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Unlocking Business Value: Integrating AI-Driven Decision-Making in Financial Reporting Systems

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Abstract: This research article investigates the synergies between artificial intelligence (AI), digital transformation (DT), and financial reporting systems within the business context. The central theme explores how organizations enhance their decision-making processes by integrating AI technologies into digital transformation initiatives, particularly in financial reporting. The focal point is comprehending how the synergy of these integrated systems can unlock substantial business value, instigate strategic innovation, and elevate overall financial analytics through the adoption of intelligent, data-driven decision-making methodologies. By harnessing advanced analytics, automation, and adaptive decision support capabilities, organizations navigate the complexities of a rapidly evolving business environment, in which neural networks emerge as a valuable tool for calibrating outcomes in the financial accounting environment, demonstrating effectiveness in processing complex financial data, identifying patterns, and making predictions, ushering in a new era of transformative possibilities. The introduction of a game theory payoff matrix in this AI decision-making tool adds a strategic framework for analyzing interactions among decision-makers, considering strategic choices and outcomes in a dynamic and competitive context.

Keywords: digital transformation; decision-making systems; integrated systems; neural networks; business financial reporting; game theory payoff matrix

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1. Introduction

Automation, artificial intelligence, and data analysis lead to significant changes in the way financial institutions operate. In the ever-evolving landscape of financial reporting, organizations face an urgent imperative to harness the transformative potential of digital technologies. The impact of digitization on finance is undeniable. The paradigm shift towards digital transformation represents a critical point where companies must not only adapt but also innovate to remain competitive in the global marketplace. Central to the objectives of this evolution is the integration of artificial intelligence (AI) technologies, which offer unprecedented opportunities to revolutionize strategic management within economic financial reporting systems. The control process, in this paradigm, evolves from rigid surveillance to dynamic orchestration.

Embedded AI systems equipped with sophisticated algorithms demonstrate the ability to continuously learn from data streams, adapt to evolving patterns, and make real-time decisions. This presents a shift from a deterministic control model to a more adaptive and probabilistic framework where control is exercised through algorithmic governance and continuous feedback loops.

In the era of post-pandemic digital transformation, the integration of artificial intelligence technologies is a cornerstone for public and private economic entities that aspire to navigate the complex landscape of financial reporting and economic productivity with

precision and agility. The convergence of artificial intelligence and the digitization of financial reporting systems [1] does not only represent a technological paradigm shift but also introduces a profound redefinition of control mechanisms and management processes. Integrated AI systems are reshaping control frameworks and empowering decision-makers in the dynamic context of financial reporting amid digital transformation.

As businesses embark on their digital transformation and digitization journey [2], the strategic and subsidized infusion of AI technologies holds the promise of unlocking unprecedented business value. Traditional financial reporting systems, rooted in deterministic methodologies, are now at a crossroads as organizations seek to incorporate advanced artificial intelligence algorithms. The integration of machine learning, predictive analytics, and cognitive computing into these systems introduces a new dimension of autonomy and adaptability. As AI becomes an active participant in decision-making processes, the contours of control mechanisms must be reevaluated.

Traditional hierarchical models are challenged by the distributed nature of decision-making in embedded AI systems [3], where algorithms learn, adapt, and contribute autonomously. The need to understand the complexities and implications of this integration has become paramount, particularly in terms of its impact on financial reporting decision-making. Traditional reporting systems, despite being an integral part of organizational functioning, now face the imperative to evolve. The following question arises: how can judicious integration of AI technologies improve decision-making processes in the context of financial reporting during the digital transformation process?

Figure 1 shows AI-driven decision-making in digital transformation. This includes digital transformation initiatives, AI integration, decision-making enhancement, benefits, use cases, consideration, future trends, implementation strategies, and measurement metrics. Each of these directions is important in the evolution of digitization. Evaluating each direction, the following can be stated:

- Digital transformation initiatives: these represent steps that contribute to DT. Components that contribute to the success of the DT process, strategic elements, and opportunities and challenges may be included.
- AI integration: this includes defining how AI has an important role in DT, the different types of associated technologies, and the implementation of opportunities and solutions. All this contributes to important support in the DT process.
- Decision-making enhancement: this refers to the use of data to gain competitive advantages, predictive analytics, and automation of organizational processes, and streamline processes through effective decision-making.
- Benefits: the benefits identified by the beneficiaries are multiple and among them are the improvement of accuracy, time and cost efficiency, the improvement of the customer's experience, and other related benefits.
- Example: evaluating the specific elements in which AI can be used, we can mention financial reporting, operation management, customer-facing the applications of AI, and many others.
- Consideration: the important elements that must be evaluated in this approach are the ethical implications, security, and human–AI collaboration.
- Future trends: this field is growing considerably, and future approaches should be anticipated at the organizational level through well-thought-out strategies and approaches (emerging trends, evolution of the field, and technological approaches).
- Implementation strategies: the elements of strategic management are opportune at the organizational level for good alignment with technological advancement.
- Measurement metrics: this entire approach must be measured, and the performance and success indicator metrics for AI implementation include correct organizational approaches.

