wang et al., 2023; Zheng et al., 2023) primarily entails optimizing resource utilization and minimizing pollution. Social performance necessitates enhancing stakeholder goodwill to achieve mutually beneficial objectives (Cheng et al., 2014; Nollet et al., 2016). Meanwhile, governance performance involves refining management teams and organizational structures (Kim & Li, 2021).

The relationship between stock market valuation and firm social and governance performance is statistically significant and negatively moderated by digitalization. Therefore, on the basis of the estimation model, we cannot reject the null hypotheses H_{2a} and H_{2c} . The Breusch-Pagan's test results support the null hypothesis H_{2a} of homoskedasticity ($r=20.66$; $p > 0.05$), and the Hausman test results ($r = 39.408$; $p > 0.05$) indicate that model VII (Social Performance), is more consistent and efficient than the alternative models. Similar to governance performance, the Breusch-Pagan's test results support the null hypothesis H_{2b} of homoskedasticity ($r=14.45$; $p > 0.05$), and the Hausman test results ($r = 37.204$; $p > 0.05$) reflect that the model X is more consistent and efficient than the alternative models. Therefore, H_{2b} and H_{2c} are accepted, as confirmed by the OLS regression model, with robust standard errors.

10.7. Robustness Check

In **Model 4**, we employed a two-step ³⁰Generalized Method of Moments (GMM) approach to validate the robustness of our findings, the role of digitalization on ESG performance, and the moderation effect of digitalization on the association between stock market valuation and ESG performance, including sub-themes performance pillar scores. This approach helps address endogeneity issues stemming from ³¹reverse causality.

The following equation presents our two-step GMM model.

³⁰ For GMM estimation, we utilize *STATA 18* and execute the “*xtabond2*” command. For further details, refer to (Roodman, 2009)

³¹ To address heteroscedasticity in robust GMM regression, we apply the “*robust*” option within the command section.

$$\begin{aligned}
ESG\ Performance\ Score_{i,t} &= \alpha_0 + \alpha_1 (ESG_{i,t-1} + ENV_{i,t-1} + SOC_{i,t-1} + GOV_{i,t-1}) \\
&+ \alpha_2 (ESG_{i,t-2} + ENV_{i,t-2} + SOC_{i,t-2} + GOV_{i,t-2}) + \beta_1 L.Digi_{i,t} + \beta_2 BVPS_{i,t} \\
&+ \beta_3 L.BVPS_{i,t} \times Digi_{i,t} + \beta_4 EPS_{i,t} + \beta_5 L.EPS_{i,t} \times Digi_{i,t} + \beta_6 FS_{i,t} + \beta_7 Growth_{i,t} \\
&+ \beta_8 Lev_{i,t} + \beta_9 ATO_{i,t} + \beta_{10} ROA_{i,t} + \sum_{j=1}^k \delta_j CV_{ji} + \varepsilon_{i,t}
\end{aligned}
\tag{4}$$

The definitions of all explanatory variables are provided in **Table A3** in the appendix section. Whereas, $(ESG_{i,t-1} + ENV_{i,t-1} + SOC_{i,t-1} + GOV_{i,t-1})$ represent a one-year lag of all dependent variables (previous year performance) while $(ESG_{i,t-2} + ENV_{i,t-2} + SOC_{i,t-2} + GOV_{i,t-2})$, denotes a two-year lag (performance from the year before the previous year). These ³²lags are included as predictors in our GMM estimation model, as shown in **Table 8**. We adopted the GMM model to re-examine and address endogeneity issues. The GMM model mitigates endogeneity by internally transforming the data through the inclusion of lagged values of the independent variables, providing superior estimation techniques compared to OLS or pooled regression, random Effect (RE), and Fixed Effect (FE) models.

[Insert Table 8 Robustness Effect Results Here]

In **Table 8**, Model I & II, the coefficients of digitalization ($\beta_1 = 0.043$; $P < 0.01$) and ($\beta_1 = 0.027$; $P < 0.5$) show a positive and statistically significant relationship with the firm's ESG performance and Environmental pillar score. It demonstrates that organizations with higher ESG performance and environmental scores experience lower risk and increased profits, leading to improved operational efficiency, transparency, and stakeholder involvement. However, the results of the social ($\beta_1 = 0.054$; $P > 0.1$) and governance ($\beta_1 = 0.063$; $P > 0.1$) performance are positive but not statistically significant. It's observed that the coefficient values of BVPS ($\beta_2 = 0.211$; $P < 0.01$) and EPS ($\beta_4 = 0.052$; $P < 0.1$) showed only a positive relationship with corporate social performance in model III, indicating that profitable firms have more resources to invest in social initiatives. Additionally, the coefficient of interaction terms β_3 (BVPS*DIGI) and β_5 (EPS*DIGI) show the lowest association level with the firm's overall ESG and environmental performance in model I and model II and are statistically insignificant. This indicates that the digitalization of BVPS does not significantly influence the firm's ESG and environmental performance due to the lack of integration between digital initiatives and ecological strategies.

³² According to (Roodman, 2009), using the lag of the dependent variable at (t-1) is sufficient to account for its persistence

Whereas the coefficients of interaction terms in model III ($\beta_3 = -0.089$; $P < 0.01$) and model IV ($\beta_3 = -0.013$; $P < 0.05$) are negatively correlated with social and governance pillar scores. This adverse correlation suggests that higher digitalization of BVPS might detract from the firm's focus on social and governance aspects, potentially due to resource allocation towards digital transformation rather than social and governance improvements. However, the interaction terms β_5 (EPS*DGI) in Model III and Model IV remain negative and do not show any association with governance and firm social pillar scores, further supporting the arguments that digital transformation efforts, when not strategically aligned with social and governance goals, may not contribute positively to these areas.

To ensure the ³³credibility of our results, we conducted Arellano-Bond first-order (AR1) and second-order (AR2) serial autocorrelation tests to estimate the panel dynamic model. The AR1 results reject the null hypothesis, indicating the necessity of using the lagged term of the dependent variable. Conversely, the AR2 results accept the null hypothesis, suggesting no autocorrelation in the disturbance terms. Additionally, the Sargan test was employed to determine the validity of the econometric model and the correctness of the specified instruments. If the null hypothesis is rejected, it implies that the model or instruments used in the estimation process need reconsideration. In our estimation model, all P-values from the Sargan test are more significant than 0.1, indicating the variables' reliability.

10.8. Conclusion and Discussion

This research empirically examines the impact of digitalization on the ESG performance of firms, with a focus on the sub-themes of the ESG pillar scores. Utilizing panel data from the Refinitiv Eikon™ database (previously known as Thomson Reuters ASSET4 ESG), the research analyzes data from publicly listed Danish companies from 2015 to 2022. This study employs a multivariate regression model approach, incorporating an Ordinary Least Square (OLS) or pooled regression model, a fixed-effect regression model, and a random-effect regression estimation model to conduct the empirical tests. These findings remain robust and do not contradict the counter-intuitive evidence, even when subjected to a two-step Generalized Method of Moments (GMM) estimation model.

The empirical results support the positive impact of digitalization on ESG firms' overall performance, as our hypothesis **H₁** states. This means the adoption of digital technologies increases a firm's ESG performance. This performance reflects the efficient use of resources and the creation of new products

³³ The GMM system estimator is employed due to its superior efficiency compared to alternative GMM estimators, as noted by (Arellano & Bond, 1991). Additionally, different GMM estimations are prone to issues with weak instruments

and services within an assembly line, which improves the firm's market position (goodwill) and also increases customer loyalty (Garcia et al., 2017; Yang & Han, 2023b; Lu et al., 2024). Furthermore, the finding indicates that the advent of digital technologies and digital transformation has opened new avenues for firms to grow. The results also indicate that the advantages of digital transformation extend beyond enhancing efficiency and competitiveness to improving ESG performance, thereby underscoring a new aspect of its impact on firms (Mo et al., 2023; S. Wang & Esperança, 2023).

By empirically testing the H_{1a} — H_{1c} , our results suggest that digitalization or digital transformation activities significantly improve all sub-themes of ESG performance. Specifically, digitalization initiatives allow firms to share data and resources with key external stakeholders, facilitating the optimization of resource usage. This, in turn, helps firms enhance their ESG scores. Organizations involved in ecological practices enhance their credibility and reputation among stakeholders (customers, investors, and regulators), resulting in improved sales, better access to capital, and improved financial performance (Q.-J. Wang et al., 2023).

In addition, the findings of social performance (Yang & Han, 2023b), show positive but low significance values, reflecting that digital transformation is associated with some unobserved factors that affect firms' social performance. It also reflects that companies with solid or high social performance prioritize social responsibilities, ecological protections, human rights, and fair competition to collaborate with these firms to improve social reputation and brand influence and attract innovative talents from the market (Truant et al., 2021). The findings of the governance performance of the firms encourage the adoption of a decentralized management approach. Firms must include digital operation efforts to reduce costs and improve efficiency. To achieve this, it is essential to implement flat management strategies that favour a horizontal organization structure over traditional vertical hierarchies. This approach enhances flexibility and adaptability in resource allocations (Cucari et al., 2018; Andersen et al., 2022).

We also uncover the moderating role of digitalization in the relationship between stock market valuation and ESG performance, including sub-themes perspectives. However, H_2 —the correlation and regression analysis results confirmed that digitalization positively moderates the relationship between companies' stock market value and ESG performance score. These findings reflect the firm's ability to effectively manage and report ESG standards, resulting in improved transparency scores and a better decision-making process.

By validating hypotheses H_{2a} — H_{2c} , the estimation results provide a refined understanding of the influence of digitalization on positively moderating the relationship between stock market and environmental performance of the firms. These outcomes align with previous research findings (Bannier et

al., 2019; Bhattacharya & Sharma, 2019; J. Feng et al., 2022; Hu et al., 2023) and support the perspective that investing in digitalization and the stock market can foster a proactive strategy. Companies invest in digital technologies not just to adapt to environmental changes but to establish a competitive advantage. These findings also highlight that the smaller firms, with limited resources, produce or emit less pollution and face more external pressures tend to have improved ecological performance. More prominent companies, engaging with a wide range of stakeholders and adhering to stringent government regulations, must skillfully manage diverse environmental data and allocate resources efficiently (Drempetic et al., 2020; Ma et al., 2023).

Our findings of **H_{2b}** and **H_{2c}** suggest that digitalization adversely moderates the relationship between stock market performance and firms' social and governance performance. These findings highlight the rising uncertainty and complexity within a business environment. For instance, investment in carbon reduction equipment, the adoption of renewable energy, the establishment of green buildings and factories, and the enhancement of low-carbon products, combined with the integration of digital technologies, all contribute to transformation risks and costs, including capital investment and expenditures (Adger, 2006b; H.-M. Chen et al., 2022; Wan et al., 2023). These activities are aimed at improving ESG performance indicators, but they significantly increase companies' operation costs, which will adversely affect their financial, social, and governance performance.

The proposed path model results indicate that the level of digitalization significantly and directly influences the ESG performance of listed Danish firms. However, applying various estimation techniques has revealed a strong correlation between firm size and digital adoption. Larger firms are more inclined to invest in digitalization, likely due to more significant financial and human capital resources. This study also identified that the primary perceived benefits of digitalization—such as enhanced competitive advantage, improved quality of goods and services, and better customer experience—serve as precursors to value generation, demonstrating a strong relationship between these benefits and performance. Successful initiatives also require a formal process for achieving both long-term and short-term goals, new organizational structures, and updated work practices. Companies that fail to plan comprehensively and act swiftly risk missing profit-generating opportunities, including those related to strategy, technology processes, culture, and practices.

10.9. Theoretical, Practical, and Policy Implications

Evidence from our study supports a theoretical perspective indicating the positive effects of digitalization on ESG performance. Our findings demonstrate that digitalization enhances companies' ESG performance, highlighting a strong relationship between digitalization investments and financial

performance. They also examine the moderation role of digitalization in the association between firm stock market valuations and ESG (sub-themes) performance. We further show that firm size and growth play a critical role when investigating key variables.

From a practical perspective, our findings hold significant implications for various stakeholders, including managers, regulators, non-governmental organizations, and entrepreneurial firms, who are interested in understanding the intricate relationship between digitalization and ESG performance. This area of investigation is relatively new and underexplored, and our research addresses the need for more empirical studies on the subject. Managers can begin by strategically investing in digitalization processes, such as blockchain technologies, artificial intelligence, and the Internet of Things, which have been shown to foster green innovation. For instance, the use of artificial intelligence can optimize resources in the production process, while the Internet of Things can monitor environmental compliance in real-time, thereby enhancing transparency and efficiency in public welfare infrastructure and advancing ESG objectives (Meng et al., 2022; F. Wang & Sun, 2022). Regulatory bodies play a crucial role in fostering an environment conducive to digital transformation, particularly for organizations with limited resources for digital investments. By actively promoting digitalization within the manufacturing and high-tech sectors, these regulatory bodies can significantly strengthen governance structures and improve the oversight of securities analysis.

From the policy implications perspective, firms must implement training programs to upskill employees in digital competencies focusing on ESG outcomes and collaborate with universities or educational institutions to integrate ESG-focused digital skills into their prospectuses. Providing subsidies or low-interest-based loans to firms for adopting digitalization that leads to better ESG performance. For example, carbon footprint monitoring software and governance risk management systems will facilitate access to these tools. Also, they can foster public-private partnerships between the government, private sectors, and technological companies to drive innovation and share best practices across industries, contributing to Denmark's more sustainable and responsible business environment.

10.9.1. Limitations and Future Research

Our research is not without its limitations. This study examines the role of digitalization in firms' ESG performance from the perspective of sustainable development, using evidence from a single country, Denmark. Future research could explore various company variables and the relationship between digitalization and other types of performance (financial, operational, or market), particularly within the context of sustainable development.

Additionally, the moderating effect of digitalization on the relationship between the stock market and firms' ESG performance may be influenced by country institutional factors, such as differing levels of corporate governance globally. Future studies are encouraged to investigate our findings in a diverse context.

The econometric estimation techniques employed in this study may introduce biases due to essential variables, although this has yet to be demonstrated. The use of various estimation techniques may mitigate this limitation.

Finally, the lack of studies on this topic suggests several avenues for future research: replicating this study with companies listed in other European countries, extending the study period (through longitudinal and cross-sectional analyses) as more recent data become available, and employing alternative estimation models.

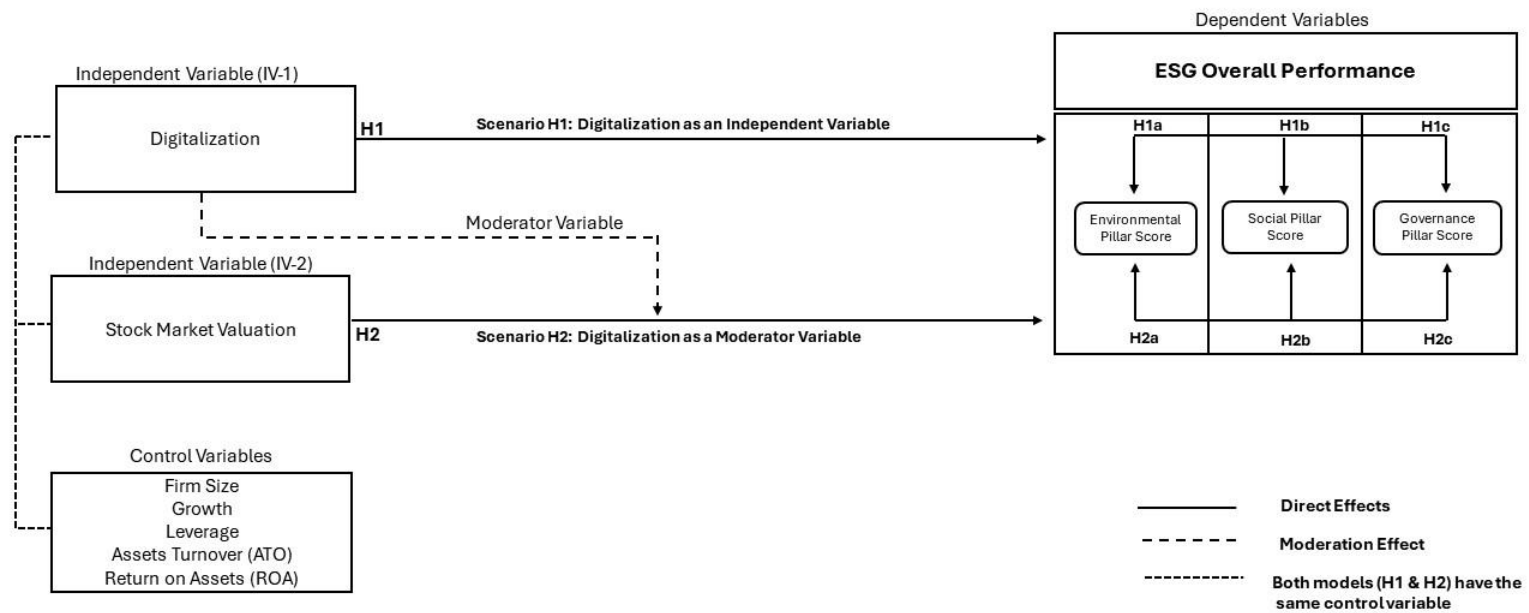
10.9.2. Additional Data.

Haseeb, M. (2024). Appendix file and Supplementary data for the research article *"Exploring the Nexus Between Digitalization and Firm's ESG Performance: An Empirical Study of Danish Listed Firms"*. Zenodo. <https://doi.org/10.5281/zenodo.13768757>

10.10. A FIGURE OF AN ARTICLE 2

10.10.1. Figure 1.

³⁴A Conceptual framework of the study.



³⁴ Source: Author Calculations

10.11. TABLES OF ARTICLE 2

10.11.1. Table No 1

³⁵Analysis of descriptive statistics for the sample of publicly listed companies.

Variables	N	Mean	Standard Deviation	Kurtosis	Min	Max
ESG Performance	536	3.7495	0.5501	8.3165	0.4641	4.4390
Environmental Performance	536	3.2866	1.2085	6.3185	-1.9988	4.4993
Social Performance	536	3.7846	0.6930	10.4612	0.3088	4.5508
Governance Performance	536	3.7662	0.5385	6.6098	0.2165	4.5218
Digitalization	536	2.8582	0.9877	2.9038	0.4895	5.6167
Book value per Share	536	1.9581	1.5040	8.2848	-7.2597	4.7843
Earnings per share	536	2.9793	1.0011	5.0243	-0.2566	5.6013
Firm size	536	2.0142	1.4991	5.7738	0.8713	1.4001
Growth	536	2.8367	1.3269	3.0310	-2.2178	5.2866
Leverage	536	1.2910	1.0466	6.0410	1.2679	5.4169
Asset Turnover	536	0.0893	0.3194	18.1245	-2.4184	0.9317
Return on Assets	536	0.0419	0.1749	12.6009	-0.8464	1.02

³⁵ **Note:** This table presents the descriptive statistics results for the variable considered in this study. The definitions of all variables are mentioned in Appendix A of this paper. Our sample contains information on 536 observations of publicly listed Danish firms over eight years (2015 to 2022). Whereas $P < 0.001^{***}$; $P < 0.05^{**}$; $P < 0.1^{*}$

10.11.2. Table No 2

³⁶Correlation analysis of publicly listed companies.

Variables	1	2	3	4	5	6	7	8	9	10	11	12
ESG Performance	1.000											
Environmental Performance	0.789***	1.000										
Social Performance	0.895***	0.627***	1.000									
Governance Performance	0.757***	0.423***	0.502***	1.000								
Digitalization	0.253***	0.197***	0.189***	0.237***	1.000							
Book value per share	0.080*	0.300***	0.015	-0.070*	0.170***	1.000						
Earnings per share	0.010	-0.018	-0.017	0.033	-0.151**	-0.098**	1.000					
Firm Size	-0.164***	-0.065	-0.249***	-0.039	0.154**	0.188***	-0.219***	1.000				
Growth	0.040	0.140	0.012	0.025	0.032	-0.114	0.173	-0.132	1.000			
Leverage	0.035	0.135	-0.027	0.056	0.034	0.160	-0.033	0.261	-0.046	1.000		
Assets Turnover	0.254***	0.253***	0.202***	0.159***	-0.143**	0.082*	0.076*	-0.034	0.593***	-0.004	1.000	
Return on Assets	0.257***	0.280***	0.196***	0.129**	-0.083*	0.017	-0.053	-0.074*	-0.367	-0.033	0.593	1.000

³⁶ **Note:** This table represents the pairwise correlation analysis results of the variable used in this study. Whereas $P < 0.001$ ***; $P < 0.05$ **; $P < 0.1$ *

10.11.3. Table No 3

³⁷Estimation of multivariate regression models I, II, and III: The dependent variable is ESG performance.

	OLS Model I	Random Effect Model II	Fixed Effect Model III
Variables	Coef.	Coef.	Coef.
Digitalization	5.242*** (6.71)	0.864** (2.97)	0.596 (2.37)
Book Value per share	0.169*** (3.88)	0.219*** (5.55)	0.239*** (5.82)
Earnings per share	0.448* (2.71)	0.227 (2.55)	0.024 (2.65)
Firm size	-7.525*** (-3.56)	3.547** (2.75)	4.431*** (3.45)
Growth	0.105** (2.12)	-0.018 (-1.77)	-0.036 (-0.77)
Leverage	0.094 (1.41)	-0.032 (-1.08)	-0.031 (-1.06)
Asset Turnover	7.664*** (2.66)	0.947* (1.73)	0.913 (1.65)
Return on Assets	14.424 (2.79)	-0.955* (-1.96)	-0.839 (-1.67)
Years of Dummies	Yes	Yes	No
F-Test	69.17		41.32
Adjusted R-Squared	73.29%		
Akaike Criterion (AIC)	4539.43		4347.31
No of Observations	536	536	536

³⁷ **Note:** This table represents the results of estimating the panel data regression parameters in three models: Model I, Ordinary Least Square; Model II, Random Effect; and Model III, Fixed Effect. All variables are defined in the Appendix A section of this study, Whereas the t-values adjusted are in Parentheses donated statistical significance at the $P < 0.001$ ***; $P < 0.05$ **; $P < 0.1$ *

10.11.4. Table No 4

³⁸Estimation of multivariate regression models IV, V, and VI: The dependent variable is Environmental performance.

	OLS Model IV	Random Effect Model V	Fixed Effect Model VI
Variables	Coef.	Coef.	Coef.
Digitalization	5.085*** (5.08)	0.449** (2.79)	0.167 (2.29)
Book Value per share	0.489*** (8.79)	0.317*** (6.17)	0.300*** (5.58)
Earnings per share	0.037** (2.10)	0.041** (2.28)	0.045** (2.33)
Firm size	-5.939** (-2.19)	-1.787* (-1.07)	-1.433 (-0.85)
Growth	0.007 (0.12)	-0.011 (-0.37)	-0.005 (-0.27)
Leverage	0.253*** (2.97)	0.031 (0.82)	0.025 (0.66)
Assets Turnover	5.684 (1.54)	0.746 (1.05)	0.547 (0.75)
Return on Assets	26.835*** (4.06)	0.837** (1.32)	0.462 (0.70)
Years of Dummies	Yes	Yes	No
F-Test	50.81		45.42
Adjusted R-Squared	57.43%		
Akaike Criterion (AIC)	4803.89		4637.97
No of Observations	536	536	536

³⁸ **Note:** This table represents the results of estimating the panel data regression parameters in three models: Model IV, Ordinary Least Square; Model V, Random Effect; and Model VI, Fixed Effect. All variables are defined in the Appendix A section of this study, Whereas the t-values adjusted are in Parentheses donated statistical significance at the $P < 0.001$ ***; $P < 0.05$ **; $P < 0.1$ *

10.11.5. Table No 5

³⁹Estimation of multivariate regression models VII, VIII, and IX: The dependent variable is Social performance.

	OLS Model VII	Random Effect Model VIII	Fixed Effect Model IX
Variables	Coef.	Coef.	Coef.
Digitalization	3.939*** (4.32)	0.600** (4.18)	0.355 (3.89)
Book Value per share	0.104** (2.05)	0.103** (2.23)	0.112** (2.34)
Earnings per share	0.079** (2.58)	0.006* (2.36)	0.008* (2.46)
Firm size	14.463*** (5.86)	2.542* (1.69)	3.699** (2.47)
Growth	0.139** (2.42)	-0.029 (-0.74)	-0.219 (-0.78)
Leverage	0.051 (0.65)	-0.098 (-0.39)	-0.069 (-0.21)
Assets Turnover	9.23*** (2.75)	0.763 (1.19)	0.511 (1.79)
Return on Assets	9.229 (3.53)	-0.191 (-2.34)	-0.091 (-0.16)
Years Dummies	Yes	Yes	No
F-Test	58.74		49.47
Adjusted R-Squared	59.80%		
Akaike Criterion (AIC)	4703.68		4512.74
No of Observations	536	536	536

³⁹ **Note:** This table represents the results of estimating the panel data regression parameters in three models: Model VII, Ordinary Least Square; Model VIII, Random Effect; and Model IX, Fixed Effect. All variables are defined in the Appendix A section of this study, Whereas the t-values adjusted are in Parentheses donated statistical significance at the $P < 0.001$ ***; $P < 0.05$ **; $P < 0.1$ *

10.11.6. Table No 6

⁴⁰Estimation of multivariate regression models X, XI, and XII: The dependent variable is Governance performance.

	OLS Model Model X	Random Effect Model XI	Fixed Effect Model XII
Variables	Coef.	Coef.	Coef.
Digitalization	6.713*** (7.06)	1.453** (2.12)	0.933 (1.35)
Book Value per share	0.007** (6.14)	0.259*** (4.31)	0.361*** (5.54)
Earnings per share	-0.028 (-2.89)	-0.030 (-1.31)	-0.033 (-1.42)
Firm size	0.793* (0.31)	5.296** (2.63)	6.575*** (3.23)
Growth	0.151** (2.53)	-0.005 (-0.13)	-0.011 (-0.31)
Leverage	0.119 (1.47)	-0.072 (-1.55)	-0.007 (-1.54)
Assets Turnover	7.727** (2.21)	1.108 (1.30)	1.564* (1.78)
Return on Assets	4.504 (0.72)	-1.809** (-2.44)	-2.04** (-2.55)
Years Dummies	Yes	Yes	No
F-Test	71.65		61.02
Adjusted R-Squared	78.41%		
Akaike Criterion (AIC)	4748.75		4841.56
No of Observations	536	536	536

⁴⁰ **Note:** This table represents the results of estimating the panel data regression parameters in three models: Model X, Ordinary Least Square; Model XI, Random Effect; and Model XII, Fixed Effect. All variables are defined in the Appendix A section of this study, Whereas the t-values adjusted are in Parentheses donated statistical significance at the $P < 0.001$ ***; $P < 0.05$ **; $P < 0.1$ *

10.11.7. Table No 7

⁴¹Estimation of coefficients in multivariate panel data regression models (I-XII): The moderating effect of digitalization on the relationship between stock market valuation and firms' environmental, social, and governance (ESG) performance.

Variables	ESG Performance			Environmental Performance			Social Performance			Governance Performance		
	OLS Model I	Random Effect Model II	Fixed Effect Model III	OLS Model IV	Random Effect Model V	Fixed Effect Model VI	OLS Model VII	Random Effect Model VIII	Fixed Effect Model IX	OLS Model X	Random Effect Model XI	Fixed Effect Model XII
	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
Digitalization	5.806*** (6.43)	0.932** (2.79)	0.656 (2.17)	5.096*** (4.96)	0.334** (2.49)	0.173 (2.30)	4.321*** (3.38)	0.764* (4.07)	0.339 (3.98)	6.813*** (6.99)	1.273** (2.34)	0.945 (1.55)
BVPS	0.071* (2.15)	0.216*** (4.89)	0.230*** (5.11)	0.036*** (4.58)	0.304*** (5.33)	0.291*** (4.91)	0.021 (2.30)	0.092* (1.79)	0.101* (1.29)	0.142* (1.86)	0.268*** (3.95)	0.351*** (4.91)
BVPS*DIGI	1.622** (2.23)	1.096 (2.25)	1.193 (2.49)	2.271** (2.47)	0.191 (0.38)	0.208 (0.40)	-2.365*** (-2.83)	-0.211 (-2.46)	-0.243 (-2.53)	-1.966 (-2.20)	-0.009 (-0.02)	-0.223 (-0.36)
EPS	7.130*** (4.80)	0.037* (2.27)	0.038** (2.02)	9.057*** (4.82)	0.488** (2.28)	0.050** (2.33)	5.788*** (3.39)	0.018 (2.94)	0.018 (2.92)	8.578*** (4.70)	0.053** (2.04)	0.054** (2.08)
EPS*DIGI	5.382*** (5.61)	0.718* (1.65)	0.746** (1.68)	6.279*** (5.18)	0.332 (0.59)	-0.310* (-0.53)	-5.625*** (-5.11)	-0.599 (-1.18)	-0.535 (-1.03)	-6.053*** (-5.14)	-1.074 (-1.60)	-1.141 (-1.62)
Firm Size	-5.843* (-2.67)	-3.575*** (-2.79)	-4.401*** (-3.43)	-3.752 (-1.36)	-1.799 (-1.08)	-1.443 (-0.86)	-13.099*** (-5.22)	-2.542* (-1.70)	-3.681** (-2.46)	-2.25 (-0.84)	-5.328*** (-2.66)	-6.529*** (-3.21)
Growth	0.118** (2.37)	-0.019 (-0.81)	-0.018 (-0.79)	0.025 (0.40)	-0.012 (-0.38)	-0.006 (-0.18)	0.157*** (2.75)	-0.021 (-0.77)	-0.022 (-0.80)	0.168*** (2.76)	-0.007 (-1.20)	-0.012 (-1.09)
Leverage	0.098 (1.46)	-0.029 (-0.98)	-0.028 (-0.96)	0.252*** (2.96)	0.033 (0.86)	-0.026 (-0.70)	0.055 (0.71)	-0.088 (-0.22)	-0.055 (-0.15)	0.128 (1.55)	-0.068 (-1.46)	-0.066 (-1.45)
Assets Turnover	11.667*** (3.77)	0.952* (1.74)	0.939* (1.69)	8.841** (2.26)	0.738 (1.04)	0.564 (1.00)	14.292*** (4.03)	0.764 (1.20)	0.534 (1.09)	12.298*** (3.25)	1.164 (1.37)	1.589* (1.82)
ROA	15.289** (2.95)	-0.986* (-2.01)	-0.898* (-1.77)	27.47*** (4.19)	-0.813 (-1.28)	-0.482 (-0.72)	9.65 (1.62)	-0.211 (-0.37)	-0.052 (-0.09)	-5.118 (-0.80)	-1.904* (-2.54)	-2.135*** (-2.66)
Years of Dummies	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No
F-Test	71.27		45.27	53.18		42.34	57.94		50.16	76.17		70.05

⁴¹ **Note:** This table represents the results of the moderation effect of digitalization on estimating panel data regression parameters across three models (I-XII). These regression models include Ordinary Least Square, Random Effect, and Fixed Effect, as described in Equation 3 of this study. All variables are defined in the Appendix A section of this study, Whereas the t-values adjusted are in Parentheses donated statistical significance at the $P < 0.001^{***}$; $P < 0.05^{**}$; $P < 0.1^{*}$

Adjusted R-Squared	79.37%			55.35%			59.34%			71.33%		
Akaike Criterion (AIC)	4550.58		4320.91	4802.48		4512.74	4698.78		4514.07	4769.84		4421.83
No of Observations	536	536	536	536	536	536	536	536	536	536	536	536

10.11.8. Table No 8

⁴²Robustness Check, using a Two-Step Generalized Method of Movement (GMM) estimation model

Variables	ESG Performance	Environmental Performance	Social Performance	Governance Performance
	SYS-GMM Model I	SYS-GMM Model II	SYS-GMM Model III	SYS-GMM Model IV
	Coef.	Coef.	Coef.	Coef.
L1.ESG	0.967*** (18.03)			
L2.ESG	0.067*** (0.95)			
L1.Env		0.912*** (17.88)		
L2.Env		0.042*** (4.69)		
L1.Soc			0.931*** (18.94)	
L2.Soc			0.089** (3.57)	
L1.Gov				0.967*** (15.15)
L2.Gov				0.115** (2.67)
Digitalization	0.043*** (2.02)	0.027** (2.51)	0.054 (1.24)	0.063 (1.32)
BVPS	0.431 (0.51)	0.092 (0.96)	0.211*** (2.60)	0.306 (1.40)
DIGI*BVPS	0.002 (1.38)	0.002 (1.44)	-0.089** (-2.49)	-0.013** (-2.28)
EPS	0.017 (0.63)	0.005 (0.14)	0.052* (1.74)	0.013 (1.28)
DIGI*EPS	0.972 (1.28)	0.001 (1.08)	-0.049 (-1.40)	-0.023 (-1.91)
Firm Size	-1.606 (-0.84)	1.538 (0.58)	-2.388 (-1.07)	-2.645 (-1.83)
Growth	0.024 (0.62)	0.034 (0.70)	0.069 (1.19)	0.039 (1.75)
Lev	-0.052 (-0.38)	-0.005 (-0.03)	-2.189 (-1.44)	2.045 (2.02)
ATO	-4.234 (-1.16)	-1.938 (-1.40)	-3.147 (-0.77)	-4.650 (-2.79)
ROA	8.520	7.496***	10.769	11.975

⁴² **Note:** This table represents the robustness test for the multivariate regression of the ESG performance of firms (including Environmental, Social, and Governance Pillar scores) as per equation 4 of this study. All variables are defined in the Appendix A section of this study, Whereas the t-values adjusted are in Parentheses donated statistical significance at the $P < 0.001$ ***; $P < 0.05$ **; $P < 0.1$ *

	(1.25)	(2.82)	(1.39)	(1.68)
AR(1) (P-value)	0.0000	0.0000	0.0022	0.0089
AR(2) (P-value)	0.9283	0.2769	0.1511	0.1456
Sagan test statistics	83.80877	73.56898	67.74912	82.74469
No. of Observations.	402	402	402	402

10.12. References

- Adedeji, B. S., Ong, T. S., Uzir, M. U. H., & Abdul Hamid, A. B. (2020). Corporate governance and performance of medium-sized firms in Nigeria: Does sustainability initiative matter? *Corporate Governance (Bingley)*, 20(3), 401–427. <https://doi.org/10.1108/CG-09-2019-0291>
- Adger, W. N. (2006a). Vulnerability. *Global Environmental Change*, 16(3), 268–281. <https://doi.org/10.1016/j.gloenvcha.2006.02.006>
- Adger, W. N. (2006b). Vulnerability. *Global Environmental Change*, 16(3), 268–281. <https://doi.org/10.1016/j.gloenvcha.2006.02.006>
- Ancillai, C., Marinelli, L., & Pascucci, F. (2022). Digital-Driven Business Model Innovation: The Role of Data in Changing Companies' Value Logic. In M. Ratajczak-Mrozek & P. Marszałek (Eds.), *Digitalization and Firm Performance: Examining the Strategic Impact* (pp. 73–98). Springer International Publishing. https://doi.org/10.1007/978-3-030-83360-2_4
- Andersen, T. C. K., Aagaard, A., & Magnusson, M. (2022). Exploring business model innovation in SMEs in a digital context: Organizing search behaviours, experimentation and decision-making. *Creativity and Innovation Management*, 31(1), 19–34. <https://doi.org/10.1111/caim.12474>
- Aouadi, A., & Marsat, S. (2018). Do ESG Controversies Matter for Firm Value? Evidence from International Data. *Journal of Business Ethics*, 151(4), 1027–1047. <https://doi.org/10.1007/s10551-016-3213-8>
- Aragón-Correa, J. A. (1998). Strategic Proactivity and Firm Approach to the Natural Environment. *The Academy of Management Journal*, 41(5), 556–567. <https://doi.org/10.2307/256942>
- Arellano, M., & Bond, S. (1991). Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations. *The Review of Economic Studies*, 58(2), 277–297. <https://doi.org/10.2307/2297968>
- Aureli, S., Gigli, S., Medei, R., & Supino, E. (2020). The value relevance of environmental, social, and governance disclosure: Evidence from Dow Jones Sustainability World Index listed companies. *Corporate Social Responsibility and Environmental Management*, 27(1), 43–52. <https://doi.org/10.1002/csr.1772>
- Bannier, C. E., Bofinger, Y., & Rock, B. (2019). Doing safe by doing good: ESG investing and corporate social responsibility in the U.S. and Europe. *CFS Working Paper Series*, Article 621. <https://ideas.repec.org/p/zbw/cfswop/621.html>
- Bhattacharya, S., & Sharma, D. (2019). Do environment, social and governance performance impact credit ratings: A study from India. *International Journal of Ethics and Systems*, 35(3), 466–484. <https://doi.org/10.1108/IJOES-09-2018-0130>
- Bloom, N., Garicano, L., Sadun, R., & Van Reenen, J. (2014). The Distinct Effects of Information Technology and Communication Technology on Firm Organization. *Management Science*, 60(12), 2859–2885. <https://doi.org/10.1287/mnsc.2014.2013>

- Bohnsack, R., Bidmon, C. M., & Pinkse, J. (2022). Sustainability in the digital age: Intended and unintended consequences of digital technologies for sustainable development. *Business Strategy and the Environment*, 31(2), 599–602. <https://doi.org/10.1002/bse.2938>
- Boukattaya, S., Ftiti, Z., Ben Arfa, N., & Omri, A. (2022). Financial performance under board gender diversity: The mediating effect of corporate social practices. *Corporate Social Responsibility and Environmental Management*, 29(5), 1871–1883. <https://doi.org/10.1002/csr.2333>
- Broadstock, D. C., Chan, K., Cheng, L. T. W., & Wang, X. (2021). The role of ESG performance during times of financial crisis: Evidence from COVID-19 in China. *Finance Research Letters*, 38, 101716. <https://doi.org/10.1016/j.frl.2020.101716>
- Brogi, M., & Lagasio, V. (2019). Environmental, social, and governance and company profitability: Are financial intermediaries different? *Corporate Social Responsibility and Environmental Management*, 26(3), 576–587. <https://doi.org/10.1002/csr.1704>
- Busch, T., & Schnippering, M. (2022). Corporate social and financial performance: Revisiting the role of innovation. *Corporate Social Responsibility and Environmental Management*, 29(3), 635–645. <https://doi.org/10.1002/csr.2225>
- Cai, Y., Jo, H., & Pan, C. (2012). Doing Well While Doing Bad? CSR in Controversial Industry Sectors. *Journal of Business Ethics*, 108(4), 467–480. <https://doi.org/10.1007/s10551-011-1103-7>
- Chen, H.-M., Kuo, T.-C., & Chen, J.-L. (2022). Impacts on the ESG and financial performances of companies in the manufacturing industry based on the climate change related risks. *Journal of Cleaner Production*, 380, 134951. <https://doi.org/10.1016/j.jclepro.2022.134951>
- Chen, P., & Hao, Y. (2022). Digital transformation and corporate environmental performance: The moderating role of board characteristics. *Corporate Social Responsibility and Environmental Management*, 29(5), 1757–1767. <https://doi.org/10.1002/csr.2324>
- Cheng, B., Ioannou, I., & Serafeim, G. (2014). Corporate social responsibility and access to finance. *Strategic Management Journal*, 35(1), 1–23. <https://doi.org/10.1002/smj.2131>
- Clark, G. L., Feiner, A., & Viehs, M. (2015). *From the Stockholder to the Stakeholder: How Sustainability Can Drive Financial Outperformance* (SSRN Scholarly Paper No. 2508281). <https://doi.org/10.2139/ssrn.2508281>
- Cucari, N., Esposito De Falco, S., & Orlando, B. (2018). Diversity of Board of Directors and Environmental Social Governance: Evidence from Italian Listed Companies. *Corporate Social Responsibility and Environmental Management*, 25(3), 250–266. <https://doi.org/10.1002/csr.1452>
- Digital Economy Report 2021*. (2021).
- Drempetic, S., Klein, C., & Zwergel, B. (2020). The Influence of Firm Size on the ESG Score: Corporate Sustainability Ratings Under Review. *Journal of Business Ethics*, 167(2), 333–360. <https://doi.org/10.1007/s10551-019-04164-1>
- Eccles, R. G., Serafeim, G., Seth, D., & Chu Yee Ming, C. (2013). The Performance Frontier: Innovating for a Sustainable Strategy: Interaction. *Harvard Business Review*, 91(7), 17–18.

- Elamer, A. A., & Boulhaga, M. (2024). ESG controversies and corporate performance: The moderating effect of governance mechanisms and ESG practices. *Corporate Social Responsibility and Environmental Management*, 31(4), 3312–3327. <https://doi.org/10.1002/csr.2749>
- Eliwa, Y., Aboud, A., & Saleh, A. (2021). ESG practices and the cost of debt: Evidence from EU countries. *Critical Perspectives on Accounting*, 79, 102097. <https://doi.org/10.1016/j.cpa.2019.102097>
- Fang, M., Nie, H., & Shen, X. (2023a). Can enterprise digitization improve ESG performance? *Economic Modelling*, 118, 106101. <https://doi.org/10.1016/j.econmod.2022.106101>
- Fang, M., Nie, H., & Shen, X. (2023b). Can enterprise digitization improve ESG performance? *Economic Modelling*, 118, 106101. <https://doi.org/10.1016/j.econmod.2022.106101>
- Fang, M., Nie, H., & Shen, X. (2023c). Can enterprise digitization improve ESG performance? *Economic Modelling*, 118, 106101. <https://doi.org/10.1016/j.econmod.2022.106101>
- Feng, G.-F., Long, H., Wang, H.-J., & Chang, C.-P. (2022). Environmental, social and governance, corporate social responsibility, and stock returns: What are the short- and long-Run relationships? *Corporate Social Responsibility and Environmental Management*, 29(5), 1884–1895. <https://doi.org/10.1002/csr.2334>
- Feng, J., Goodell, J. W., & Shen, D. (2022). ESG rating and stock price crash risk: Evidence from China. *Finance Research Letters*, 46, 102476. <https://doi.org/10.1016/j.frl.2021.102476>
- Forcadell, F. J., Aracil, E., & Úbeda, F. (2020). The Impact of Corporate Sustainability and Digitalization on International Banks' Performance. *Global Policy*, 11(S1), 18–27. <https://doi.org/10.1111/1758-5899.12761>
- Freeman, J., Carroll, G. R., & Hannan, M. T. (1983). The Liability of Newness: Age Dependence in Organizational Death Rates. *American Sociological Review*, 48(5), 692–710. <https://doi.org/10.2307/2094928>
- Friede, G., Busch, T., & Bassen, A. (2015). ESG and financial performance: Aggregated evidence from more than 2000 empirical studies. *Journal of Sustainable Finance & Investment*, 5(4), 210–233. <https://doi.org/10.1080/20430795.2015.1118917>
- Garcia, A. S., Mendes-Da-Silva, W., & Orsato, R. J. (2017). Sensitive industries produce better ESG performance: Evidence from emerging markets. *Journal of Cleaner Production*, 150, 135–147. <https://doi.org/10.1016/j.jclepro.2017.02.180>
- George, G., Merrill, R. K., & Schillebeeckx, S. J. D. (2021). Digital Sustainability and Entrepreneurship: How Digital Innovations Are Helping Tackle Climate Change and Sustainable Development. *Entrepreneurship Theory and Practice*, 45(5), 999–1027. <https://doi.org/10.1177/1042258719899425>
- Goldfarb, A., & Tucker, C. (2019). Digital Economics. *Journal of Economic Literature*, 57(1), 3–43. <https://doi.org/10.1257/jel.20171452>

- Guo, Q., Geng, C., & Yao, N. (2023). How does green digitalization affect environmental innovation? The moderating role of institutional forces. *Business Strategy and the Environment*, 32(6), 3088–3105. <https://doi.org/10.1002/bse.3288>
- Haque, F. (2017). The effects of board characteristics and sustainable compensation policy on carbon performance of UK firms. *The British Accounting Review*, 49(3), 347–364. <https://doi.org/10.1016/j.bar.2017.01.001>
- Harasheh, M., & Provasi, R. (2023). A need for assurance: Do internal control systems integrate environmental, social, and governance factors? *Corporate Social Responsibility and Environmental Management*, 30(1), 384–401. <https://doi.org/10.1002/csr.2361>
- Hauke-Lopes, A., Ratajczak-Mrozek, M., & Wierzeczycki, M. (2022). Digitalisation and the Process of Creating and Appropriating Value by Small Companies – the Network Approach. In M. Ratajczak-Mrozek & P. Marszałek (Eds.), *Digitalization and Firm Performance: Examining the Strategic Impact* (pp. 45–72). Springer International Publishing. https://doi.org/10.1007/978-3-030-83360-2_3
- Hsiao, C. (2022). *Analysis of Panel Data*. Cambridge University Press.
- Hu, J., Zou, Q., & Yin, Q. (2023). Research on the effect of ESG performance on stock price synchronicity: Empirical evidence from China's capital markets. *Finance Research Letters*, 55, 103847. <https://doi.org/10.1016/j.frl.2023.103847>
- Karathanassis, G. A., & Spilioti, S. N. (2003). An empirical investigation of the traditional and the clean surplus valuation models. *Managerial Finance*, 29(9), 55–66. <https://doi.org/10.1108/03074350310768472>
- Kim, S., & Li, Z. (Frank). (2021). Understanding the Impact of ESG Practices in Corporate Finance. *Sustainability*, 13(7), Article 7. <https://doi.org/10.3390/su13073746>
- Koh, H.-K., Burnasheva, R., & Suh, Y. G. (2022). Perceived ESG (Environmental, Social, Governance) and Consumers' Responses: The Mediating Role of Brand Credibility, Brand Image, and Perceived Quality. *Sustainability*, 14(8), Article 8. <https://doi.org/10.3390/su14084515>
- Kölbel, J. F., Busch, T., & Jancso, L. M. (2017). How Media Coverage of Corporate Social Irresponsibility Increases Financial Risk. *Strategic Management Journal*, 38(11), 2266–2284. <https://doi.org/10.1002/smj.2647>
- Kotarba, M. (2017). Measuring Digitalization – Key Metrics. *Foundations of Management*, 9(1), 123–138. <https://doi.org/10.1515/fman-2017-0010>
- Kuo, T.-C., Chen, H.-M., & Meng, H.-M. (2021). Do corporate social responsibility practices improve financial performance? A case study of airline companies. *Journal of Cleaner Production*, 310, 127380. <https://doi.org/10.1016/j.jclepro.2021.127380>
- Li, H., Wu, Y., Cao, D., & Wang, Y. (2021). Organizational mindfulness towards digital transformation as a prerequisite of information processing capability to achieve market agility. *Journal of Business Research*, 122, 700–712. <https://doi.org/10.1016/j.jbusres.2019.10.036>

- Li, T.-T., Wang, K., Sueyoshi, T., & Wang, D. D. (2021). ESG: Research Progress and Future Prospects. *Sustainability*, 13(21), Article 21. <https://doi.org/10.3390/su132111663>
- Li, Y., Gong, M., Zhang, X.-Y., & Koh, L. (2018). The impact of environmental, social, and governance disclosure on firm value: The role of CEO power. *The British Accounting Review*, 50(1), 60–75. <https://doi.org/10.1016/j.bar.2017.09.007>
- Liang, Y., Lee, M. J., & Jung, J. S. (2022). Dynamic Capabilities and an ESG Strategy for Sustainable Management Performance. *Frontiers in Psychology*, 13. Scopus. <https://doi.org/10.3389/fpsyg.2022.887776>
- Lin, B., & Ma, R. (2022). How does digital finance influence green technology innovation in China? Evidence from the financing constraints perspective. *Journal of Environmental Management*, 320, 115833. <https://doi.org/10.1016/j.jenvman.2022.115833>
- Lin, C.-S., Chang, R.-Y., & Dang, V. T. (2015). An Integrated Model to Explain How Corporate Social Responsibility Affects Corporate Financial Performance. *Sustainability*, 7(7), Article 7. <https://doi.org/10.3390/su7078292>
- Lseg-annual-report-2021.pdf*. (n.d.). Retrieved 7 August 2024, from https://www.lseg.com/content/dam/lseg/en_us/documents/investor-relations/annual-reports/lseg-annual-report-2021.pdf
- Lu, Y., Xu, C., Zhu, B., & Sun, Y. (2024). Digitalization transformation and ESG performance: Evidence from China. *Business Strategy and the Environment*, 33(2), 352–368. <https://doi.org/10.1002/bse.3494>
- Ma, Y. M., Deng, Z., Teng, Y., Yang, Z., & Zheng, X. (Vivian). (2023). Firms' multi-sided platform construction efforts and ESG performance: An information processing theory perspective. *Industrial Marketing Management*, 115, 455–469. <https://doi.org/10.1016/j.indmarman.2023.10.018>
- Marcysiak, A., & Pleskacz, Ż. (2021). Determinants of digitization in SMEs. *Entrepreneurship and Sustainability Issues*, 9(1), 300–318. [https://doi.org/10.9770/jesi.2021.9.1\(18\)](https://doi.org/10.9770/jesi.2021.9.1(18))
- Marszałek, P., & Ratajczak-Mrozek, M. (2022). Introduction: Digitalization as a Driver of the Contemporary Economy. In M. Ratajczak-Mrozek & P. Marszałek (Eds.), *Digitalization and Firm Performance: Examining the Strategic Impact* (pp. 1–15). Springer International Publishing. https://doi.org/10.1007/978-3-030-83360-2_1
- McElheran, K. (2014). Delegation in Multi-Establishment Firms: Evidence from I.T. Purchasing. *Journal of Economics & Management Strategy*, 23(2), 225–258. <https://doi.org/10.1111/jems.12054>
- Meng, S., Su, H., & Yu, J. (2022). Digital Transformation and Corporate Social Performance: How Do Board Independence and Institutional Ownership Matter? *Frontiers in Psychology*, 13. <https://doi.org/10.3389/fpsyg.2022.915583>
- Mo, Z., Liu, Y., Lu, C., & Yu, J. (2023). Influences of industrial internet platform firms' ESG performance and digital leadership on user firms' innovation performance: The mediating role of inter-firm trust. *Journal of Digital Economy*, 2, 204–220. <https://doi.org/10.1016/j.jdec.2024.01.002>

- Montero Guerra, J. M., Danvila-del-Valle, I., & Méndez-Suárez, M. (2023). The impact of digital transformation on talent management. *Technological Forecasting and Social Change*, 188, 122291. <https://doi.org/10.1016/j.techfore.2022.122291>
- Nasiri, M., Ukko, J., Saunila, M., Rantala, T., & Rantanen, H. (2020). Digital-related capabilities and financial performance: The mediating effect of performance measurement systems. *Technology Analysis & Strategic Management*, 32(12), 1393–1406. <https://doi.org/10.1080/09537325.2020.1772966>
- Nollet, J., Filis, G., & Mitrokostas, E. (2016). Corporate social responsibility and financial performance: A non-linear and disaggregated approach. *Economic Modelling*, 52, 400–407. <https://doi.org/10.1016/j.econmod.2015.09.019>
- Petersen, M. A. (2009). Estimating Standard Errors in Finance Panel Data Sets: Comparing Approaches. *The Review of Financial Studies*, 22(1), 435–480. <https://doi.org/10.1093/rfs/hhn053>
- Poncibò, C. (2022). The Digitalization of Contracts in International Trade and Finance: Comparative Law Perspectives on Smart Contracts. In M. Ratajczak-Mrozek & P. Marszałek (Eds.), *Digitalization and Firm Performance: Examining the Strategic Impact* (pp. 131–155). Springer International Publishing. https://doi.org/10.1007/978-3-030-83360-2_6
- Qin, X., Wu, H., & Li, R. (2022). Digital finance and household carbon emissions in China. *China Economic Review*, 76, 101872. <https://doi.org/10.1016/j.chieco.2022.101872>
- Ratajczak-Mrozek, M., & Marszałek, P. (Eds.). (2022). *Digitalization and Firm Performance: Examining the Strategic Impact*. Springer International Publishing. <https://doi.org/10.1007/978-3-030-83360-2>
- Ricci, F., Scafarto, V., Ferri, S., & Tron, A. (2020). Value relevance of digitalization: The moderating role of corporate sustainability. An empirical study of Italian listed companies. *Journal of Cleaner Production*, 276, 123282. <https://doi.org/10.1016/j.jclepro.2020.123282>
- Roodman, D. (2009). How to do Xtabond2: An Introduction to Difference and System GMM in Stata. *The Stata Journal*, 9(1), 86–136. <https://doi.org/10.1177/1536867X0900900106>
- Schiavone, F., Leone, D., Caporuscio, A., & Lan, S. (2022). Digital servitization and new sustainable configurations of manufacturing systems. *Technological Forecasting and Social Change*, 176, 121441. <https://doi.org/10.1016/j.techfore.2021.121441>
- Schultz, F., Castelló, I., & Morsing, M. (2013). The Construction of Corporate Social Responsibility in Network Societies: A Communication View. *Journal of Business Ethics*, 115(4), 681–692. <https://doi.org/10.1007/s10551-013-1826-8>
- Sebastian, I. M., Ross, J. W., Beath, C., Mockler, M., Moloney, K. G., & Fonstad, N. O. (2020). How Big Old Companies Navigate Digital Transformation. In R. D. Galliers, D. E. Leidner, & B. Simeonova (Eds.), *Strategic Information Management* (5th ed., pp. 133–150). Routledge. <https://doi.org/10.4324/9780429286797-6>
- Serafeim, G. (2015). Integrated Reporting and Investor Clientele. *Journal of Applied Corporate Finance*, 27(2), 34–51. <https://doi.org/10.1111/jacf.12116>

- Sherwood, M. W., & Pollard, J. L. (2018). The risk-adjusted return potential of integrating ESG strategies into emerging market equities. *Journal of Sustainable Finance & Investment*, 8(1), 26–44. <https://doi.org/10.1080/20430795.2017.1331118>
- Sima, V., Gheorghe, I. G., Subić, J., & Nancu, D. (2020). Influences of the Industry 4.0 Revolution on the Human Capital Development and Consumer Behavior: A Systematic Review. *Sustainability*, 12(10), Article 10. <https://doi.org/10.3390/su12104035>
- Tan, Y., & Zhu, Z. (2022). The effect of ESG rating events on corporate green innovation in China: The mediating role of financial constraints and managers' environmental awareness. *Technology in Society*, 68, 101906. <https://doi.org/10.1016/j.techsoc.2022.101906>
- Tremblay, D.-G., Yagoubi, A., & Psyché, V. (2022). Digital Transformation: An Analysis of the Role of Technology Service Providers in Montreal's Emerging AI Business Ecosystem. In M. Ratajczak-Mrozek & P. Marszałek (Eds.), *Digitalization and Firm Performance: Examining the Strategic Impact* (pp. 17–44). Springer International Publishing. https://doi.org/10.1007/978-3-030-83360-2_2
- Truant, E., Broccardo, L., & Dana, L.-P. (2021). Digitalisation boosts company performance: An overview of Italian listed companies. *Technological Forecasting and Social Change*, 173, 121173. <https://doi.org/10.1016/j.techfore.2021.121173>
- Wan, J., Pu, Z., & Tavera, C. (2023). The impact of digital finance on pollutants emission: Evidence from chinese cities. *Environmental Science and Pollution Research*, 30(15), 42923–42942. <https://doi.org/10.1007/s11356-021-18465-4>
- Wang, F., & Sun, Z. (2022). Does the Environmental Regulation Intensity and ESG Performance Have a Substitution Effect on the Impact of Enterprise Green Innovation: Evidence from China. *International Journal of Environmental Research and Public Health*, 19(14), Article 14. <https://doi.org/10.3390/ijerph19148558>
- Wang, Q.-J., Wang, H.-J., Feng, G.-F., & Chang, C.-P. (2023). Impact of digital transformation on performance of environment, social, and governance: Empirical evidence from China. *Business Ethics, the Environment & Responsibility*, 32(4), 1373–1388. <https://doi.org/10.1111/beer.12573>
- Wang, S., & Esperança, J. P. (2023). Can digital transformation improve market and ESG performance? Evidence from Chinese SMEs. *Journal of Cleaner Production*, 419, 137980. <https://doi.org/10.1016/j.jclepro.2023.137980>
- Wang, W., Sun, Z., Wang, W., Hua, Q., & Wu, F. (2023). The impact of environmental uncertainty on ESG performance: Emotional vs. rational. *Journal of Cleaner Production*, 397, 136528. <https://doi.org/10.1016/j.jclepro.2023.136528>
- Yang, Y., & Han, J. (2023a). Digital transformation, financing constraints, and corporate environmental, social, and governance performance. *Corporate Social Responsibility and Environmental Management*, 30(6), 3189–3202. <https://doi.org/10.1002/csr.2546>

- Yang, Y., & Han, J. (2023b). Digital transformation, financing constraints, and corporate environmental, social, and governance performance. *Corporate Social Responsibility and Environmental Management*, 30(6), 3189–3202. <https://doi.org/10.1002/csr.2546>
- Zhao, C., Guo, Y., Yuan, J., Wu, M., Li, D., Zhou, Y., & Kang, J. (2018). ESG and Corporate Financial Performance: Empirical Evidence from China's Listed Power Generation Companies. *Sustainability*, 10(8), Article 8. <https://doi.org/10.3390/su10082607>
- Zheng, M., Feng, G.-F., Jiang, R.-A., & Chang, C.-P. (2023). Does environmental, social, and governance performance move together with corporate green innovation in China? *Business Strategy and the Environment*, 32(4), 1670–1679. <https://doi.org/10.1002/bse.3211>

11. PAPER 3:

Understanding Dynamics of Digitalization and ESG Performance and the Moderating Effects of Key Governance Factors.

Muhammad Haseeb

Department of Advanced Technologies and Medicine & Dentistry (*DITM&O*). Center for Advanced Studies and Technology (CAST). G. D'Annunzio University of Chieti–Pescara (Italy).

Maria Josefina Figueroa

Department of Management Society and Communications (MSC). CBS Sustainability – Center for Business and Development Studies. Copenhagen Business School, Denmark.

Stefania Migliori

Department of Management and Business Administration. G. D'Annunzio University of Chieti–Pescara, Italy.

Augusta Consorti

Department of Management and Business Administration. G. D'Annunzio University of Chieti–Pescara, Italy.

Submitted to:

Journal of Business Ethics (Under-Review)

⁴³**Abstract**

In the present digital age, organizations must be aware of the challenges of digital transformation. Despite its growing importance, there is a lack of research exploring the effects of digitalization on a firm's ESG (Environmental, Social, and Governance) performance. In this study, we examine the impact of digitalization on ESG performance while assessing the moderation roles of board gender diversity, ESG controversies, and research and development (R&D) intensity.

We utilized panel data from 145 publicly listed firms in Northern Europe between 2019 and 2023, sourced from the Refinitiv Eikon™ database. To address potential endogeneity bias, an Ordinary Least Square (OLS) regression model was applied. Findings reveal that digitalization significantly improves ESG performance. Board Gender Diversity is identified as having a strong positive moderating impact, whereas the ESG Controversy score adversely influences the relationship between digitalization and ESG performance. R&D intensity, while positively moderating this relationship, shows a comparatively weaker impact.

To validate the robustness of these findings, additional analyses were performed using dynamic panel methods, including the two-step Generalized Method of Moments (GMM) and lagged OLS approach. These robustness checks confirm that core findings are consistent and not compromised by endogeneity concerns. This research provides valuable insights for stakeholders and policymakers and highlights how board gender diversity, ESG controversies, and R&D intensity shape the interplay between digitalization and ESG performance. The results offer a foundation for making informed decisions and fostering sustainable and responsible business practices.

Keywords: ESG Performance, Sustainability, Digitalization, Board Gender Diversity, ESG Controversies, R&D Intensity.

⁴³ **Abbreviations:** ESG–Environmental Social and Governance; OLS–Ordinary Least Square; GMM–Generalized Method of Movements; R&D–Research and Development; BGD–Board Gender Diversity

11.1. Introduction

In today's academic and practical spheres, digitalization is an increasingly significant topic of discussion. Digital transformation enables organizational change (Verhoef et al., 2021), increases collaboration between departments in firms (Q. Huang et al., 2023), and improves production efficiency (C. Ren et al., 2023), thus benefiting the firm's value (Lin et al., 2022). Integrating digital technologies into traditional business operations offers companies new opportunities for growth, creating positive prospects for future development and improving their value in the eyes of external investors (Amit & Han, 2017; Q. Huang et al., 2023). The integration of digital transformation and technologies into core business operations—for instance, information and communication technologies, cloud computing, big data analytics, and artificial intelligence encourages companies to enhance their research and development efforts (C. Ren et al., 2023), increase investments (Lin et al., 2022), address stakeholders' digital demands (Chouaibi & Chouaibi, 2021), and improve organizational efficiency (Andronie et al., 2023). The literature argues that embedding digitalization in an organization requires alignment with its belief system. For example, top management is crucial in embracing changes to adapt to evolving or emerging market dynamics. Similarly, with a direct approach, a firm can adopt technologies for higher digitalization. However, bringing digital tools into organizations involves more than just enhancing operations; it calls for significant updates to their core infrastructure (Amit & Han, 2017; Xu et al., 2022; Tuyen et al., 2023). These updates shift how businesses function and create value for customers often, opening doors to innovative products and new business models. Organizations that embrace transformational changes can achieve long-term competitive advantage, effectively develop and deliver value to customers, and ultimately improve profitability (Fang et al., 2023; Rozeboom, 2021).

Today, investors prioritize a company's commitment to sustainable practices over its immediate operational and financial achievements. Companies that overlook ESG (Environmental, Social, and Governance) factors and fail to embed these criteria into their business operations have progressively faced negative repercussions from investors (Esposito De Falco et al., 2021; Shakil, 2021). According to (T.-T. Li et al., 2021), ESG refers to “the consideration of environmental, social, and governance factors alongside financial factors in the investment decision-making process.” This framework integrates key aspects of corporate social responsibility (CSR), particularly those related to environmental and social considerations, with indicators of corporate governance (Pulino et al., 2022). ESG is broadly recognized as a core strategy for corporate sustainability, especially within financial institutions. Companies that allocate resources strategically to enhance ESG commitments not only strengthen their financial position but also foster greater customer loyalty (Johnson, 2003; Elmghaamez et al., 2024).

A company's ESG performance has become a critical metric in evaluating how well it meets stakeholders' expectations (investors, employees, regulatory authorities, and government agencies). Firms that effectively address ESG issues are more likely to build stronger, more trust-based relationships with their stakeholders. Investors, in particular, are increasingly cautious about companies that neglect ESG concerns, often viewing them as higher-risk investments, especially in terms of long-term sustainability. Therefore, integrating ESG initiatives into corporate strategies to meet stakeholders' needs and protect corporate reputation has become a widely accepted approach (Hillman & Keim, 2001; Esposito De Falco et al., 2021). However, the cost and benefits linked with ESG initiatives remain a subject of ongoing debate. Unlike traditional financial metrics, ESG assessments focus on environmental, social, and governance factors, which are key in shaping market perceptions and influencing investment decisions (Doh et al., 2010).

The relationship between digitalization and ESG (environmental, social and governance) performance in technological firms remains a subject of ongoing debate in the literature (Gu, 2024; X. Ren et al., 2023; Fang et al., 2023). While some scholars argue that digital technology enhances corporate performance (Fang et al., 2023), enabling firms to reduce costs (Eliwa et al., 2021), streamline internal operations, foster specialization (Hollo et al., 2012), and driving innovation in new business models (Bican & Brem, 2020), others present a contrasting view (Shang et al., 2023; Verhoef et al., 2021), suggesting that pursuing digitalization alongside ESG objectives may lead to higher operational costs, potentially hindering overall performance. Furthermore, research highlights that ESG engagement and outcomes are shaped by a range of factors, including national economic conditions in cultural and institutional contexts (Cai et al., 2016), legal frameworks (Ferrell et al., 2016), ownership structures (Meng et al., 2022), and the characteristics and compensation of CEOs (E-Vahdati & Binesh, 2022; Ghardallou, 2022). To address these varying viewpoints, this study seeks to contribute to the existing literature with a fresh perspective on ESG that examines the nuanced relationship between digitalization and ESG performance within technological firms by exploring the causal link between digital transformation and ESG outcomes. The novelty of this approach is in examining the moderating effects of key governance dimensions such as board gender diversity (BGD), ESG controversies, and R&D intensity on the relationship between digitalization and ESG performance. Although these three dimensions are very different, they all relate and highlight aspects measuring the governance dimension within ESG.

The extant literature endorses the knowledge that firms with poor social and environmental practices or those involved in controversies often face considerable backlash from investors (Kyaw et al., 2017; Aouadi & Marsat, 2018a; Shakil, 2021). ESG controversies typically involve negative news regarding a firm's activities, such as allegations of unethical practices or product-related scandals (Cai et al., 2012).

While prior research has extensively examined the financial benefits of strong social performance, it has largely overlooked the economic risk of irresponsible behaviors. However, companies can be involved in controversial industries—often called “sin stock,” including sectors like alcohol, tobacco, gambling, and firearms—that frequently raise ethical concerns (J. Li et al., 2019; Shakil, 2021; Brinette et al., 2024). Such controversies highlight dubious or unlawful practices, drawing intense media scrutiny and public disapproval and jeopardizing the trust of stakeholders (Nirino et al., 2021). These incidents can seriously harm a firm’s reputation, reduce stakeholder confidence, and consequently threaten its overall value (Brinette et al., 2024; Shakil et al., 2024).

Research indicates that gender diversity is essential for enhancing a firm’s ESG performance (Sila et al., 2016; Kyaw et al., 2017; Muhammad & Migliori, 2023). Female board members are often considered more attentive to social and environmental responsibilities in corporate sustainability efforts than their male counterparts (Kyaw et al., 2017; Tariq et al., 2024). Studies suggest that companies with highly qualified women on their boards tend to introduce more environmentally focused innovations. Additionally, female directors can bring unique perspectives to strategic decision-making, potentially reducing risk and improving financial outcomes (Muhammad et al., 2022b; Muhammad & Migliori, 2023). Data from S&P 500 companies shows that women make up 44.7% of the workforce, with 36.9% in first-mid-level management roles and 5.8% serving as CEOs (Hegde & Mishra, 2019). Gender diversity in boardrooms plays a significant role in shaping a firm's approach to environmental and social initiatives (Kyaw et al., 2017; Muhammad & Migliori, 2023; Muhammad, Paolone, et al., 2024).

The existing literature suggests that the presence of female board members can positively influence a company’s financial performance (Kyaw et al., 2017; Muhammad, Paolone, et al., 2024; Shakil et al., 2024), although this diversity does not always extend to improvements in environmental or social outcomes (Shakil et al., 2024; Tariq et al., 2024). Some scholars attribute the positive impact of BGD on financial outcomes to the unique skills, perspectives, and knowledge that female directors bring, which are increasingly recognized as valuable assets for organizational competitiveness (Burgess & Tharenou, 2002; Horbach & Jacob, 2018). Board gender diversity can contribute to more comprehensive decision-making processes (Kyaw et al., 2017; Muhammad, Paolone, et al., 2024), enriching the board’s ability to assess risks and manage uncertainty effectively (Muhammad et al., 2022a; Sila et al., 2016). However, existing research primarily examines the impact of BGD on financial outcomes and firm-level risk, particularly in larger corporations, which tend to benefit from economies of scale, improved access to financing, and exclude profit retention (Benlemlih & Girerd-Potin, 2017; Shakil et al., 2020; Tariq et al., 2024).

Firms with advanced technological capabilities are often better positioned to leverage R&D opportunities, enabling them to diversify their activities, capitalize on emerging technological trends, and

foster innovation (Brown et al., 2009; Ramadhan et al., 2023; Ali, Rangone, et al., 2024). Finally, over the past decade, studies have highlighted the critical role of R&D investments in accelerating innovation and technological progress, both vital indicators of a firm's long-term growth potential and market competitiveness (Brown et al., 2012; Muhammad, Migliori, et al., 2024). Many researchers contend that sustained R&D intensity (investments) is essential for firms to remain competitive in fast-evolving markets. However, the impact of these investments depends mainly on a firm's strategic alignment and effective implementation (Ali, Rangone, et al., 2024). For R&D to translate into market success and competitive advantage, sustainable firms must not only commit to these investments but also integrate them carefully into their business strategies, ensuring that R&D efforts are well and effectively executed (Ali, Muhammad, et al., 2024).

Based on the arguments above in the literature, while extensive research existed on the impact of digitalization on various business outcomes, the specific association between digitalization and ESG performance remained underexplored. Additionally, the moderating effects of ESG controversies, Board gender diversity (BGD), and R&D intensity on this association have not been thoroughly investigated. This research gap is particularly relevant given the increasing importance of ESG metrics in corporate evaluation and investment decisions. To test this relationship, we collected longitudinal panel data and annual reports of 145 publicly listed Northern European firms (excluding the financial sector) from the period of 05 years from 2019 to 2023, retrieved from the Refinitiv Eikon™ database. This study utilizes the ordinary least square (OLS) panel regression model to address the issue of endogeneity. To ensure robustness and account for heterogeneity, we implemented a two-step generalized method of moments (GMM), using one-year lags ($t-1$) for both the instrumental and dependent variables, alongside a pooled regression model with lagged instrumental variables based on longitudinal panel data.

This study makes several significant contributions to the literature. First, it elucidates the impact of digitalization on a firm's ESG performance, highlighting how digital transformation fosters long-term growth opportunities for companies. Second, it investigates the moderating effects of ESG controversies, BGD, and R&D intensity on the association between digitalization and ESG outcomes. It offers investors valuable insights into these factors before making investment decisions. These findings assist portfolio managers in mitigating risk by favoring investments in firms with stronger social and environmental governance practices. Finally, this study provides actionable insights for regulators and policymakers—including institutions, environmental agencies, and securities commissions—by suggesting revisions to ESG criteria, enhanced ranking systems based on ESG performance, and penalty frameworks tied to controversy scores. It further advocates regulatory measures to promote women's board participation and increased funding for research and development.

The structure of this study is organized as follows: **Section 2** outlines literature and the development of the hypothesis. **Section 3** covers the research design, including data collection process, measurement techniques, and model specifications. **Section 4** outlines the results and accompanying discussions. **Section 5** examines the robustness checks conducted to validate study's findings. Finally, **Section 6** presents a discussion of the conclusions drawn from the study and relevant policy recommendations.

11.2. Literature Review and Hypothesis Development

11.2.1. The Role of Digitalization in Shaping ESG Performance

Digitalization refers to systematically integrating digital technologies across various business functions to enhance operational efficiency, communication, and service delivery. Through the adoption of information technology and digital tools, firms can better address stakeholders' expectations while improving organizational processes (Broccardo et al., 2023; S. Wang & Esperança, 2023a). Digital transformation not only enhances a company's attractiveness to ESG-conscious investors by improving transparency and reducing information asymmetry and transaction cost, but it also strengthens corporate governance and social responsibility initiatives (Vial, 2019). Furthermore, digitalization fosters innovation, promotes the development of ESG-related product lines, and enhances the overall implementation of ESG strategies, thereby contributing to the improvement of firm-level ESG performance (Khattak et al., 2021; Danneels & Viaene, 2022; Cheng et al., 2023).

Freeman's Stakeholder Theory (2010), contends that placing too much emphasis on maximizing shareholders' profits at the expense of other stakeholders is inconsistent with the principle of "*Pareto optimality*." Organizations that manage to balance the interests of both shareholders and broader stakeholders are better positioned to make a positive impact on the wider social and economic landscape. Such companies are also more likely to earn the trust of key stakeholders, which can, in turn, attract investment and financial backing (S. Wang & Esperança, 2023b). A 2021 survey conducted by the Boston Consulting Group found that many companies consider environmental, social, and governance (ESG) goals to be critical to their digital initiatives. In fact, 62% of the companies surveyed identified ESG performance as a primary priority in their digital strategies, aiming to connect stakeholders through a customer-centered digital network that enhances overall stakeholder welfare (Arvidsson & Dumay, 2022; Wu & Lu, 2023).

While digitalization offers numerous benefits, it also poses significant challenges to the Environmental, Social and Governance (ESG) performance of companies. According to (Trittin-Ulbrich et al., 2021), the process of digital transformation often demands substantial resources and investment and incurs significant opportunity costs. This transformation comes with inherent risks of failure, which can

adversely impact both economic and social development. Additionally, challenges in adapting to digitalization can disrupt the existing organizational order, potentially resulting in unintended consequences and negative consequences for firm development (Peng & Tao, 2022). Furthermore, (Guo et al., 2023) highlight that poorly managed or misaligned digital transformations may lead to a scenario where marginal revenues fall below marginal cost, thereby impairing ESG performance and undermining the long-term sustainability of enterprises. Similarly, research (Yang & Han, 2024) reveals that enterprises' digitalization exhibits an inverted U-shaped relationship with ESG performance. This indicates that while moderate levels of digital transformation can improve ESG performance, excessive digitalization can lead to inefficiencies, increase ineffective investments, and ultimately harm ESG outcomes.

In addition to exploring these effects (Z. Wang et al., 2023), expanding the discussion by identifying a non-linear relationship between digital transformation and ESG performance. Their findings underscore that while digital transformation has the potential to enhance ESG outcomes, it also introduces risks that could hinder sustainable development. Overall, the challenges associated with the cost, opportunity cost, and adaptability issues inherent in digital transformation create uncertainties in advancing enterprise sustainability and improving ESG performance. Addressing these complexities requires a balanced and strategic approach to digital transformation to maximize its benefits while minimizing its adverse impacts on ESG outcomes.

From an Environmental Perspective: digital technologies offer powerful tools for addressing a range of complex challenges, including air pollution, carbon emissions, wastewater management, and climate change (Bahadori et al., 2021; J. Huang et al., 2021). The integration of digital transformation strategies can significantly enhance energy efficiency and contribute to sustainable development. For instance, firms can implement intelligent and sustainable manufacturing practices by leveraging digital platforms to optimize and automate strategic decision-making processes, particularly in the areas of energy efficiency and renewable energy consumption (Cardinali & De Giovanni, 2022; Shang et al., 2023). Companies with high carbon footprints can take advantage of technologies like 5G and big data analytics to measure, track, and reduce their emission, providing critical support for efforts aimed at lowering their environmental impacts (Andronie et al., 2023; Cappa et al., 2021; Lăzăroiu et al., 2023).

In the meantime, the existing literature (Mikalef et al., 2021; Lăzăroiu et al., 2023) on digital transformation also highlights that pursuing such initiatives (mentioned above) without proper alignment with a company's operational strategies may adversely affect environmental sustainability. This lack of coherence can lead to inefficient resource utilization and increased environmental impacts, thereby compromising the organizational commitments to sustainable practices. Overemphasis on (digital) transformation risks excessive energy consumption, e-waste generation, and a decline in ecological

performance. Furthermore, poorly aligned digital initiatives can disrupt organizational efficiency, leading to internal conflicts and reducing quality control, thereby undermining the value of such investments.

Simultaneously, the environmental impacts of establishing and maintaining digital infrastructure continue to be a significant and pressing issue that raises serious concerns among policymakers and environmentalists alike. Such as data centers in the United States (U.S.) consume approximately 1.8% of the nation's electricity, require substantial water for both cooling and electricity generation, and contribute to 0.5% of total greenhouse gas emissions. Most of these impacts stem from operations in regions experiencing moderate to severe water stress (Siddik et al., 2021). While digitalization offers opportunities for innovation and regulatory compliance, its environmental ramifications necessitate careful management. A balanced approach is essential to ensure that the benefits of digital transformation do not compromise ecological sustainability

Regarding a Firm's Social Performance: digitalization is pivotal in strengthening engagement and communication with stakeholders (Johnson, 2003). By integrating digital technologies, businesses can effectively communicate their brand messages and relate with customers through a range of online platforms. This facilitates real-time exchanges of information, reducing information asymmetry and lowering transaction costs (Cappa et al., 2021). Through the process of digital transformation, firms are better equipped to integrate the diverse needs of customers, employees, and suppliers, thereby fostering more robust and mutually beneficial relationships with stakeholders. The interconnectedness not only improves collaborative efforts but also reinforces a firm's commitment to corporate social responsibility (Orazalin, 2020; Fatima & Elbanna, 2023). From a strategic perspective, digitalization enhances a firm's capacity to fulfill its social obligations, leading to improvements in service delivery, product quality, corporate image, and overall reputation (Andronie et al., 2023; Ratajczak-Mrozek & Marszałek, 2022).

Further the literature also highlights that the initial stages of digitization are generally less complex and often contribute to improving internal controls. They incur a lower cost of implementation and have minimal challenges associated with organizational management alignment. However, as the degree of digital (transformation) progresses, alignment challenges become more pronounced, and the related cost rises gradually. These challenges can erode internal efficiencies, disrupt social initiatives, and ultimately diminish the firm's capacity to meet its social performance objectives, reflecting broader negative effects on its ESG reporting (Arvidsson & Dumay, 2022; Rauf et al., 2024). It also observes that if companies fail to adapt their organizational management to advancements in digital transformation, misalignment may arise. Organizational inertia and conflicts with existing structures can prevent digitalization from enhancing internal control instead of undermining it. This misalignment negatively impacts the social dimension of

ESG performance, as weakened internal control can hinder a firm's ability to manage stakeholder relationships effectively (Yang & Han, 2024).

From the Governance Context: the integration of digital technologies and platforms can mitigate agency problems and reduce information asymmetry between stakeholders, which arise due to the separation of ownership and control. This leads to more rational decision-making by management, positively influencing the overall effectiveness of corporate governance (Orazalin, 2020; Zhong & Ren, 2023). The widespread adoption of social media has significantly increased corporate visibility and investor oversight, thereby reducing the risks of governance failures, such as equity dilution, ownership restrictions, and non-compliance with disclosure regulations (Gouvea et al., 2022). Digital platforms contribute to greater organizational transparency by facilitating seamless information sharing across departments (Anastasiadou et al., 2021). Reducing information asymmetry through tools like transparency portals strengthens governance practices by decreasing the likelihood of corrupt activities, like commercial bribery, in the sales and procurement process (Gouvea et al., 2022; Peng & Tao, 2022). These advancements safeguard the interests of shareholders and creditors and contribute to improving governance scores within the organization.

However, the literature observes that digital transformation introduced complex technologies that often outpace traditional governance frameworks, creating oversight gaps and weakening accountability, which may increase the risk of errors and ethical breaches (Fernando & Lawrence, 2014). Additionally, digital transformation increases a firm's vulnerability to cybersecurity risks, as governance mechanisms are often unprepared to address the legal and operational consequences, eroding stakeholder trust (Garcia et al., 2017). Over-reliance on digital tools for governance tasks, such as ad monitoring, may reduce human oversight and critical judgment, as automated systems often lack the adaptability required for effective decision-making (Lăzăroiu et al., 2023). Additionally, (Chouaibi & Chouaibi, 2021; Rauf et al., 2024) posits that the practice of greenwashing places companies under heightened regulatory scrutiny and increases their vulnerability to legal challenges. This exposure can significantly undermine their governance performance. Organizations that lack robust governance frameworks often fail to foresee or effectively manage these multifaceted risks. Consequently, they may find themselves facing substantial fines, drawn-out litigation, and severe damage to their reputation, all of which can have lasting detrimental effects on their credibility and operational stability.

A growing number of empirical evidence highlights (X. Ren et al., 2023; Tuyen et al., 2023; Wen et al., 2022) a significant role of a firm's digitalization in boosting ESG performance. According to Studies (D. Wang & Xia, 2024; Ribeiro-Navarrete et al., 2021; Chen, 2020), 60% of companies consider ESG factors a key driver in their digital transformation efforts. Firms that excel in ESG performance are better

positioned to break down informational barriers with stakeholders (Benlemlih et al., 2018; Esposito De Falco et al., 2021). This facilitates the acquisition of resources necessary for their continued digitalization. The existing literature emphasizes the diverse impacts of digital transformation on ESG reporting, which can range from positive to negative, mixed or even take on an inverted U-shaped pattern. In the light of these findings, we propose that a higher degree of digital transformation can significantly enhance a firm's ESG performance by fostering stronger alignment with sustainability goals. Conversely, limited digital transformation may hinder ESG performance; with this understanding, we put forth the following hypothesis:

H1: Digitalization influences a firm's ESG performance.

11.2.2. Board Gender Diversity as Moderator between Digitalization and ESG Performance.

In corporate governance research, BGD is increasingly recognized as a crucial factor that can influence agency conflicts and overall governance effectiveness (Gulamhussen & Santa, 2015; Hinings et al., 2018). From the perspective of resource dependency theory, gender diversity on boards brings valuable resources in the form of diverse skills, attitudes, and expertise, all of which contribute to more efficient decision-making and resource utilization (AlNuaimi et al., 2022). According to the literature, leadership styles, and strategic priorities often differ between male and female executives. For instance, female board members tend to emphasize environmental and social concerns more, while male members may be more focused on maximizing profits (Hinings et al., 2018; AlNuaimi et al., 2022). Women are generally more attentive to the interests of a broad range of stakeholders and are more likely to avoid strategies that could harm communities or the environment (Horbach & Jacob, 2018). By promoting socially responsible and environmentally sustainable solutions, female directors can guide firms toward more informed and balanced decision-making on ESG issues. Moreover, a higher representation of women on boards has been linked to a reduction in environmental-related litigation, further strengthening the firm's ESG performance (Gulamhussen & Santa, 2015; Reguera-Alvarado et al., 2017).

Gender diversity also enhances governance practices and is an important strategic asset in fostering digitalization and the adoption of new technologies. Female directors, who are often more attuned to the concerns of various stakeholders, are typically more receptive to the potential benefits of digital tools and technologies (Kyaw et al., 2017; Tariq et al., 2024). This awareness positions them to guide companies through effective digital transformation processes. They play a critical role in building collaborative networks that enhance the digital competencies necessary for organizations to succeed in the increasingly digital business environment (Ribeiro-Navarrete et al., 2021). A gender-balanced board can drive

innovation by balancing stakeholders' needs with technological advancements, helping companies develop and provide updated services and solutions for customers. This combination has the potential to create synergies that not only improve organizational performance but also contribute to better sustainability outcomes. Companies with more gender-diverse boards tend to benefit more from digitalization, as the inclusion of diverse perspectives leads to more inclusive and effective ESG strategies (Gulamhussen & Santa, 2015; Tariq et al., 2024). By leveraging digital tools to engage more effectively with customers and stakeholders, firms can enhance their conversion rates, improve financial performance, and simultaneously strengthen their ESG performance (Muhammad, Paolone, et al., 2024; Shakil et al., 2020).

Based on the following discussion, we propose the following hypothesis:

H2: *Board Gender Diversity influences the relationship between digitalization and a firm's ESG performance.*

11.2.3. ESG Controversies as a Moderator between Digitalization and ESG Performance

ESG controversies arise from negative media coverage and public scrutiny of a firm's environmental, social, and governance practices. These controversies, such as scandals or unethical behavior related to a firm's products or operations, can severely damage its reputation (Aouadi & Marsat, 2018a). When firms face negative corporate social responsibility (CSR) news typically loses market share and public trust. Furthermore, illegal or irresponsible actions erode stakeholder confidence, resulting in both reputational damage and adverse financial outcomes (Cai et al., 2012; J. Li et al., 2019). In order to mitigate these effects, firms that mainly belong to those in highly scrutinized or sensitive industries (sectors) often increase their disclosure of sustainability-related information, seeking to restore their public image. While this may enhance ESG performance, to some extent, the reputational damage caused by negative news can persist, leading to diminished market value and increased perceived risk, challenging the credibility of the firm's ESG initiatives (Dong & Xu, 2016; Curran, 2017; Dilling & Harris, 2018). According to the literature, companies operating in controversial sectors, such as nuclear energy, mining, oil and gas, frequently employ CSR initiatives as a strategic means to meet social expectations and maintain legitimacy. (Curran, 2017; Hoffmann & Kristensen, 2017). In these industries, where social expectations are heightened and regulatory demands are stringent, CSR efforts are used to secure a "social license to operate." However, ESG controversies undermine these efforts by casting doubt on the firm's ability to align with societal norms and expectations, eroding public trust. The negative perceptions surrounding a firm's controversial actions exacerbate the volatility of its reputation and can lead to fluctuating market performance (Cai et al., 2012; Curran, 2017; Garcia et al., 2017).

Firms facing high levels of ESG controversy often experience a reduced positive impact of digitalization on their ESG performance (Kuo & Chen, 2013). Despite efforts to use digital technologies to increase openness and stakeholder involvement, ongoing debates overshadow these developments. Negative media coverage and public skepticism regarding a company's ESG standards can dilute the benefits of digitalization as stakeholders remain focused on past scandals rather than present advancements (Aouadi & Marsat, 2018a; J. Li et al., 2019; Shakil, 2021). As a result, firms struggling with ESG controversies may find it challenging to fully realize the potential gains from digital transformation in enhancing their ESG performance (Brinette et al., 2024; J. Huang et al., 2021). In light of this context, we propose the following hypothesis:

H3: *ESG Controversies negatively moderate the relationship between digitalization and a firm ESG performance.*

11.2.4. R&D Intensity as a Moderator between Digitalization and ESG Performance.

In the literature (Ali, Rangone, et al., 2024; Muhammad et al., 2022b; Ramadhan et al., 2023), significant variations in R&D spending across industries imply that a firm's business characteristics, such as its stage in the product life cycle, influence its social performance. In the context of digitalization, ESG initiatives increasingly serve as differentiation strategies as firms progress through their industry's lifecycle (Rauf et al., 2024). Digital transformation in the early phase's primary focus is on operational efficiency and market expansion, offering limited product differentiation. However, as industries mature, digitalization enables more significant innovation and strategic ESG integration (E-Vahdati & Binesh, 2022). Firms in different lifecycle stages adopt varying approaches to ESG and its incorporation into R&D, mainly through digitalization. Corporate social responsibility is closely linked to technological innovation, especially in manufacturing, where digital tools enhance transparency and efficiency in addressing social and environmental challenges (Ramadhan et al., 2023). While some firms perceive pollution control as a financial burden, others view it as a technological deficiency that can be remedied through digital solutions. This reflects how digitalization can either support or impede ESG objectives (Arvidsson & Dumay, 2022; Lin et al., 2022).

Empirical pieces of evidence (Bahadori et al., 2021; Elmghaamez et al., 2024) suggest that environmentally responsible companies are more productive and profitable, particularly when utilizing digital technologies or transformation to meet their ESG goals. R&D intensity, which contrasts with other industries, is exceptionally high in manufacturing, where digitization drives innovation. For instance, in response to environmental concerns, rising fuel prices, and climate regulations, the automotive industry sector has adopted digital technologies to strengthen competitiveness and address ESG considerations. This

has fueled the expansion of ESG programs driven by both digital transformation and increased stakeholder expectations (Esposito De Falco et al., 2021; Ramadhan et al., 2023). Industries with high R&D activities, such as pharmaceuticals, are well-positioned to leverage digital technologies to advance ESG objectives. These industries often receive incentives to adopt digital tools that support ESG initiatives, including those aimed at building a skilled workforce and promoting sustainability (Bhagat et al., 2022). In the manufacturing sector, digitalization amplifies ESG impacts, as regulators' pressures drive firms to adopt advanced technologies to mitigate environmental damage. The financial and ecological costs of industrial operations encourage firms to use digital innovations to support their ESG strategies (Ali, Rangone, et al., 2024; Wen et al., 2022).

Additionally, from the literature (Muhammad et al., 2022b; Elmghaamez et al., 2024; Ali, Rangone, et al., 2024), contingency theory suggests that firm size significantly affects R&D investment decisions, particularly in relation to digitalization and ESG. Larger (bigger) firms with more advanced digital infrastructure are better equipped to integrate ESG into their R&D efforts. These firms are more likely to undertake diverse digital projects, gaining access to superior resources while managing risks associated with ESG driven R&D initiatives (J. Huang et al., 2021). However, few studies argue that large firms may face difficulties maintaining agility in R&D, particularly when digitalization complicates ESG implementations (Dong & Xu, 2016; Esposito De Falco et al., 2021; D. Wang & Xia, 2024). The relationship between digitalization and ESG performance is influenced by R&D intensity in a complex way. High R&D intensity can lead to digital innovation that improves ESG outcomes, and it may also redirect resources from immediate ESG improvements, resulting in a neutral effect. Although previous studies (E-Vahdati & Binesh, 2022; Ramadhan et al., 2023; Muhammad, Migliori, et al., 2024) have explored the connection between R&D and ESG investments, but the moderating effect of R&D intensity in digitalization remains underexamined. Based on this analysis, we propose the following hypothesis:

***H4:** The relationship between digitalization and ESG performance is moderated by R&D intensity, with the effect being neutral (positive and negative)*

The theoretical framework presented in this research clarifies the relationships among various variables, as illustrated in **Figure No. 1**. This framework serves as a foundation for understanding the underlying dynamics within the study's context.

[Insert Figure 1: Theoretical Framework Of The Study Here]

11.3. Research Design

11.3.1. Sample, Data, and Methodology

In this study, we employed a panel data approach, focusing on a sample of 145 publicly listed technology firms based in Northern Europe. The data cover five years, from 2019 to 2023, and were obtained from the Refinitiv Eikon™ database (formerly known as Thomson Reuters ASSET4 ESG), resulting in 726 longitudinal observations (Refinitiv Eikon Datastream, 2021). Data for 170 Northern European firms within the technology sector were initially available. However, 25 firms were excluded due to incomplete data on key variables essential to the study.

The dataset used in this study was entirely derived from ⁴⁴Refinitiv Eikon™, a highly regarded and comprehensive global financial and accounting database. Refinitiv Eikon™ provides access to over 35 million individual data points across various asset classes, including 8.5 million economic indicators. The database includes multiple financial assets, including stocks, bonds, commodities, scores related to ESG factors, derivatives, and other essential financial, accounting, and macroeconomic information. Due to its transparency, breadth, and data quality, Refinitiv Eikon™ is frequently utilized by academics and researchers to ensure robust and reliable results.

11.4. ⁴⁵Measurements

A. Dependent Variable.

11.4.1. ESG Performance or Score.

The environmental, social, and governance (ESG) performance of companies has become a prominent research topic in academia. ESG performance is typically assessed using ESG rating scores, which involve a quantitative analysis and holistic evaluation of a company's performance across environmental, social, and governance dimensions. For this study, ESG ratings from the Refinitiv Eikon™ database have been utilized, as these ratings are widely recognized in the existing literature.

Refinitiv Eikon™ evaluates ESG performance using a comprehensive set of indicators—68 for environmental pillar scores and 62 for social pillar scores. And 56 for governance aspects. The ratings are expressed as a percentage score ranging from 0 to 100. Environmental metrics include 20 indicators related to resource use, 28 for emissions, and 20 for innovation. Social performance is measured through 30 workforce-related metrics, 08 human rights metrics, 14 community-focused indicators—and 10 product responsibility measures. Governance performance is evaluated using 35 management-related metrics, 12

⁴⁴ (LSEG Annual Report _ 2023 _ Partnering to Transform)

⁴⁵ For further details, See Appendix A, Table A2 Source of Variables, Definition, and Measurement

shareholder-associated metrics, and 09 indicators that assess corporate responsibility (CSR) strategies. An ESG score between 0 and 25 indicates relatively bad performance, while scores between 75 and 100 reflect excellent performance. This study adopts the ESG scores from the ⁴⁶Refinitiv Eikon™ database is considered a reliable and widely used source of ESG metrics in academic research. Many scholars have relied on Refinitiv's ESG scores in their studies, underscoring its credibility in measuring ESG performance scores.

B. Independent Variable

11.4.2. Digitalization

This study adopts a text analytics methodology or approaches (Fang et al., 2023; S. Wang & Esperança, 2023a; Qi et al., 2024; Tariq et al., 2024), to develop a digitalization index for firms, aligning with a progressive and increasingly utilized methodological framework in contemporary research. Drawing from recent research, the digital indicators are built for North European firms in the technological sectors using text analysis and word frequency statistics. The analysis proceeds in three key steps: *First*, a the ⁴⁷**digital-related thesaurus** has been developed to cover five key dimensions: artificial intelligence, big data, cloud computing, blockchain, and digital technology applications. *Second*, Python's "Jieba" word segmentation tool is used to analyze the text files (.txt) of annual reports from listed companies, based on the established thesaurus, to perform word frequency analysis. *Third*, the word frequency of each digital-related keyword is summed for each company, and the total word frequency is logarithmized to measure the firm's degree of digitalization.

This study adopts word frequency statistics from annual reports of listed tech firms to measure their digitalization levels for four primary reasons. **(1)** analyzing the frequency of digital-technology-related terms provides a quantitative assessment, enabling an objective analysis and minimizing the risk of bias that may arise from subjective evaluations. **(2)** annual reports are publicly available, offering transparent and reliable data that can be accessed through public channels, ensuring the credibility of the information. **(3)** the regular release of these reports reflects the latest advancements in the application or adoption of digital technology by firms, providing timely data to support the analysis. **(4)** these reports are available in the Refinitiv Eikon™ database, specifically within the Management Discussion and Analysis (MD&A) section, providing detailed insights into the company's digitalization efforts and strategies.

C. Moderating variables

⁴⁶ (LSEG_Sustainability_Databook_2023)

⁴⁷ For further details, see Appendix A Section, Table A1.

11.4.3. Board Gender Diversity

Board gender diversity is defined as the proportion of female members on a company's board of directors. This metric is commonly used in the literature, (Kyaw et al., 2017; Muhammad & Migliori, 2023; Muhammad & Ali, n.d.; Shakil et al., 2024; Tariq et al., 2024; Muhammad, Paolone, et al., 2024) as a proxy for measuring female representation at the firm's board level.

11.4.4. ESG Controversies Score

The ESG controversies score is calculated based on 23 controversial topics, reflecting a company's involvement in negative media coverage related to fines, lawsuits, or regulatory disputes. This score is expressed in percentage (%) and captures a firm's controversy exposure during a fiscal year. The ESG controversy score also addresses potential market capitalization bias, as larger firms tend to attract more media scrutiny than smaller firms. The scoring methodology is derived from the Refinitiv Eikon™ database, which provides standardized ESG controversy scores. (Refinitiv Eikon Datastream, 2021).

11.4.5. R&D Intensity

R&D intensity is the ratio of a firm's total R&D expenditure to its total assets or sales. This variable is a proxy for a company's commitment to research and development activities. Previous studies (E-Vahdati & Binesh, 2022; Ramadhan et al., 2023; Rauf et al., 2024), have established a positive correlation between R&D intensity and ESG reporting, indicating that firms with higher R&D spending are more likely to engage in comprehensive ESG practices. Several other studies have further corroborated this association (Brown et al., 2012; E-Vahdati & Binesh, 2022; Muhammad, Migliori, et al., 2024)

11.5. Economic Model Setting

We apply a series of econometric models (Muhammad et al., 2022a; Muhammad & Migliori, 2023; Ali, Rangone, et al., 2024; Muhammad, Migliori, et al., 2024) to investigate how digitalization influences the ESG performance of Northern European firms. Additionally, we explore the moderating effects of Board Gender Diversity, ESG Controversy, and R&D Intensity on this relationship. **Model I** examines the impact of digitalization on ESG Performance. **Model II** assesses the moderating role of Board Gender Diversity on the digitalization and ESG performance link. **Model III** investigates how ESG Controversy moderates this relationship. **Model IV** explores whether R&D Intensity influences the effect of digitalization on ESG performance.

a. Direct Effect

To evaluate whether digitalization positively or negatively affects ESG performance (Hypothesis 1), we use the following base model:

$$\begin{aligned}
 & ESG \text{ Performance Score}_{i,t} \\
 &= \alpha + \beta_1 Digi_{i,t} + \beta_2 BGD_{i,t} + \beta_3 ESG_CON_{i,t} + \beta_4 R\&D_INT_{i,t} \\
 &+ \beta_5 \sum ControlVariable_{i,t} + \lambda_i + \mu_t + \varepsilon_{i,t}
 \end{aligned}
 \tag{1}$$

b. Moderation Effect

For the moderation hypothesis (Hypothesis 2 through Hypothesis 4), we apply the following models to assess the interaction effects:

$$\begin{aligned}
 & ESG \text{ Performance Score}_{i,t} \\
 &= \alpha + \beta_1 Digi_{i,t} + \beta_2 BGD_{i,t} + \beta_3 ESG_CON_{i,t} + \beta_4 R\&D_INT_{i,t} + \beta_5 Digi \times BGD_{i,t} \\
 &+ \beta_6 \sum ControlVariable_{i,t} + \lambda_i + \mu_t + \varepsilon_{i,t}
 \end{aligned}
 \tag{2}$$

$$\begin{aligned}
 & ESG \text{ Performance Score}_{i,t} \\
 &= \alpha + \beta_1 Digi_{i,t} + \beta_2 BGD_{i,t} + \beta_3 ESG_CON_{i,t} + \beta_4 R\&D_INT_{i,t} \\
 &+ \beta_5 Digi \times ESG_CON_{i,t} + \beta_6 \sum ControlVariable_{i,t} + \lambda_i + \mu_t + \varepsilon_{i,t}
 \end{aligned}
 \tag{3}$$

$$\begin{aligned}
 & ESG \text{ Performance Score}_{i,t} \\
 &= \alpha + \beta_1 Digi_{i,t} + \beta_2 BGD_{i,t} + \beta_3 ESG_CON_{i,t} + \beta_4 R\&D_INT_{i,t} \\
 &+ \beta_5 Digi \times R\&D_INT_{i,t} + \beta_6 \sum ControlVariable_{i,t} + \lambda_i + \mu_t + \varepsilon_{i,t}
 \end{aligned}
 \tag{4}$$

These variables are defined as follows: $ESG\ Performance\ Score_{i,t}$ is the dependent variable representing the ESG performance of firms i at time t . $Digi_{i,t}$ a measure of the firm's digitalization. $BGD_{i,t}$ an indicator of gender diversity on the firm's board. $ESG_CON_{i,t}$ a score reflecting controversies related to environmental, social and governance practices. $R\&D_INT_{i,t}$ is the firm's level of investment in research and development. However, the interaction terms – $Digi \times BGD_{i,t}$, $Digi \times ESG_CON_{i,t}$, and $Digi \times R\&D_INT_{i,t}$ – are used to assess the moderation effects of Board Gender Diversity, ESG Controversy Score and R&D Intensity on the relationship between digitalization and ESG performance.

Whereas in this model we include the following parameters. α the intercept or constant term. $\beta_1 - \beta_8$ Coefficients represent the impact of each variable. λ_i Firm-specific fixed effect. μ_t Time-specific fixed effect. $\varepsilon_{i,t}$ the error term, capturing unexplained variability.

11.6. Results and Discussions

11.6.1. Descriptive Statistics and Correlation Matrix

Table No. 1 represents descriptive statistics of each variable used in this study. ESG Performance, with a mean of 37.825 and high variability (SD=20.667), indicates a wide range of environmental, social, and governance outcomes among firms due to differences in industry norms, regulatory environments, and stakeholder pressures. This explains the considerable range observed in ESG performance, where firms may be at different stages of integrating sustainability into their core operations (Arvidsson & Dumay, 2022). Digitalization has a mean of 0.298, suggesting moderate adoption across firms, while Board Gender Diversity shows a notable variation (Mean = 43.699, SD = 28.414), reflecting the diversity in gender representation on boards. The results suggest that while digitalization is critical for firms' competitiveness, the pace of adaption is often constrained by factors such as resource availability and firm capabilities.

The ESG controversies score has a high mean of 98.035 and a relatively low standard deviation of 10.607, which aligns with the growing importance of reputation management in corporate sustainability strategies. R&D Intensity shows a negative mean of -0.917, indicating low investment in R&D relative to revenues, with a significant variability (Standard Deviation of 1.576). Firms in the tech sectors often face fluctuating R&D investment levels due to rapid technological changes and the risk associated with innovations (Bhagat et al., 2022). High Variability in financial measures such as dividend per share, firm leverage, and firm growth (with large ranges in values) suggests that firms adopt different strategies in response to competitive pressure, technological advancements, and regulatory environment.

[Insert Table 1: Descriptive Statistical Analysis Here]

Table No. 2, describes the results of the correlation analysis, which indicates the relationship between variables employed in this study. As expected, Digitalization, Board Gender diversity, R&D Intensity, and Firm Size are significantly associated with ESG Performance. We employed a variance inflation factor (VIF) to account for multicollinearity, as shown in **Table No. 2**. According to (Serafeim, 2015), multicollinearity becomes a significant concern only when the correlation between predictors exceeds 0.9. In our analysis, none of the pairwise correlation coefficients among the independent variables surpass this threshold, indicating that multicollinearity is not an issue in the dataset.

[Insert Table 2: Correlation Matrix Analysis Here]

11.6.2. Baseline Regression Results and Discussion

Table 3, presents the key regression results for all variables used in this study. We applied an Ordinary Least Square (OLS) regression model to analyze the relationship between digitalization and a firm's ESG performance. Additionally, we explored how Board Gender Diversity, ESG Controversies, and R&D Intensity influence this relationship as moderating factors, as shown in **Figure No. 2**. The regression results confirmed that the null hypothesis of constant variance in the Breusch–Pagan and White's test for heteroscedasticity could not be rejected. Furthermore, all regression models (I, II, III, and IV) incorporated firm and year-fixed effects, ensuring consistency in the analysis.

[Insert Figure 2: Structural Model of the Study Here]

Examining the **H1** in our study, we investigate how digitalization influences a firm's ESG performance. Our analysis employs a regression model in which ESG performance (α_1) is the dependent variable, and digitalization serves as the predictor variable in **Model I**. The results indicate that in Model I, the coefficient ($\beta_1 = 11.467$; $p < 0.01$) value of digitalization is positive and statistically significantly associated with the ESG performance of firms. This shows that one unit increase (1% level) in the degree of digitalization leads to an 11.467 unit increase in the ESG performance of technological firms. This correlation highlights the significant role of digital technologies in enhancing operational efficiency, promoting transparency, and fostering meaningful engagement with stakeholders. Moreover, integrating digital processes into reporting can yield more precise and timely disclosures, thereby contributing to the enhancement of ESG ratings (Broccardo et al., 2023; Verhoef et al., 2021). The observation underscores the transformative impact of digitalization on corporate reporting practices and its ability to drive sustainable business outcomes. The results confirm **H1**, suggesting that companies with more advanced levels of digital transformation are linked to better ESG performance. The creative adoption and utilization of cutting-edge digital technologies such as AI, blockchain, cloud computing, and big data have offered

practical solutions to enhance a firm's ESG capabilities and have emerged as a significant driving force for promoting ESG development (Vial, 2019; Xu et al., 2022; Broccardo et al., 2023).

The Board gender diversity coefficient ($\beta_8 = 0.211$; $p < 0.01$) indicates a positive and statistically significant relationship, suggesting that greater gender diversity is linked to improved ESG performance. The estimated coefficient suggests that a 1% increase in gender diversity on the boards results in a 21.10% enhancement in the ESG performance of firms in the technological sector. This finding supports the idea that boards with gender diversity are more inclined to consider various perspectives, ultimately leading to enhanced corporate social responsibility (CSR) and ESG performance. This diversity contributes to improved strategic decision-making, particularly in areas related to sustainability practices. However, these results support the literature (Muhammad & Ali, n.d.; Muhammad & Migliori, 2023; Tariq et al., 2024) that incorporating women into board supervision is essential for enhancing ESG performance. Gender diversity fosters diverse perspectives, leading to more effective decision-making and oversight. Women are often seen as more detail-oriented, contributing to more efficient monitoring and potentially improving a firm's economic outcomes.

The ESG Controversies Score ($\beta_{10} = -0.401$; $p < 0.01$) exhibits a negative and statistically significant correlation, indicating that higher controversy scores, which signify adverse ESG incidents, are linked to lower ESG performance. These detrimental incidents have the potential to damage a company's reputation, resulting in decreased overall ESG performance, reduced investor confidence, and lower sustainability ratings. These findings provide compelling evidence that companies thrust into the media spotlight due to misconduct and controversial actions are not disregarded by investors, jeopardizing their reputation and creditability and consequently diminishing their value (Nirino et al., 2021; Brinette et al., 2024).

The results of the co-efficient of β_{11} have also shown a positive and significant relationship between R&D intensity and the ESG performance of firms, with a coefficient of ($\beta_{11} = 1.358$; $p < 0.01$). This implies that a 1% increase in R&D intensity leads to a 13.58% enhancement in the ESG performance of firms within technological sectors. These findings suggest that firms in this sector tend to invest significantly in research and development to enhance their ESG outcomes. Such investments often result in creating sustainable products and developing more efficient processes, both of which are vital for advancing environmentally friendly technologies and promoting sustainable business practices. Furthermore, our analysis indicates that R&D intensity plays a crucial role in reducing operational costs and enhancing productivity through innovation in the product development process. This allows companies to diversify their offerings and differentiate themselves from competitors (Brown et al., 2012; J. Huang et al., 2021; Muhammad et al.,

2022b). By investing in R&D, firms can gain a competitive advantage, promoting technological innovation even in the face of challenges such as limited resources and restricted access to external funding.

In examining the control variables of the study **Model I**, the coefficient values for firm leverage ($\beta_3 = -0.854$; $p < 0.01$) and firm size ($\beta_5 = -1.417$; $p < 0.01$) are found to be significantly and negatively associated with ESG performance. Specifically, a 1% increase in firm leverage and size corresponds to approximately 84.50% and 14.17% reductions in ESG performance tech sector firms. This suggests that higher leverage restricts a firm's ability to invest in non-core activities such as sustainability initiatives, indicating the negative relationship between leverage and ESG performance. Similarly, larger firms tend to face more significant difficulties in implementing consistent practices across their complex and diverse operations, leading to lower ESG performance (Ali, Rangone, et al., 2024). On the other hand, the coefficient values for the other control variables, including dividend per share yield, firm growth, firm age, and return on assets (ROA), are positive and statistically significant at the 1% level.

Further, the results of the Breusch–pagan test (p-value: 0.9083) and White’s test (p-value: 0.2708) indicate that heteroscedasticity is not a significant concern, thus supporting the reliability of the model’s estimates. The R-squared value of 0.4267 implies that approximately 42.67% of the variance in ESG performance is explained by model I, indicating a good fit. Consequently, the hypothesis (**H1**) cannot be rejected, and the estimation model, confirmed through OLS with robust standard errors, demonstrates that digitalization positively and significantly impacts a firm’s ESG performance.

[Insert Table 3: OLS Regression Analysis Results Here]

In **Model II** of **Table No. 3**, the moderation effect of BGD is analyzed. To test the Hypothesis (**H2**), we introduced an interaction term (Digi X BGD) to evaluate how BGD influence the relationship between digitalization and ESG performance. The coefficient for digitalization ($\beta_1 = 6.264$; $p < 0.01$) remains positive and highly significant, indicating a strong association. Similarly, the coefficient for board gender diversity ($\beta_8 = 0.252$; $p < 0.01$) is also positive and significant, consistent with the findings from **Model I**. However, the interaction term (Digi X BGD) yields a positive coefficient ($\beta_9 = 0.139$; $p < 0.05$), indicating that the positive effect of digitalization on ESG performance is amplified in firms with higher levels of gender diversity on their boards. The findings indicate that gender diversity is fundamental in empowering firms to embrace digital transformation and adapt to evolving consumer needs (Muhammad & Ali, n.d.; Wu & Lu, 2023; Fang et al., 2023). Organizations can significantly improve their financial resilience by leveraging digital tools to engage with consumers and meet their demands actively. Moreover, the results suggest that having female directors fosters digitalization, enabling firms to serve new customer segments better, expand their market presence, and strengthen ESG performance indicators (AlNuaimi et

al., 2022). Executives in the technological industry should prioritize recruiting and integrating female directors, understanding that their contributions go well beyond mere gender representation. Female directors on boards foster cognitive diversity, which is vital for competing in today's fast-paced and technologically advanced environment and critical for improving a firm's financial stability (Qi et al., 2024; Tariq et al., 2024).

In addition, all control variables in **Model II** exhibit statistically significant coefficients. Notable, the coefficient of firm size ($\beta_5 = 1.434$; $p < 0.01$) is positive and significant compared to **Model I**, suggesting that large tech firms are financially stable and possess greater resources to enhance operational efficiency. Improved efficiency results in increased cash inflow–outflow. Enabling firms to manage risk better and improve ESG performance. The Breusch–Pagan test (p-value: 0.7508) indicates that heteroscedasticity is not a significant concern, supporting the reliability of the model estimates. With an R-squared value of 0.4227, approximately 42.27% of the variance in ESG performance is accounted for by **Model II**, indicating a good fit. Consequently, **H2** cannot be rejected, and this is further affirmed by the estimation model using OLS with robust standard errors, demonstrating that board gender diversity positively moderates the relationship between digitalization and a firm's ESG performance.

Table No. 3, further illustrates the moderating effect of ESG Controversies on the relationship between digitalization and ESG performance, as shown in **Model III**. The coefficient for digitalization ($\beta_1 = 2.748$; $p < 0.01$) reveals a positive and statistically significant relationship with the firm's ESG performance, consistent with the findings in **Models I** and **II**. Specifically, a one-unit digitalization increase corresponds to a 2.74-unit increase in the ESG performance score of technology firms. Conversely, the coefficient for ESG controversies ($\beta_{10} = -0.365$; $p < 0.01$) is negative and statistically significant, indicating that a 1% rise in ESG Controversies Score results in a 36.5% decline in ESG Performance of firms.

Further, the interaction term between digitalization and ESG Controversies (Digi X ESG_CON) exhibits a negative coefficient ($\beta_{11} = -0.088$; $p < 0.05$), which is statistically significant at the 5% level. This negative moderation effect suggests that the presence of ESG controversies diminishes the positive impact of digitalization on ESG performance. These results support the literature findings that controversies can foster negative perceptions among stakeholders, undermining the benefits of digitization. Such controversies reflect deeper issues, such as governance or social concerns, which cannot be remedied solely through digital transformation efforts (J. Li et al., 2019; Nirino et al., 2021; Brinette et al., 2024). The findings also emphasize that firms engaging in illegal or irresponsible behaviors experience significant harm to ESG performance, generating negative reactions among stakeholders. Such firms risk losing market share due to adverse CSR–related news coverage and negative media attention, which can damage a firm's reputation, leading to reduced market value and heightened risk (Cai et al., 2012; J. Li et al., 2019).

Tests for heteroscedasticity, including the Breusch–Pagan test (p-value: 0.8998) and White’s test (p-value: 0.7887), confirm that heteroscedasticity is not a major concern, bolstering the robustness of the model’s estimates. The R-squared value of 0.4267 indicates that approximately 42.67% of the variance in ESG performance is explained by **Model III**, suggesting a good fit. As a result, hypothesis **H3** is supported, confirming that ESG controversies negatively moderate the relationship between digitalization and ESG performance, as demonstrated by the OLS model with robust standard errors.

Finally, **Model IV** highlights the moderating effect of R&D intensity on the relationship between digitalization and ESG performance. The coefficients for both digitalization ($\beta_1 = 10.47$; $p < 0.01$) and R&D intensity ($\beta_{12} = 1.968$; $p < 0.01$) are positive and significantly related to the firm’s ESG performance scores, indicating that 1% increases in digitalization and R&D intensity results in a 104.70% and 196.80% improvement in ESG performance, respectively. This suggests that increased focus on both digitalization and R&D intensity substantially enhances ESG outcomes.

However, the interaction term for digitalization and R&D intensity (Digi X R&D intensity) yields a positive but statistically insignificant coefficient ($\beta_{13} = 2.495$; $t = 1.58$), providing limited support for the hypothesis (**H4**) that digitalization could amplify the positive effects of R&D activities. Although digital transformation can enhance innovation, optimize resource management, and incorporate sustainable practices, its overall impact is insufficient to definitively determine a combined effect on ESG performance. Previous literature (Ali, Muhammad, et al., 2024; Ali, Rangone, et al., 2024) highlights the strategic value of R&D investments, particularly for technology firms. These investments provide a competitive edge by reducing reliance on external financing and mitigating growth risks through participation in strategic knowledge networks. Additionally, digital transformation enhances R&D efficiency by fostering innovation in both product and process development (Ramadhan et al., 2023). Tools like AI, blockchain, and big data allow firms to optimize their R&D capabilities, enabling more focused efforts and cross-departmental knowledge sharing. Furthermore, R&D intensity has been demonstrated to increase green innovation, including the development of environmentally friendly products and processes, which positively impact ESG performance (Brown et al., 2009, 2012; Ramadhan et al., 2023).

Tests for heteroscedasticity, including the Breusch–Pagan test (p-value: 0.8165) and White’s test (p-value: 0.4507), indicate that this issue is insignificant, affirming the reliability of the model’s estimates. The R-squared value of 0.4289 means that approximately 42.89% of the variance in ESG performance is explained by Model IV, indicating a good model fit. Therefore, the results support **Hypothesis 4**, which posits that R&D intensity positively moderates the relationship between digitalization and ESG performance, although the interaction effect is less conclusive.

In all models, the control variables—dividend per share yield, firm leverage, firm growth, firm size, firm age, and return on assets—demonstrate statistically significant relationships with ESG performance. Specifically, in **Model III**, the coefficient for firm growth ($\beta_4 = -0.189$; $p = < 0.05$) reveals a negative association with the ESG performance of tech firms, while the coefficient for firm size ($\beta_5 = 1.434$; $p = < 0.01$) indicates a positive relationship in **Model II**. These findings align with previous research, which suggests that larger firms possess higher profitability. This enables them to allocate more resources towards digital transformation efforts, ultimately improving ESG performance indicators.

11.7. Robustness Validation

We performed a series of robustness checks to ensure the reliability of our findings and address potential endogeneity issues. Previous investigations (Broccardo et al., 2023; Ribeiro-Navarrete et al., 2021; Sila et al., 2016), have often used traditional linear regression models, such as Random Effect (RE) and Fixed Effect (FE), to analyze the impact of digitalization on environmental, social, and governance (ESG) performance. However, these models are susceptible to biases from unobserved heterogeneity and endogeneity. To overcome these limitations, we employed a two-step system, the **(A)** Generalized Method of Movement (GMM) Model, using a one-year lag for both the instrument and the dependent variables. (Arellano & Bond, 1991; Roodman, 2009), as well as the **(B)** One-Year Lagged OLS Model (D. Wang & Xia, 2024). These methods effectively address endogeneity by leveraging internal instruments from the dataset and accounting for unobserved firm-specific shocks (Roodman, 2009).

A. Robustness Check with GMM

ESG Performance Score_{i,t}

$$\begin{aligned}
&= \alpha + ESG\ Performance\ Score_{(t-1)} + \beta_1 Digi_{i,t} + \beta_2 BGD_{i,t} + \beta_3 ESG_CON_{i,t} \\
&+ \beta_4 R\&D_INT_{i,t} + \beta_5 Digi \times BGD_{i,t} + \beta_6 Digi \times ESG_CON_{i,t} + \beta_7 Digi \times R\&D_INT_{i,t} \\
&+ \beta_8 \sum Control\ Variable_{i,t} + \lambda_i + \mu_t + \varepsilon_{i,t}
\end{aligned}$$

(5)

B. Robustness Check with One-Year Lagged OLS Model

ESG Performance Score_{i,t}

$$\begin{aligned}
&= \alpha + \beta_1 Digi_{i,(t-1)} + \beta_2 BGD_{i,(t-1)} + \beta_3 ESG_CON_{i,(t-1)} + \beta_4 R\&D_INT_{i,(t-1)} \\
&+ \beta_5 Digi \times BGD_{i,(t-1)} + \beta_6 Digi \times ESG_CON_{i,(t-1)} + \beta_7 Digi \times R\&D_INT_{i,(t-1)} \\
&+ \beta_8 \sum ControlVariable_{i,(t-1)} + \lambda_i + \mu_t + \varepsilon_{i,t}
\end{aligned}$$

(6)

The terms used for robustness check are defined as follows: *ESG Performance Score_{i,t}* is the dependent variable representing the ESG performance. *i* refers to the individual firms, *t* represents the time-period, α is the intercepts or constant terms. $\beta_1 - \beta_8$ coefficients represent the impact of each variable. λ_i Firm-specific fixed effect. μ_t Time-specific fixed effect. $\varepsilon_{i,t}$ The error term, capturing unexplained variability.

11.7.1. GMM Model for Robustness Check

In **Table No. 4, Model I** reveals a statistically significant and positive relationship between digitalization and ESG performance ($\beta_1 = 5.518$; $p < 0.01$), indicating that a 1% increase in digitalization leads to a 5.518% improvement in the ESG scores of technology firms. Additionally, the coefficient value of BGD ($\beta_9 = 0.859$; $p < 0.05$), and R&D intensity ($\beta_{12} = 0.821$; $p < 0.05$), are positively correlated with ESG performance at the 5% significance level. On the contrary, ESG controversies ($\beta_{10} = -0.011$; $p < 0.05$), are negatively associated with ESG scores, indicating that a 1% increase in controversies reduces ESG performance by 0.011%. These findings support **Hypothesis 1**. In **Model II**, the coefficient for digitalization remains significant ($\beta_1 = 2.049$; $p < 0.05$), reflecting a 2.049% improvement in ESG performance for every 1% increase in digitization. The positive relationship with BGD ($\beta_9 = 0.086$; $p < 0.05$), and R&D intensity ($\beta_{12} = 0.822$; $p < 0.05$), is maintained. The interaction between digitalization and BGD (Digi X BGD) shows a positive but weak association with ESG performance ($\beta_9 = 0.084$; $p < 0.1$), suggesting some moderating effect, though less significant. The control variables, including dividend per share yield, firm leverage, size, age growth, and ROA, reinforce the robustness of these results, supporting **Hypothesis 2**.

Model III, digitalization exhibits a positive relationship with ESG performance ($\beta_1 = 1.689$; $p < 0.05$), while ESG controversies display a negative coefficient ($\beta_{10} = -0.026$; $p < 0.05$). The interaction between digitalization and ESG controversies score (Digi X ESG_CON) shows an insignificant negative effect ($\beta_{11} = -0.039$; $t = 0.29$), indicating an inconclusive relationship that requires further investigation. As

a result, **Hypothesis 3** is not rejected, although the findings are inconclusive. **Model IV** shows a consistent positive relationship between digitalization and ESG performance, with a statistically significant coefficient at the 5% level. R&D intensity ($\beta_{12} = 2.712$; $p < 0.05$) also significantly enhances ESG performance in technology firms. However, the interaction between digitalization and R&D intensity (Digi X R&D) is insignificant, suggesting no notable moderating effect, supporting **Hypothesis 4**.

To further confirm the validity of the models, we applied the GMM estimators using lagged differenced ($t-1$) as instruments. Post-estimation tests such as the Sargan and Arellano-Bond tests were conducted to detect autocorrelation and over-identification issues. The Sargan test, a key tool in GMM estimation, assesses the validity of the instruments by testing whether the imposed moment conditions align with the data. (Arellano & Bond, 1991; Roodman, 2009). In this analysis, the Sargan test's p-value for all models exceeds the recommended threshold of 5%, confirming that the instruments used are appropriate and that the models fit the data well. Higher p-values indicate a better model fit, and in our case, all results are within acceptable limits, validating the robustness of our model.

[Insert Table 4: GMM Model For Robustness Check Here]

11.7.2. One-Year Lagged OLS Model for Robustness Test

To further address concerns regarding reverse causality in our previous findings, we employed a one-year lag for both the predictor and control variables using an Ordinary Least Square (OLS) regression model (Shang et al., 2023; D. Wang & Xia, 2024). As presented in **Table No. 5**, the digitalization level of technological firms from the prior period shows a significant positive effect on all four models concerning ESG performance. In relation to the moderation effect, the interaction terms with digitization [(Digi x BGD) + (Digi x ESG_CON) + (Digi x R&D intensity)] were also lagged by one year. These results remain statistically significant and provide continued support for the hypothesis. Additionally, controlling the interaction of firm and year-fixed effects in **Table No. 5**, does not diminish the significance of the findings, which remain robust at the 1% and 5% significance levels. Several post-estimation tests were conducted to verify the validity of the instruments used. Overall, the results align with previous findings, indicating that potential endogeneity concerns do not drive the observed relationships.

[Insert Table 5: OLS Lagged Model For Robustness Check Here]

11.8. Conclusion.

This study empirically examines the impact of digitalization on a firm's ESG (Environmental, Social, and Governance) performance, focusing on 145 publicly listed technological firms in Northern Europe from 2019 to 2023. Utilizing panel data from the Refinitiv Eikon™ database and employing

Ordinary Least Square (OLS) estimation, we first examine the direct effect of digitalization on ESG performance within the technology sector. Furthermore, we explore the moderating roles of Board Gender Diversity (BGD), ESG controversies, and Research and Development (R&D) intensity in this relationship. To ensure the robustness of our findings, we conducted additional analysis using dynamic panel data approaches, specifically the two-step system Generalized Method of Moments (GMM) with lagged dependent variables as instruments. Alternative measures were also utilized through a Pooled regression model with lagged (independent and control) variables, yielding results consistent with our baseline regression model. Moreover, instrumental variable regression techniques were applied to address potential endogeneity concerns. The robustness checks confirm that our main findings remain consistent and not compromised by endogeneity issues.

Our empirical results support Hypothesis **H1**, showing that digitalization significantly impacts a firm's ESG performance. This finding underscores the fundamental role of digital technologies in enhancing operational efficiency, promoting transparency, and fostering meaningful stakeholder engagement. The integration of digital processes into corporate reporting leads to more precise and timely disclosures, thereby improving ESG ratings (X. Ren et al., 2023; Gu, 2024; Qi et al., 2024). This evidence highlights the transformative effect of digitalization on corporate reporting practices and its capacity to drive sustainable business outcomes. The innovative adoption of cutting-edge digital technologies, such as cloud computing, artificial intelligence, blockchain, and big data analytics, provides practical solutions for enhancing a firm's ESG capabilities and is emerging as a significant driving force in indorsing ESG development (Broccardo et al., 2023; Qi et al., 2024).

In testing Hypothesis **H2** regarding the moderating effect/influence of Board Gender Diversity (BGD) on the relationship between digitalization and ESG performance, we find that BGD positively and significantly enhances this relationship. The findings emphasize that female directors enhance a firm's digital transformation efforts by considering stakeholders' interests and adapting services to meet customers' changing needs. Utilizing digital tools to engage with customers effectively contributes to a firm's ability to maintain its financial stability (Kyaw et al., 2017; Muhammad & Migliori, 2023). Our research recommends increasing the number of female directors on corporate boards through initiatives recognizing diversity's strategic value rather than relying solely on regulatory mandates. Fostering a diverse and inclusive corporate environment is a moral obligation and a strategic necessity (Gulamhussen & Santa, 2015). Executives should prioritize the hiring and integration of gender-diverse boards, understanding that their contributions go beyond just gender representations. The presence of female directors introduces cognitive diversity, which is essential for competing in today's dynamic business environment and central to enhancing a firm's financial stability (Orazalin, 2020).

Confirming Hypothesis **H3**, our results indicate that ESG controversies negatively correlate with digitalization and ESG performance. These findings align with the existing literature suggesting that controversies generate negative perceptions among stakeholders, thereby undermining the benefits derived from digitalization efforts (Aouadi & Marsat, 2018b; J. Li et al., 2019). Such controversies often reflect deeper issues, including governance deficiencies or social concerns, which cannot be addressed solely through digital transformation (Digitalization). The findings also emphasize that firms engaged in illegal or irresponsible activities suffer significant damage to their ESG performance, causing adverse/negative reactions from stakeholders (Esposito De Falco et al., 2021). These firms risk losing market share due to negative corporate social responsibility-related media coverage. Although technology firms may respond by increasing the transparency of their sustainability reports, potentially leading to higher ESG performance relative to other sectors, negative media attention can nonetheless damage a firm's reputation, resulting in decreased market value and increased risk.

Our investigation into Hypothesis **H4** reveals that R&D intensity positively moderates the relationship between digitalization and ESG performance, although the statistical significance is somewhat less pronounced (insignificant). Prior literature underscores the strategic value of R&D investments, especially for technology firms, as these investments confer a competitive advantage by reducing dependence on external financing and mitigating growth risks through participation in strategic knowledge networks. (Brown et al., 2012; Bican & Brem, 2020). Digital transformation enhances R&D efficiency by promoting product and process development innovation. Using digital tools allows firms to optimize their R&D capabilities, facilitating more targeted efforts and promoting cross-departmental knowledge sharing. Furthermore, increased R&D intensity has been associated with the advancement of green innovation, including the development of environmentally friendly products and processes that positively influence ESG performance (Banerjee & Gupta, 2019; Ramadhan et al., 2023).

Overall, understanding and comprehending the relevance of ESG is critical for managers who want to secure their firm's survival and legitimacy by meeting the demands of all stakeholders, including employees, investors, customers, and society at large. Proactive participation in ESG efforts can boost corporate value and develop stakeholder trust. Firms focusing primarily on financial activity and prioritizing short-term gains undermine investors' perceptions and stakeholder relationships (Hillman & Keim, 2001; Lozano, 2011; Esposito De Falco et al., 2021). Companies engaged in contentious operations may face risks to their legitimacy and may need to ramp up their reputation and legitimize their conduct. As a result, in today's dynamic business environment, organizations seeking sustainable growth and competitive advantage must integrate digitalization with strategic ESG considerations while considering the moderating effects of board diversity and R&D intensity.

11.9. Theoretical, Practical and Policy Implications.

Our study contributes to the theoretical understanding of how digitalization positively influences ESG performance. By establishing a statistically significant connection between digitalization and ESG performance, this research underscores the critical role of digital transformations in driving investments in ESG initiatives. Further, it investigates the moderating effects of board gender diversity, ESG controversies, and R&D intensity on the associations between digitalization and ESG performance in Northern European technological firms. These findings emphasize the need for proactive engagement with ESG strategies to boost corporate value, foster stakeholder trust, and mitigate negative social impacts such as corruption and environmental degradation. Firms that focus only on financial perspectives (profit maximization) and neglect stakeholders' interests lead to damage investor confidence.

From a practical perspective, organizations from emerging areas (sectors) still encounter considerable challenges in implementing ESG initiatives. Limited profitability and weak international competitiveness often prevent these firms from prioritizing sustainability initiatives. In the context of the digital economy, companies must accelerate digital transformation to enhance economic and social value, supporting sustainable competitiveness (Agrawal et al., 2021). Digital transformation enables firms to address environmental issues more effectively, strengthen stakeholder connections, reduce agency conflicts and information asymmetry, and enhance their ESG performance. By integrating digital tools into the ESG framework, firms can create substantial social and environmental value, ultimately reshaping traditional business approaches to align with contemporary demands for sustainability (Cirillo et al., 2023; Haq & Huo, 2023; Rusch et al., 2023).

From a policy implication perspective, Governments could introduce financial incentives, such as tax breaks or subsidies, for digital innovations demonstrating advanced sustainability, encouraging widespread adoption. To strengthen governance, policies mandating or incentivizing board gender diversity may prove beneficial, as research suggests that diverse boards are more effective in overseeing ESG outcomes, particularly when employing digital tools. Moreover, policymakers might consider implementing mandatory digital frameworks for ESG risk monitoring, which could enhance transparency and aid firms in managing reputational risk associated with ESG controversies. Furthermore, requirements for detailed disclosure of R&D investments, particularly those aimed at sustainability, could foster greater accountability and ensure alignment with ESG objectives. For board members, digital literacy training programs in ESG could improve their capacity to govern this initiative effectively.

11.9.1. Limitations and Future Research

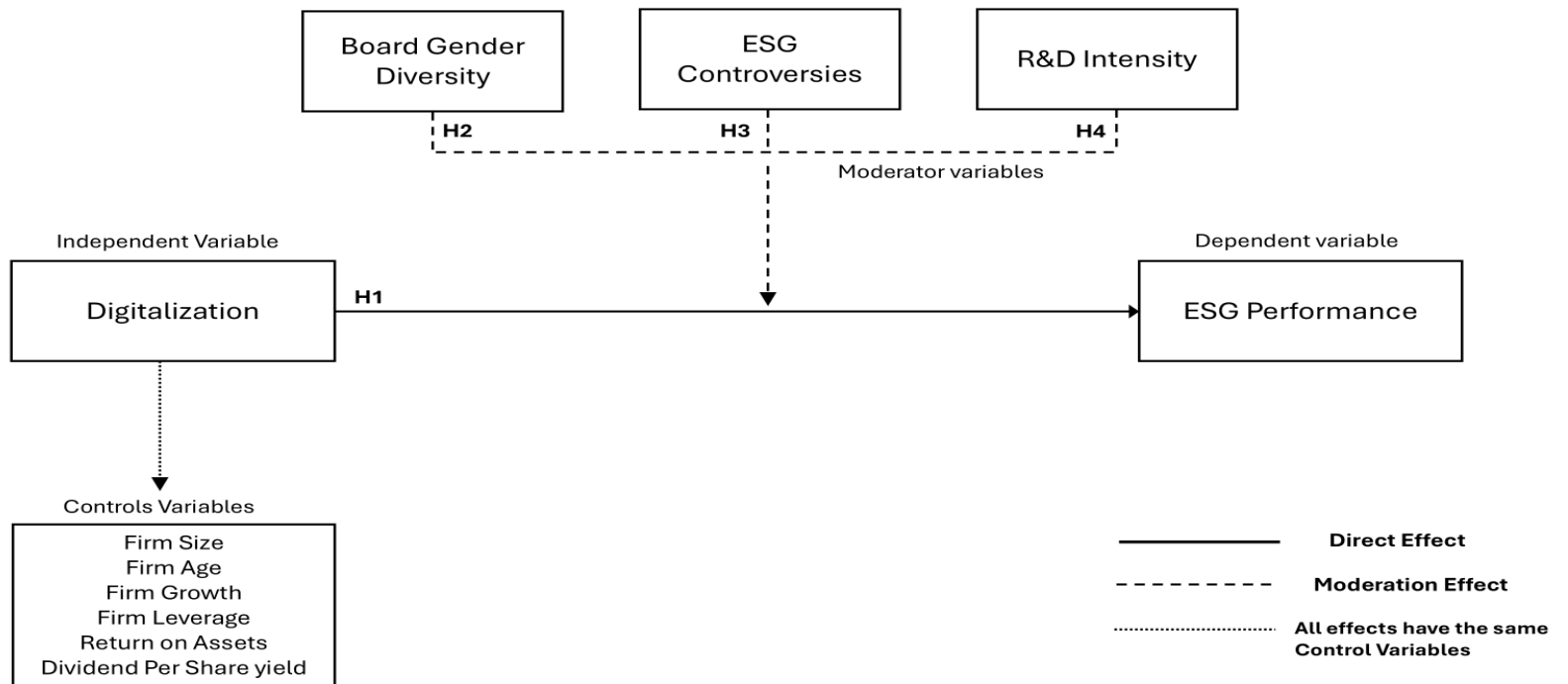
This study analyzed data from 145 publicly listed Northern European technological-related firms in the Refinitiv Eikon™ database. However, due to data limitations, numerous technological firms could not be included in the sample, potentially impacting the generalizability of these findings across a broader range of firms. Future research could strengthen the robustness of these results by expanding the sample to a larger and more diverse set of technology companies, possibly sourced from alternative databases (Bloomberg, Sustainalytics, and Wharton), to enhance representativeness.

Additionally, this research focused on data from five years (2019-2023), during which the technology industry has rapidly evolved and increasingly adopted sustainable practices. Given the dynamic nature of digital transformation and ESG practices, future studies should consider how the relationship between digitalization (transformations) and ESG performance might shift as these trends develop. Expanding the time horizon would allow examining potential changes in these associations over long periods. Further, this study primarily focused on ESG performance or scored further suggestions for future research to explore the effects of Corporate Social Responsibility (CSR) investments on financial performance across multiple sectors. Also, for the moderation role of key variables (BGD, ESG_CON and R&D Intensity) that are considered in this study, future studies could examine other potential moderating factors, for example, firm size, organizational risk profile, firm age, board independence, CEO influence and ownership concentration, to provide more nuanced understanding how these variables may shape this relationship. In this study, we adopted a quantitative approach that may still fail to capture the depth of certain findings. Future studies could consider integrating qualitative or mixed methodologies, such as case studies, cross-sectional analysis, or conceptual research, to address this. These may offer richer insight into unexpected results and cover deeper contextual (theoretical or practical) details.

11.10. FIGURES OF THE ARTICLE 3

11.10.1. Figure No 1:

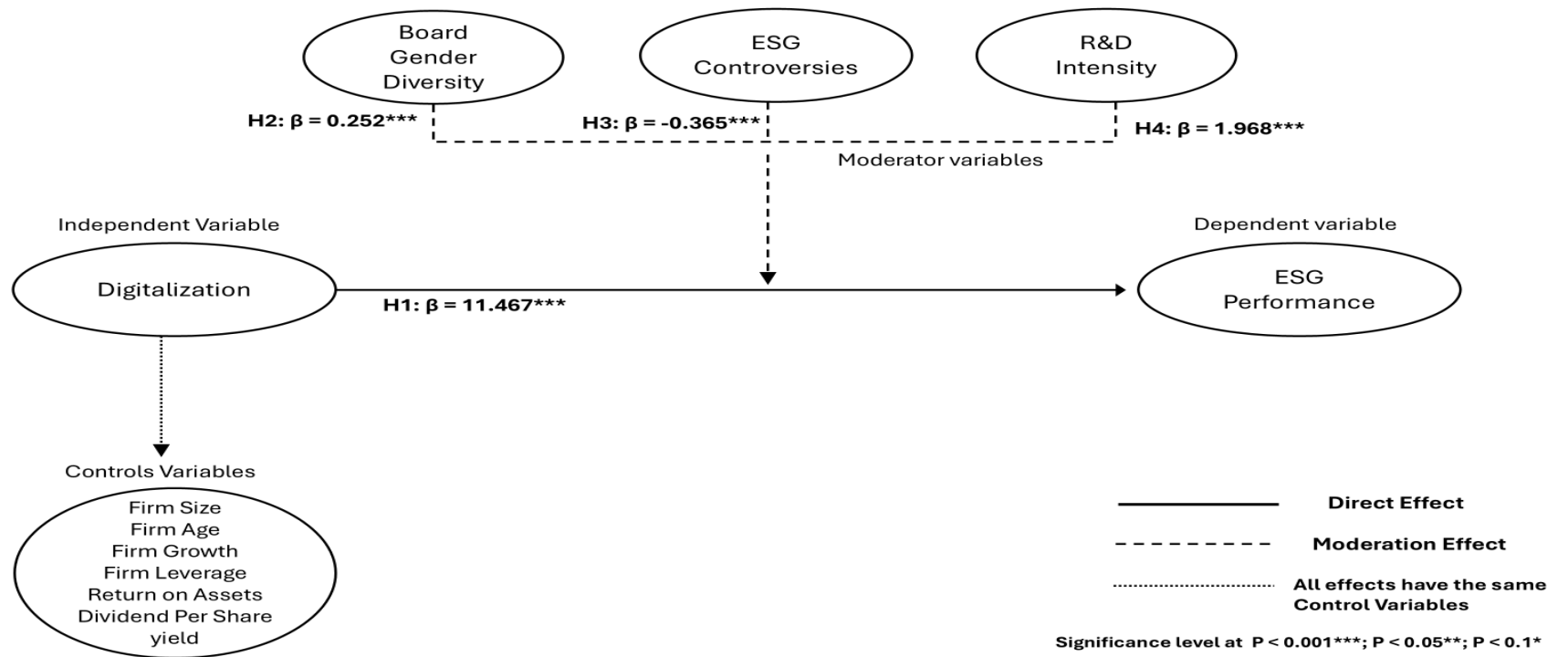
⁴⁸Theoretical Framework of the Study



⁴⁸ Source: Author Calculations

11.10.2. Figure No 2:

⁴⁹Structural Model of the Study



⁴⁹ **Source:** Author Calculations

11.11. TABLES OF THE ARTICLE 3

11.11.1. Table No 1:

⁵⁰Analysis of descriptive Statistics of publicly listed Northern European Firms.

Variables	Observations	Mean	Standard Deviation	Minimum	Maximum	VIF
ESG Performance	725	37.825	20.667	2.434	92.042	
Digitalization	725	0.298	0.2189	0.000	2.084	1.07
Board Gender Diversity	725	43.699	28.414	0.382	99.763	1.05
ESG Controversies Score	725	98.035	10.607	10.00	100.00	1.09
R&D Intensity	725	-0.917	1.576	-7.467	0.000	1.14
Dividend Per Share	725	1.544	2.202	0.000	22.998	1.17
Firm Leverage	725	1.290	2.686	0.000	31.737	1.04
Firm Growth	725	2.355	6.751	-45.409	61.156	1.13
Firm Size	725	18.656	3.991	0.000	24.605	1.28
Firm Age	725	1.233	0.454	0.000	2.100	1.10
Return on Assets	725	4.868	16.558	-49.134	221.256	1.10

⁵⁰ **Note:** The table provides the descriptive statistics of the variables used in this study. Key definitions of all variables can be found in Appendix Section (A). The sample consists of data from 725 observations of publicly listed Northern European firms in the technological sector, covering a period of 5 years from 2019 to 2023.

11.11.2. Table No 2:

⁵¹Correlation Analysis.

Variables	ESG Score	Digitalization	Board Gender Diversity	ESG Controversies Score	R&D Intensity	Dividend Per Share Yield	Firm Leverage	Firm Growth	Firm Size	Firm Age	Return on Assets
ESG Score	1.000										
Digitalization	0.082***	1.000									
Board Gender Diversity	0.394***	0.060	1.000								
ESG Controversies Score	-0.315***	-0.101***	-0.067*	1.000							
R&D Intensity	-0.230***	0.027	0.089**	0.116***	1.000						
Dividend Per Share Yield	0.232***	-0.005	0.065*	-0.185***	0.028	1.000					
Firm Leverage	0.119***	-0.063*	-0.038	-0.006	0.058	0.021	1.000				
Firm Growth	0.217***	-0.075**	0.070*	-0.118***	0.170***	0.045	-0.062*	1.000			
Firm Size	0.403***	0.170***	0.108***	-0.208***	-0.239***	0.234***	0.107***	0.211***	1.000		
Firm Age	0.186***	0.003	0.062*	-0.087**	-0.101***	0.240***	-0.038	-0.012	-0.020	1.000	
Return on Assets	0.233***	-0.072*	0.154***	-0.003	0.048	0.048	-0.086**	0.209***	0.082**	0.023	1.000

⁵¹ **Note:** The table represents the pairwise correlation analysis results of the variables used in this study. Key definitions of all variables can be found in Appendix Section (A). Whereas P < 0.001***, P < 0.05**, P < 0.1*

11.11.3. Table No 3:

⁵²OLS Baseline Regression Analysis – Full Sample.

Dependent Variable: → ESG Performance				
	Model I OLS	Model II OLS	Model III OLS	Model IV OLS
Independent Variable: ↓				
Digitalization	11.467*** (4.12)	6.264*** (3.35)	2.748*** (3.09)	10.47*** (3.67)
Control Variables: ↓				
Dividend Per Share yield	0.651** (2.26)	0.646** (2.24)	0.639** (2.19)	0.732** (2.50)
Firm Leverage	-0.854*** (-3.84)	-0.857*** (-3.86)	-0.851*** (-3.82)	-0.889*** (-3.99)
Firm Growth	0.189** (2.05)	0.184** (2.00)	-0.189** (-2.04)	0.188** (2.03)
Firm Size	-1.417*** (-8.53)	1.434*** (8.62)	-1.419*** (-8.53)	1.389*** (8.33)
Firm Age	5.903*** (4.37)	5.951*** (4.40)	5.918*** (4.37)	6.011*** (4.44)
Return on Assets	0.190*** (5.13)	0.186*** (5.00)	0.190*** (5.12)	0.192*** (5.18)
Moderation Effect: ↓				
Board Gender Diversity	0.211*** (9.97)	0.252*** (6.97)	0.211*** (9.96)	0.211*** (9.99)
Digi*BGD		0.139** (2.41)		
ESG Controversies Score	-0.401*** (-6.94)	-0.403*** (-6.98)	-0.365*** (-4.49)	-0.398*** (-6.90)
Digi*ESG_CON			-0.088** (-2.27)	
R&D Intensity	1.358*** (3.42)	1.357*** (3.42)	1.364*** (3.42)	1.968*** (3.92)
Digi*R&D Intensity				2.495 (1.58)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
R ²	0.4267	0.4278	0.4267	0.4289
F-Test	52.916	48.351	48.049	48.432
Breusch-Pagan test	0.10	0.20	0.20	0.50
(p-value)	(0.9083)	(0.7508)	(0.8998)	(0.8165)
White's test	202.10	208.28	207.72	230.92

⁵² **Note:** The table reports OLS regression results for a full sample on ESG performance. All variables are defined in the Appendix A section of this study, Whereas the t-values adjusted are in Parentheses donated statistical significance at the P < 0.001***; P < 0.05**; P < 0.1*

(p-value)	(0.2708)	(0.7046)	(0.7887)	(0.4507)
No of Observations	725	725	725	725

11.11.4. Table No 4:

⁵³GMM Model of Robustness Check.

Dependent Variable: → ESG Score				
	Model I GMM	Model II GMM	Model III GMM	Model IV GMM
ESG Score _(t-1)	0.701*** (12.02)	0.698*** (11.87)	0.702*** (12.01)	0.699*** (10.75)
Independent Variables: ↓				
Digitalization	5.518*** (3.92)	2.049** (2.43)	1.689** (2.12)	6.933** (2.36)
Control Variables: ↓				
Dividend Per Share yield	0.224** (2.53)	0.238** (2.57)	0.227** (2.54)	0.171** (2.40)
Firm Leverage	-0.214** (-2.26)	-0.225*** (-2.37)	-0.215** (-2.27)	-0.206** (-2.27)
Firm Growth	0.048 (0.62)	0.047 (0.62)	-0.059 (-0.65)	0.047 (0.65)
Firm Size	-0.343 (-0.36)	0.334 (0.35)	-0.344 (-0.36)	0.336 (0.35)
Firm Age	4.215** (2.70)	3.954** (2.65)	4.165** (2.69)	5.52** (2.88)
Return on Assets	0.070 (0.12)	0.090 (0.15)	0.070 (0.12)	0.013 (0.20)
Moderation Effect: ↓				
Board Gender Diversity	0.059** (2.32)	0.086** (2.56)	0.069** (2.33)	0.057** (2.23)
Digi*BGD		0.084* (1.15)		
ESG Controversies Score	-0.011** (-2.59)	-0.014** (-2.81)	-0.026** (-2.57)	-0.012** (-2.62)
Digi*ESG_CON			-0.039 (-0.29)	
R&D Intensity	0.821** (2.07)	0.822** (2.07)	0.819** (2.07)	2.712** (2.97)
Digi*R&D Intensity				3.255 (1.34)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Wald Chi ²	372.661***	380.327***	374.463***	344.174***

⁵³ **Note:** This table displays the robustness results of the whole sample with the Two-Step GMM regression model. The Arellano–Bond test for AR (1) and AR (2) is used to look for possible autocorrelation issues. All variables are defined in the Appendix A section of this study, Whereas the t-values adjusted are in Parentheses donated statistical significance at the P < 0.001***; P < 0.05**; P < 0.1*.

AR (1)	5.87 (0.0000)	5.77 (0.0000)	5.88 (0.0000)	5.65 (0.0000)
AR (2)	-1.57 (0.1162)	-1.64 (0.1992)	-1.56 (0.1178)	-1.49 (0.1343)
Sargan Test (p-value)	40.21 (0.154)	41.89 (0.152)	40.97 (0.155)	33.39 (0.164)
No of Observations	580	580	580	580

11.11.5. Table No 5:

⁵⁴Robustness Check: with lagged values (Lagged OLS Model).

Dependent Variable: → ESG Score				
	Model I OLS	Model II OLS	Model III OLS	Model IV OLS
Independent Variable: ↓				
L.Digitalization	11.209*** (3.65)	4.749** (2.95)	10.196** (2.28)	10.337** (2.30)
Moderation Effect :↓				
L.Board Gender Diversity	0.199*** (8.21)	0.252*** (6.23)	0.199*** (8.20)	0.199*** (8.22)
L.Digi*BGD		0.177* (1.65)		
L.ESG Controversies Score	-0.406*** (-6.05)	-0.419*** (-6.12)	-0.401** (-2.31)	-0.404*** (-6.02)
L.Digi*ESG_CON			-0.010 (-0.03)	
L.R&D Intensity	1.255** (2.77)	1.25** (2.76)	1.255** (2.76)	1.623* (2.68)
L.Digi*R&D Intensity				2.148 (1.22)
Constants	37.631*** (4.59)	35.707*** (4.32)	37.175** (2.06)	37.142*** (4.53)
Control Variables: →	Included	Included	Included	Included
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
R ²	0.416	0.418	0.416	0.417
F-Test	40.457	37.138	36.714	36.947
Breusch-Pagan test (p-value)	0.77 (0.3789)	0.53 (0.5123)	0.77 (0.3799)	0.51 (0.4738)
White's test (p-value)	156.66 (0.8762)	162.87 (0.2105)	161.99 (0.8862)	179.22 (0.7263)
No of Observations	580	580	580	580

⁵⁴ **Note:** This table displays the robustness test results for the OLS regression, incorporating lagged (Independent, Moderating, and Control) variables. The dependent variable in this analysis is ESG Performance. All variables are defined in the Appendix A section of this study, Whereas the t-values adjusted are in Parentheses donated statistical significance at the $P < 0.001$ ***; $P < 0.05$ **; $P < 0.1$ *.

11.12. References

- Agrawal, R., Wankhede, V. A., Kumar, A., Upadhyay, A., & Garza-Reyes, J. A. (2021). Nexus of circular economy and sustainable business performance in the era of digitalization. *International Journal of Productivity and Performance Management*, 71(3), 748–774. <https://doi.org/10.1108/IJPPM-12-2020-0676>
- Ali, S., Muhammad, H., & Migliori, S. (2024). R&D investment and SMEs performance: The role of capital structure decisions. *EuroMed Journal of Business*, ahead-of-print(ahead-of-print). <https://doi.org/10.1108/EMJB-11-2023-0311>
- Ali, S., Rangone, A., & Muhammad, H. (2024). Capital structure decisions and R&D investment: The contingency role of firm size. *Journal of General Management*, 03063070241284895. <https://doi.org/10.1177/03063070241284895>
- AlNuaimi, B. K., Kumar Singh, S., Ren, S., Budhwar, P., & Vorobyev, D. (2022). Mastering digital transformation: The nexus between leadership, agility, and digital strategy. *Journal of Business Research*, 145, 636–648. <https://doi.org/10.1016/j.jbusres.2022.03.038>
- Amit, R., & Han, X. (2017). Value Creation through Novel Resource Configurations in a Digitally Enabled World. *Strategic Entrepreneurship Journal*, 11(3), 228–242. <https://doi.org/10.1002/sej.1256>
- Anastasiadou, E., Alkire, L., & Rëndell, J. (2021). Digitalisation for sustainability: Conceptualisation, Implications and Future Research Directions. In *Management and Information Technology after Digital Transformation*. Routledge.
- Andronie, M., Iatagan, M., Uță, C., Hurloiu, I., Dijmărescu, A., & Dijmărescu, I. (2023). Big data management algorithms in artificial Internet of Things-based fintech. *Oeconomia Copernicana*, 14(3), Article 3. <https://doi.org/10.24136/oc.2023.023>
- Aouadi, A., & Marsat, S. (2018a). Do ESG Controversies Matter for Firm Value? Evidence from International Data. *Journal of Business Ethics*, 151(4), 1027–1047. <https://doi.org/10.1007/s10551-016-3213-8>
- Aouadi, A., & Marsat, S. (2018b). Do ESG Controversies Matter for Firm Value? Evidence from International Data. *Journal of Business Ethics*, 151(4), 1027–1047. <https://doi.org/10.1007/s10551-016-3213-8>

- Arellano, M., & Bond, S. (1991). Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations. *The Review of Economic Studies*, 58(2), 277–297. <https://doi.org/10.2307/2297968>
- Arvidsson, S., & Dumay, J. (2022). Corporate ESG reporting quantity, quality and performance: Where to now for environmental policy and practice? *Business Strategy and the Environment*, 31(3), 1091–1110. <https://doi.org/10.1002/bse.2937>
- Bahadori, N., Kaymak, T., & Seraj, M. (2021). Environmental, social, and governance factors in emerging markets: The impact on firm performance. *Business Strategy & Development*, 4(4), 411–422. <https://doi.org/10.1002/bsd2.167>
- Banerjee, R., & Gupta, K. (2019). The effect of environmentally sustainable practices on firm R&D: International evidence. *Economic Modelling*, 78, 262–274. <https://doi.org/10.1016/j.econmod.2018.09.024>
- Benlemlih, M., & Girerd-Potin, I. (2017). Corporate social responsibility and firm financial risk reduction: On the moderating role of the legal environment. *Journal of Business Finance & Accounting*, 44(7–8), 1137–1166. <https://doi.org/10.1111/jbfa.12251>
- Benlemlih, M., Shaukat, A., Qiu, Y., & Trojanowski, G. (2018). Environmental and Social Disclosures and Firm Risk. *Journal of Business Ethics*, 152(3), 613–626. <https://doi.org/10.1007/s10551-016-3285-5>
- Bhagat, P. R., Naz, F., & Magda, R. (2022). Role of Industry 4.0 Technologies in enhancing sustainable firm performance and green practices. *Acta Polytechnica Hungarica*, 19(8), 229–248.
- Bican, P. M., & Brem, A. (2020). Digital Business Model, Digital Transformation, Digital Entrepreneurship: Is there a sustainable ‘digital’? *Sustainability (Switzerland)*, 12(13). <https://doi.org/10.3390/su12135239>
- Brinette, S., Sonmez, F. D., & Tournus, P. S. (2024). ESG Controversies and Firm Value: Moderating Role of Board Gender Diversity and Board Independence. *IEEE Transactions on Engineering Management*, 71, 4298–4307. *IEEE Transactions on Engineering Management*. <https://doi.org/10.1109/TEM.2023.3236667>
- Broccardo, L., Truant, E., & Dana, L.-P. (2023). The interlink between digitalization, sustainability, and performance: An Italian context. *Journal of Business Research*, 158, 113621. <https://doi.org/10.1016/j.jbusres.2022.113621>

- Brown, J. R., Fazzari, S. M., & Petersen, B. C. (2009). Financing Innovation and Growth: Cash Flow, External Equity, and the 1990s R&D Boom. *The Journal of Finance*, 64(1), 151–185. <https://doi.org/10.1111/j.1540-6261.2008.01431.x>
- Brown, J. R., Martinsson, G., & Petersen, B. C. (2012). Do financing constraints matter for R&D? *European Economic Review*, 56(8), 1512–1529. <https://doi.org/10.1016/j.euroecorev.2012.07.007>
- Burgess, Z., & Tharenou, P. (2002). Women Board Directors: Characteristics of the Few. *Journal of Business Ethics*, 37(1), 39–49. <https://doi.org/10.1023/A:1014726001155>
- Cai, Y., Jo, H., & Pan, C. (2012). Doing Well While Doing Bad? CSR in Controversial Industry Sectors. *Journal of Business Ethics*, 108(4), 467–480. <https://doi.org/10.1007/s10551-011-1103-7>
- Cai, Y., Pan, C. H., & Statman, M. (2016). Why do countries matter so much in corporate social performance? *Journal of Corporate Finance*, 41, 591–609. <https://doi.org/10.1016/j.jcorpfin.2016.09.004>
- Cappa, F., Oriani, R., Peruffo, E., & McCarthy, I. (2021). Big Data for Creating and Capturing Value in the Digitalized Environment: Unpacking the Effects of Volume, Variety, and Veracity on Firm Performance*. *Journal of Product Innovation Management*, 38(1), 49–67. <https://doi.org/10.1111/jpim.12545>
- Cardinali, P. G., & De Giovanni, P. (2022). Responsible digitalization through digital technologies and green practices. *Corporate Social Responsibility and Environmental Management*, 29(4), 984–995. <https://doi.org/10.1002/csr.2249>
- Chen, Y. (2020). Improving market performance in the digital economy. *China Economic Review*, 62, 101482. <https://doi.org/10.1016/j.chieco.2020.101482>
- Cheng, R., Ho, C.-Y., & Huang, S. (2023). Digitalization and firm performance: Channels and heterogeneities. *Applied Economics Letters*, 30(17), 2401–2406. <https://doi.org/10.1080/13504851.2022.2097178>
- Chouaibi, S., & Chouaibi, J. (2021). Social and ethical practices and firm value: The moderating effect of green innovation: evidence from international ESG data. *International Journal of Ethics and Systems*, 37(3), 442–465. <https://doi.org/10.1108/IJOES-12-2020-0203>
- Cirillo, V., Fanti, L., Mina, A., & Ricci, A. (2023). New digital technologies and firm performance in the Italian economy. *Industry and Innovation*, 30(1), 159–188.

- Curran, G. (2017). Social licence, corporate social responsibility and coal seam gas: Framing the new political dynamics of contestation. *Energy Policy*, 101, 427–435.
<https://doi.org/10.1016/j.enpol.2016.10.042>
- Danneels, L., & Viaene, S. (2022). Identifying Digital Transformation Paradoxes. *Business & Information Systems Engineering*, 64(4), 483–500. <https://doi.org/10.1007/s12599-021-00735-7>
- Dilling, P. F. A., & Harris, P. (2018). Reporting on long-term value creation by Canadian companies: A longitudinal assessment. *Journal of Cleaner Production*, 191, 350–360.
<https://doi.org/10.1016/j.jclepro.2018.03.286>
- Doh, J. P., Howton, S. D., Howton, S. W., & Siegel, D. S. (2010). Does the Market Respond to an Endorsement of Social Responsibility? The Role of Institutions, Information, and Legitimacy. *Journal of Management*, 36(6), 1461–1485. <https://doi.org/10.1177/0149206309337896>
- Dong, S., & Xu, L. (2016). The impact of explicit CSR regulation: Evidence from China's mining firms. *Journal of Applied Accounting Research*, 17(2), 237–258. Scopus. <https://doi.org/10.1108/JAAR-03-2014-0030>
- Eliwa, Y., Aboud, A., & Saleh, A. (2021). ESG practices and the cost of debt: Evidence from EU countries. *Critical Perspectives on Accounting*, 79, 102097.
<https://doi.org/10.1016/j.cpa.2019.102097>
- Elmghaamez, I. K., Nwachukwu, J., & Ntim, C. G. (2024). ESG disclosure and financial performance of multinational enterprises: The moderating effect of board standing committees. *International Journal of Finance & Economics*, 29(3), 3593–3638. <https://doi.org/10.1002/ijfe.2846>
- Esposito De Falco, S., Scandurra, G., & Thomas, A. (2021). How stakeholders affect the pursuit of the Environmental, Social, and Governance. Evidence from innovative small and medium enterprises. *Corporate Social Responsibility and Environmental Management*, 28(5), 1528–1539.
<https://doi.org/10.1002/csr.2183>
- E-Vahdati, S., & Binesh, F. (2022). The impact of CEO's attributes on R&D intensity and ESG practices. *Spanish Journal of Finance and Accounting / Revista Española de Financiación y Contabilidad*, 51(3), 326–349. <https://doi.org/10.1080/02102412.2021.1944459>
- Fang, M., Nie, H., & Shen, X. (2023). Can enterprise digitization improve ESG performance? *Economic Modelling*, 118, 106101. <https://doi.org/10.1016/j.econmod.2022.106101>

- Fatima, T., & Elbanna, S. (2023). Corporate Social Responsibility (CSR) Implementation: A Review and a Research Agenda Towards an Integrative Framework. *Journal of Business Ethics*, 183(1), 105–121. <https://doi.org/10.1007/s10551-022-05047-8>
- Fernando, S., & Lawrence, S. (2014). A theoretical framework for CSR practices: Integrating legitimacy theory, stakeholder theory and institutional theory. *Journal of Theoretical Accounting Research*, 10, 149–178.
- Ferrell, A., Liang, H., & Renneboog, L. (2016). Socially responsible firms. *Journal of Financial Economics*, 122(3), 585–606. <https://doi.org/10.1016/j.jfineco.2015.12.003>
- Freeman, R. E. (2010). *Strategic Management: A Stakeholder Approach*. Cambridge University Press.
- Garcia, A. S., Mendes-Da-Silva, W., & Orsato, R. J. (2017). Sensitive industries produce better ESG performance: Evidence from emerging markets. *Journal of Cleaner Production*, 150, 135–147. <https://doi.org/10.1016/j.jclepro.2017.02.180>
- Ghardallou, W. (2022). Corporate Sustainability and Firm Performance: The Moderating Role of CEO Education and Tenure. *Sustainability (Switzerland)*, 14(6). <https://doi.org/10.3390/su14063513>
- Gouvea, R., Li, S., & Montoya, M. (MJR). (2022). Does transitioning to a digital economy imply lower levels of corruption? *Thunderbird International Business Review*, 64(3), 221–233. <https://doi.org/10.1002/tie.22265>
- Gu, J. (2024). Digitalization, Spillover and Environmental, Social, and Governance Performance: Evidence From China. *The Journal of Environment & Development*, 33(2), 286–311. <https://doi.org/10.1177/10704965231225781>
- Gulamhussen, M. A., & Santa, S. F. (2015). Female directors in bank boardrooms and their influence on performance and risk-taking. *Global Finance Journal*, 28, 10–23. <https://doi.org/10.1016/j.gfj.2015.11.002>
- Guo, X., Li, M., Wang, Y., & Mardani, A. (2023). Does digital transformation improve the firm's performance? From the perspective of digitalization paradox and managerial myopia. *Journal of Business Research*, 163, 113868.
- Haq, I. U., & Huo, C. (2023). Digital strategy and environmental performance: The mediating role of digitalization in SMEs. *Digital Economy and Sustainable Development*, 1(1), 9. <https://doi.org/10.1007/s44265-023-00010-5>

- Hegde, S. P., & Mishra, D. R. (2019). Married CEOs and corporate social responsibility. *Journal of Corporate Finance*, 58, 226–246. <https://doi.org/10.1016/j.jcorpfin.2019.05.003>
- Hillman, A. J., & Keim, G. D. (2001). Shareholder value, stakeholder management, and social issues: What's the bottom line? *Strategic Management Journal*, 22(2), 125–139. [https://doi.org/10.1002/1097-0266\(200101\)22:2<125::AID-SMJ150>3.0.CO;2-H](https://doi.org/10.1002/1097-0266(200101)22:2<125::AID-SMJ150>3.0.CO;2-H)
- Hinings, B., Gegenhuber, T., & Greenwood, R. (2018). Digital innovation and transformation: An institutional perspective. *Information and Organization*, 28(1), 52–61. <https://doi.org/10.1016/j.infoandorg.2018.02.004>
- Hoffmann, J., & Kristensen, M. E. (2017). Sustainable oil and profitable wind: The communication of corporate responsibilities as inverted positioning. *Nordicom Review*, 38(2), 79–96.
- Hollos, D., Blome, C., & Foerstl, K. (2012). Does sustainable supplier co-operation affect performance? Examining implications for the triple bottom line. *International Journal of Production Research*, 50(11), 2968–2986. <https://doi.org/10.1080/00207543.2011.582184>
- Horbach, J., & Jacob, J. (2018). The relevance of personal characteristics and gender diversity for (eco-)innovation activities at the firm-level: Results from a linked employer–employee database in Germany. *Business Strategy and the Environment*, 27(7), 924–934. <https://doi.org/10.1002/bse.2042>
- Huang, J., Zhao, J., & Cao, J. (2021). Environmental regulation and corporate R&D investment—Evidence from a quasi-natural experiment. *International Review of Economics & Finance*, 72, 154–174. <https://doi.org/10.1016/j.iref.2020.11.018>
- Huang, Q., Xu, C., Xue, X., & Zhu, H. (2023). Can digital innovation improve firm performance: Evidence from digital patents of Chinese listed firms. *International Review of Financial Analysis*, 89, 102810. <https://doi.org/10.1016/j.irfa.2023.102810>
- Johnson, H. H. (2003). Does it pay to be good? Social responsibility and financial performance. *Business Horizons*, 46(6), 34–40. [https://doi.org/10.1016/S0007-6813\(03\)00086-7](https://doi.org/10.1016/S0007-6813(03)00086-7)
- Khattak, A., Tabash, M. I., Yousaf, Z., Radulescu, M., Nassani, A. A., & Haffar, M. (2021). Towards innovation performance of SMEs: Investigating the role of digital platforms, innovation culture and frugal innovation in emerging economies. *Journal of Entrepreneurship in Emerging Economies*, 14(5), 796–811. <https://doi.org/10.1108/JEEE-08-2021-0318>

- Kuo, L., & Chen, V. Y.-J. (2013). Is environmental disclosure an effective strategy on establishment of environmental legitimacy for organization? *Management Decision*, 51(7), 1462–1487. Scopus. <https://doi.org/10.1108/MD-06-2012-0395>
- Kyaw, K., Olugbode, M., & Petracci, B. (2017). Can board gender diversity promote corporate social performance? *Corporate Governance (Bingley)*, 17(5), 789–802. Scopus. <https://doi.org/10.1108/CG-09-2016-0183>
- Lăzăroiu, G., Bogdan, M., Geamănu, M., Hurloiu, L., Luminița, L., & Ștefănescu, R. (2023). Artificial intelligence algorithms and cloud computing technologies in blockchain-based fintech management. *Oeconomia Copernicana*, 14(3), Article 3. <https://doi.org/10.24136/oc.2023.021>
- Li, J., Haider, Z. A., Jin, X., & Yuan, W. (2019). Corporate controversy, social responsibility and market performance: International evidence. *Journal of International Financial Markets, Institutions and Money*, 60, 1–18. <https://doi.org/10.1016/j.intfin.2018.11.013>
- Li, T.-T., Wang, K., Sueyoshi, T., & Wang, D. D. (2021). ESG: Research Progress and Future Prospects. *Sustainability*, 13(21), Article 21. <https://doi.org/10.3390/su132111663>
- Lin, S., Lin, J., Han, F., & Luo, X. (Robert). (2022). How big data analytics enables the alliance relationship stability of contract farming in the age of digital transformation. *Information & Management*, 59(6), 103680. <https://doi.org/10.1016/j.im.2022.103680>
- Lozano, R. (2011). Addressing stakeholders and better contributing to sustainability through game theory. *Journal of Corporate Citizenship*, 43, 45–62.
- LSEG Annual Report—2023 _ Partnering to transform.pdf*. (n.d.).
- Lseg-sustainability-databook-2023 (2).pdf*. (n.d.).
- Meng, S., Su, H., & Yu, J. (2022). Digital Transformation and Corporate Social Performance: How Do Board Independence and Institutional Ownership Matter? *Frontiers in Psychology*, 13. <https://doi.org/10.3389/fpsyg.2022.915583>
- Mikalef, P., van de Wetering, R., & Krogstie, J. (2021). Building dynamic capabilities by leveraging big data analytics: The role of organizational inertia. *Information & Management*, 58(6), 103412. <https://doi.org/10.1016/j.im.2020.103412>

- Muhammad, H., & Ali, S. (n.d.). The interplay of board gender diversity, debt financing, and sustainable investment: Evidence from Europe. *Journal of Sustainable Finance & Investment*, 0(0), 1–21. <https://doi.org/10.1080/20430795.2024.2414245>
- Muhammad, H., & Migliori, S. (2023). Effects of board gender diversity and sustainability committees on environmental performance: A quantile regression approach. *Journal of Management & Organization*, 29(6), 1051–1076. <https://doi.org/10.1017/jmo.2022.8>
- Muhammad, H., Migliori, S., & Consorti, A. (2024). Corporate governance and R&D investment: Does firm size matter? *Technology Analysis & Strategic Management*, 36(3), 518–532. <https://doi.org/10.1080/09537325.2022.2042508>
- Muhammad, H., Migliori, S., & Mohsni, S. (2022a). Corporate governance and firm risk-taking: The moderating role of board gender diversity. *Meditari Accountancy Research*, 31(3), 706–728. <https://doi.org/10.1108/MEDAR-07-2020-0949>
- Muhammad, H., Migliori, S., & Mohsni, S. (2022b). Corporate governance and R&D investment: The role of debt financing. *Industrial and Corporate Change*, 31(3), 628–653. <https://doi.org/10.1093/icc/dtab056>
- Muhammad, H., Paolone, F., & Migliori, S. (2024). Board gender diversity and accounting conservatism: The role of corporate social responsibility. *Sustainability Accounting, Management and Policy Journal*, ahead-of-print(ahead-of-print). <https://doi.org/10.1108/SAMPJ-11-2023-0835>
- Nirino, N., Santoro, G., Miglietta, N., & Quaglia, R. (2021). Corporate controversies and company's financial performance: Exploring the moderating role of ESG practices. *Technological Forecasting and Social Change*, 162, 120341. <https://doi.org/10.1016/j.techfore.2020.120341>
- Orazalin, N. (2020). Do board sustainability committees contribute to corporate environmental and social performance? The mediating role of corporate social responsibility strategy. *Business Strategy and the Environment*, 29(1), 140–153. <https://doi.org/10.1002/bse.2354>
- Peng, Y., & Tao, C. (2022). Can digital transformation promote enterprise performance? —From the perspective of public policy and innovation. *Journal of Innovation & Knowledge*, 7(3), 100198. <https://doi.org/10.1016/j.jik.2022.100198>
- Pulino, S. C., Ciaburri, M., Magnanelli, B. S., & Nasta, L. (2022). Does ESG Disclosure Influence Firm Performance? *Sustainability (Switzerland)*, 14(13). <https://doi.org/10.3390/su14137595>

- Qi, Y., Han, M., & Zhang, C. (2024). The Synergistic Effects of Digital Technology Application and ESG Performance on Corporate Performance. *Finance Research Letters*, 61, 105007. <https://doi.org/10.1016/j.frl.2024.105007>
- Ramadhan, M. A., Mulyany, R., & Mutia, E. (2023). The irrelevance of R&D intensity in the ESG disclosure? Insights from top 10 listed companies on global Islamic indices. *Cogent Business & Management*, 10(1), 2187332. <https://doi.org/10.1080/23311975.2023.2187332>
- Ratajczak-Mrozek, M., & Marszałek, P. (Eds.). (2022). *Digitalization and Firm Performance: Examining the Strategic Impact*. Springer International Publishing. <https://doi.org/10.1007/978-3-030-83360-2>
- Rauf, F., Wanqiu, W., Naveed, K., Qadri, S. U., & Ali, M. S. e. (2024). How ESG reporting is effected by sustainable finance and green innovation: Moderating role of sales growth. *Environmental Science and Pollution Research*, 31(5), 7246–7263. <https://doi.org/10.1007/s11356-023-31479-4>
- Refinitiv Eikon. (n.d.). Retrieved 15 November 2024, from <https://eikon.refinitiv.com/>
- Reguera-Alvarado, N., de Fuentes, P., & Laffarga, J. (2017). Does Board Gender Diversity Influence Financial Performance? Evidence from Spain. *Journal of Business Ethics*, 141(2), 337–350. <https://doi.org/10.1007/s10551-015-2735-9>
- Ren, C., Lee, S.-J., & Hu, C. (2023). Digitalization Improves Enterprise Performance: New Evidence by Text Analysis. *Sage Open*, 13(2), 21582440231175871. <https://doi.org/10.1177/21582440231175871>
- Ren, X., Zeng, G., & Zhao, Y. (2023). Digital finance and corporate ESG performance: Empirical evidence from listed companies in China. *Pacific-Basin Finance Journal*, 79, 102019. <https://doi.org/10.1016/j.pacfin.2023.102019>
- Ribeiro-Navarrete, S., Botella-Carrubi, D., Palacios-Marqués, D., & Orero-Blat, M. (2021). The effect of digitalization on business performance: An applied study of KIBS. *Journal of Business Research*, 126, 319–326. <https://doi.org/10.1016/j.jbusres.2020.12.065>
- Roodman, D. (2009). How to do Xtabond2: An Introduction to Difference and System GMM in Stata. *The Stata Journal*, 9(1), 86–136. <https://doi.org/10.1177/1536867X0900900106>
- Rozeboom, G. J. (2021). Grow the Pie: How Great Companies Deliver Both Purpose and Profit, by Alex Edmans. Cambridge: Cambridge University Press, 2020. 382 pp. *Business Ethics Quarterly*, 31(4), 644–647. <https://doi.org/10.1017/beq.2021.29>

- Rusch, M., Schöggl, J.-P., & Baumgartner, R. J. (2023). Application of digital technologies for sustainable product management in a circular economy: A review. *Business Strategy and the Environment*, 32(3), 1159–1174. <https://doi.org/10.1002/bse.3099>
- Serafeim, G. (2015). Integrated Reporting and Investor Clientele. *Journal of Applied Corporate Finance*, 27(2), 34–51. <https://doi.org/10.1111/jacf.12116>
- Shakil, M. H. (2021). Environmental, social and governance performance and financial risk: Moderating role of ESG controversies and board gender diversity. *Resources Policy*, 72, 102144. <https://doi.org/10.1016/j.resourpol.2021.102144>
- Shakil, M. H., Munim, Z. H., Zamore, S., & Tasnia, M. (2024). Sustainability and financial performance of transport and logistics firms: Does board gender diversity matter? *Journal of Sustainable Finance & Investment*, 14(1), 100–115. <https://doi.org/10.1080/20430795.2022.2039998>
- Shakil, M. H., Tasnia, M., & Mostafiz, M. I. (2020). Board gender diversity and environmental, social and governance performance of US banks: Moderating role of environmental, social and corporate governance controversies. *International Journal of Bank Marketing*, 39(4), 661–677. <https://doi.org/10.1108/IJBM-04-2020-0210>
- Shang, Y., Raza, S. A., Huo, Z., Shahzad, U., & Zhao, X. (2023). Does enterprise digital transformation contribute to the carbon emission reduction? Micro-level evidence from China. *International Review of Economics & Finance*, 86, 1–13. <https://doi.org/10.1016/j.iref.2023.02.019>
- Siddik, M. A. B., Shehabi, A., & Marston, L. (2021). The environmental footprint of data centers in the United States. *Environmental Research Letters*, 16(6), 064017. <https://doi.org/10.1088/1748-9326/abfb1>
- Sila, V., Gonzalez, A., & Hagendorff, J. (2016). Women on board: Does boardroom gender diversity affect firm risk? *Journal of Corporate Finance*, 36, 26–53. <https://doi.org/10.1016/j.jcorpfin.2015.10.003>
- Tariq, W., Chen, Y., Tariq, A., & Torkkeli, M. (2024). Breaking the glass ceiling in banking: The impact of female directors, digitalization, and income diversification on financial stability. *The Bottom Line, ahead-of-print*(ahead-of-print). <https://doi.org/10.1108/BL-08-2023-0234>
- Trittin-Ulbrich, H., Scherer, A. G., Munro, I., & Whelan, G. (2021). Exploring the dark and unexpected sides of digitalization: Toward a critical agenda. *Organization*, 28(1), 8–25. <https://doi.org/10.1177/1350508420968184>

- Tuyen, B. Q., Phuong Anh, D. V., Mai, N. P., & Long, T. Q. (2023). Does corporate engagement in social responsibility affect firm innovation? The mediating role of digital transformation. *International Review of Economics & Finance*, 84, 292–303. <https://doi.org/10.1016/j.iref.2022.11.005>
- Verhoef, P. C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Qi Dong, J., Fabian, N., & Haenlein, M. (2021). Digital transformation: A multidisciplinary reflection and research agenda. *Journal of Business Research*, 122, 889–901. <https://doi.org/10.1016/j.jbusres.2019.09.022>
- Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *The Journal of Strategic Information Systems*, 28(2), 118–144. <https://doi.org/10.1016/j.jsis.2019.01.003>
- Wang, D., & Xia, X. (2024). The impact of digital transformation on firms' value: Examining the role of ESG performance and the effect of information interaction. *Business Process Management Journal*, 30(4), 1236–1265. <https://doi.org/10.1108/BPMJ-06-2023-0469>
- Wang, S., & Esperança, J. P. (2023a). Can digital transformation improve market and ESG performance? Evidence from Chinese SMEs. *Journal of Cleaner Production*, 419, 137980. <https://doi.org/10.1016/j.jclepro.2023.137980>
- Wang, S., & Esperança, J. P. (2023b). Can digital transformation improve market and ESG performance? Evidence from Chinese SMEs. *Journal of Cleaner Production*, 419, 137980. <https://doi.org/10.1016/j.jclepro.2023.137980>
- Wang, Z., Lin, S., Chen, Y., Lyulyov, O., & Pimonenko, T. (2023). Digitalization effect on business performance: Role of business model innovation. *Sustainability*, 15(11), Article 11.
- Wen, H., Zhong, Q., & Lee, C.-C. (2022). Digitalization, competition strategy and corporate innovation: Evidence from Chinese manufacturing listed companies. *International Review of Financial Analysis*, 82, 102166. <https://doi.org/10.1016/j.irfa.2022.102166>
- Wu, K., & Lu, Y. (2023). Corporate digital transformation and financialization: Evidence from Chinese listed firms. *Finance Research Letters*, 57, 104229. <https://doi.org/10.1016/j.frl.2023.104229>
- Xu, C., Chen, X., & Dai, W. (2022). Effects of Digital Transformation on Environmental Governance of Mining Enterprises: Evidence from China. *International Journal of Environmental Research and Public Health*, 19(24), Article 24. <https://doi.org/10.3390/ijerph192416474>
- Yang, X., & Han, Q. (2024). Nonlinear effects of enterprise digital transformation on environmental, social and governance (ESG) performance: Evidence from China. *Sustainability Accounting, Management and Policy Journal*, 15(2), 355–381. <https://doi.org/10.1108/SAMPJ-08-2023-0553>

Zhong, X., & Ren, G. (2023). Independent and joint effects of CSR and CSI on the effectiveness of digital transformation for transition economy firms. *Journal of Business Research*, 156, 113478.
<https://doi.org/10.1016/j.jbusres.2022.113478>

12. APPENDIX SECTION

12.1. Appendix A Paper 1:

Haseeb, M. (2024). Supplementary/Additional data file for the manuscript titled: *When Digitalization Meets Sustainability: Insights from a Bibliometric and Systematic Literature Review of its Impacts on Firm Performance*. <https://doi.org/10.5281/zenodo.13305800>

12.2. Appendix B Paper 2:

Table B1.**⁵⁵Thesaurus of Digitalization-related All Keywords**

Digitalization-related keywords
‘Big Data’, ‘Cloud Computing’, ‘Artificial Intelligence’, ‘Data Management’, ‘Data Mining’, ‘Data Network’, ‘Data Platform’, ‘Data Center’, ‘Data Science’, ‘Digital Control’, ‘Digital Technology’, ‘Digital Communication’, ‘Digital Network’, ‘Digital Intelligence’, ‘Digital Terminal’, ‘Digital Marketing’, ‘Digitalization’, ‘Cloud IT’, ‘Cloud Ecology’, ‘Cloud Services’, ‘Cloud Platform’, ‘Blockchain’, ‘Internet Of Things’, ‘Machine Learning’, ‘ERP’, ‘High-end Intelligence’, ‘Industrial Intelligence’, ‘Mobile Intelligence’, ‘Smart Control’, ‘Smart Terminal’, ‘Smart Mobile’, ‘Smart Management’, ‘Smart Factory’, ‘Smart Logistics’, ‘Smart Manufacturing’, ‘Smart Storage’, ‘Smart Technology’, ‘Smart Equipment’, ‘Smart Production’, ‘Intelligent Network’, ‘Intelligent System’, ‘Intelligent’, ‘Automatic Control’, ‘Automatic Monitoring’, ‘Automatic Inspection’, ‘Automatic Production’, ‘CNC Integration’, ‘Integration’, ‘Integrated Solution’, ‘Integrated Control’, ‘Integrated System’, ‘Industrial Cloud’, ‘Factory of the Future’, ‘Intelligent Troubleshooting’, ‘Lifecycle Management’, ‘Manufacturing Execution System’, ‘Virtualization’, ‘Virtual Manufacturing’, ‘AI’, ‘CAD’, ‘CAM’, ‘Computer-Aided Design’, ‘Computer-Aided Manufacturing’, ‘Information Sharing’, ‘Information Management’, ‘Information Integration’, ‘Information Software’, ‘Information System’, ‘Information Network’, ‘Information Terminal’, ‘Information Center’, ‘Informatization’, ‘Networking’, ‘Industrial Information’, ‘Industrial Communication’, ‘E-Commerce’, ‘Internet Marketing’, ‘Mobile Internet’, ‘Industrial Internet’, ‘Industrial Internet’, ‘Internet Solutions’, ‘Internet Technology’, ‘Internet Thinking’, ‘Internet Action’, ‘Internet Business’, ‘Internet Mobile’, ‘Internet Application’, ‘Internet Strategy’, ‘Internet Platform’, ‘Internet Model’, ‘Internet Business Model’, ‘Internet Ecology’, ‘E-Commerce’, ‘Online Sales’, ‘Internet’, ‘Internet+’, ‘Online to Offline’, ‘Online and Offline’, ‘O2O’, ‘B2B’, ‘C2C’, ‘B2C’, ‘C2B’, ‘5G’, ‘WeChat’, ‘Intranet’

⁵⁵ **Note:** This thesaurus of digitalization-related keywords has been employed in the scholarly literature (Ratajczak-Mrozek & Marszałek, 2022; Schultz et al., 2013; Fang et al., 2023) to assess the level of digitalization empirically within firms.

Table B2

⁵⁶**Components of the LSEG Annual Sustainability Report 2023.**

Pillars	Categories	Themes
Environmental	Emission	Emissions
		Waste
		Biodiversity* ⁵⁷
		Environment management system*
	Innovation	Product Innovation
		Green revenues, research and development (R&D), and Capital expenditures (CapEx)
	Resource Use	Water
		Energy
		Sustainable packaging*
Social	Community	Environmental Supply Chain*
		Equally important to all industry groups. Hence, a median weight of five is assigned to all.
	Human rights	Human rights
		Responsible marketing
	Product responsibility	Product Quality
		Data privacy
		Diversity and inclusion
		Career development and training
		Working conditions
Governance	Workforce	Health and Safety
		CSR strategy
	CSR strategy	ESG reporting and transparency
		Structure (independence, diversity, committees)
	Management	Compensation
		Shareholder rights
	Shareholders	Takeover defenses

⁵⁶ **Note:** This table provides an overview of ESG themes or pillar scores in each firm's Environment, Social, and Governance (ESG) performance. Each pillar score or performance indicator included multiple themes or topics of concern for in-depth examination. For more information, consult the LSEG annual sustainability report 2023.

⁵⁷* No data points available that may be used as a proxy for ESG magnitude/materiality.

Table B3

⁵⁸Source of Variables and Explanations.

Variables	Definition	Source
ESG Overall Performance	Refinitiv ESG score is an overall company score based on the self-reported information in the environmental, social, and corporate governance pillars.	Refinitiv (Eikon)
Environmental Pillar Score	The environmental pillar measures a company's impact on living and non-living natural systems, including the air, land, and water, as well as complete ecosystems. It reflects how well a company uses best management practices to avoid environmental risks and capitalize on environmental opportunities in order to generate long-term shareholder value.	Refinitiv (Eikon)
Social Pillar Score	The social pillar measures a company's capacity to generate trust and loyalty with its workforce, customers, and society through its use of best management practices. It is a reflection of the company's reputation and the health of its license to operate, which are key factors in determining its ability to generate long-term shareholder value.	Refinitiv (Eikon)
Governance Pillar Score	The corporate governance pillar measures a company's systems and processes, which ensure that its board members and executives act in the best interests of its long-term shareholders. It reflects a company's capacity, through its use of the best management practices, to direct and control its rights and responsibilities through the creation of incentives, as well as checks and balances, in order to generate long-term shareholder value.	Refinitiv (Eikon)
Digitalization	The author's calculation is based on the text of the company's annual reports, equaling the number of digitalization keywords over all words in the "Management Discussion and Analysis" section of the annual reports of the listed companies.	Author's Calculation
Book value Per Share	This is the ratio of total equity at the end of the fiscal period to basic weighted average shares outstanding for the same period.	Refinitiv (Eikon)
Earnings Per Share	The statistical average of all broker estimates was determined to be on the majority accounting basis. Earning per share is defined as the EPS that the contributing analyst considers to be that with which to value a security. This figure may include or exclude certain items depending on the contributing analyst's specific model.	Refinitiv (Eikon)
Firm Size	(Market capitalization+ Book value of total debt)/Total Assets. Total Debt includes short and long-term debt for the most recent fiscal period. Enterprise value represents the sum of market capitalization, total debt, preferred stock, and minority interest minus cash and short-term investments for the most recent fiscal period. Market Capitalization is calculated by multiplying the current total shares outstanding by the latest close price. For banks, cash and due from banks are considered in place of cash and short-term investments.	Refinitiv (Eikon)
Firm Growth	(Current year operating revenue/previous year operating revenue) -1 / 100. The difference between the firm's current period value and the previous year's period value divided by the previous year's (ending) value multiplied by 100	Refinitiv (Eikon)
Leverage	The leverage ratio is calculated by dividing the total debt balance by EBITDA in the coinciding period.	Refinitiv (Eikon)
Assets Turnover	To calculate this divide net sales or revenue by the average total assets. Net sales is the total amount of revenue retained by a company. Its gross sales from a specific period have fewer returns, allowances or discounts from customers.	Refinitiv (Eikon)
Return on Assets	This value is calculated as the income after taxes for the fiscal period divided by the average total assets and is expressed as a percentage. Average total assets are the average of total assets at the beginning and the end of the year.	Refinitiv (Eikon)
Years (2015 – 2022)	Years dummy (fixed effect included)	Author's Calculation

⁵⁸ **Note:** This table list includes definitions and sources of all variables that are used in this study.

Industry	Industry dummy (fixed effect Included)	Author's Calculation
----------	--	-------------------------

12.3. Appendix C Paper 3:

Table C1:**⁵⁹Thesaurus of Keywords Associated with Digitalization.**

Level	Indicators	Digitalization related keywords
Technology	<i>Big data</i> →	Big data, data mining, text mining, virtual reality, mixed reality, heterogeneous data, credit reporting, data visualization, and augmented reality
	<i>Blockchain</i> →	Smart contracts, decentralization, digital currency, differential privacy technology, consensus mechanism, distributed computing, and blockchain.
	<i>Artificial intelligence</i> →	Face recognition, identity verifications, biometrics, image understanding, voice recognition, semantic search, investment decisions support system, machine learning, deep learning, business intelligence, artificial intelligence, and natural language processing.
	<i>Cloud computing</i> →	Graph computing, cloud computing, in-memory computing, green computing, multi-party secure computing, brain-like computing, streaming computing, cognitive computing, fusion architecture, information physics system, billion-level co-currency, and EB-level storage.
Applications		B2B, B2C, C2B, C2C, Fintech, NFC payment, O2O, third-party payment, e-commerce, Industrial Internet, Internet Finance, Internet health, Financial technology, Open banking, Quantitative finance, Digital Finance, Digital marketing, Internet connection, Unnamed retail, Internet of Things, Mobile Internet, Mobile Payment, Smart Agriculture, Smart Wears, Smart grid, Smart environmental protection, smart robots, smart home, intelligent transportation, intelligent financial contracts, intelligent customer services, intelligent energy, intelligent data analysis, intelligent investment advisory, intelligent culture and tourism, intelligent healthcare, intelligent marketing, and autonomous driving.

⁵⁹ **Note:** The following thesaurus includes a comprehensive compilation of keywords associated with digitalization. These keywords have been utilized in scholarly literature to quantitatively assess the degree of digitalization within firms.

Table C2.

⁶⁰Source of Variables, Definition, and Measurement

Variable Categories	Variable	Description	Sources
Dependent Variables →			
	ESG Performance/Score	Refinitiv ESG Score is an overall company score based on the self-reported information in the environmental, social, and corporate governance pillars.	Refinitiv (Eikon)
Independent Variables →			
	Digitalization	The author's calculation is based on the text of the company's annual reports, equaling the number of digitalization keywords over all words in the "Management Discussion and Analysis" section of the listed companies' annual reports.	Author's calculation
Moderating Variables →			
	Board Gender Diversity	Percentage of female members or directors on the technological sector firm's board.	Refinitiv (Eikon)
	ESG Controversies	The ESG Controversies category measures a company's exposure to environmental, social, and governance controversies and negative events in global media.	Refinitiv (Eikon)
	Research and Development Intensity	The company's actual value normalized to reflect the I/B/E/S default currency and corporate actions (e.g. stock splits). R&D expenses and research and development expenses incurred for a given period. It's calculated by dividing total R&D spending into total revenue.	Refinitiv (Eikon)
Moderation Effects →			

⁶⁰ **Note:** This table list includes definitions and sources of all variables used in this study.

Control Variables →	Digi X BGD	Interaction of Digitalization term with Board Gender Diversity.	Author's calculation
	Digi X ESG_CON	Interaction of Digitalization Terms with ESG Controversies Score	Author's calculation
	Digi X R&D Intensity	Interaction of Digitalization term with R&D Intensity	Author's calculation
	Dividend Per Share yield	Dividends per share are a corporation's annual common stock dividends divided by the average number of common shares outstanding for the year.	Refinitiv (Eikon)
	Firm Leverage	A measurement of leverage is calculated as a company's net debt divided by its EBITDA. Net Debt is total debt minus cash and short-term investments for the most recent fiscal period. EBITDA is LTM earnings before interest, taxes, depreciation and amortization. The total debt to EBITDA ratio is not calculated when LTM EBITDA or Net debt is less than or equal to zero.	Refinitiv (Eikon)
	Firm Growth	Annual percentage change in sales.	Author's calculation
	Firm Size	Natural logarithm of total assets.	Author's calculation
	Firm Age	Log years by the firm's establishment.	Author's calculation
	Return on Assets	The Company's actual value is normalized to reflect the I/B/E/S default currency and corporate actions (e.g., stock splits). Return on Assets is a profitability ratio gauging a company's investment return. Specifically, ROA measures a company's operating efficiency regardless of its financial structure (in particular, without regard to the degree of leverage a company uses) and is calculated by dividing its net income prior to financing costs by total assets.	Refinitiv (Eikon)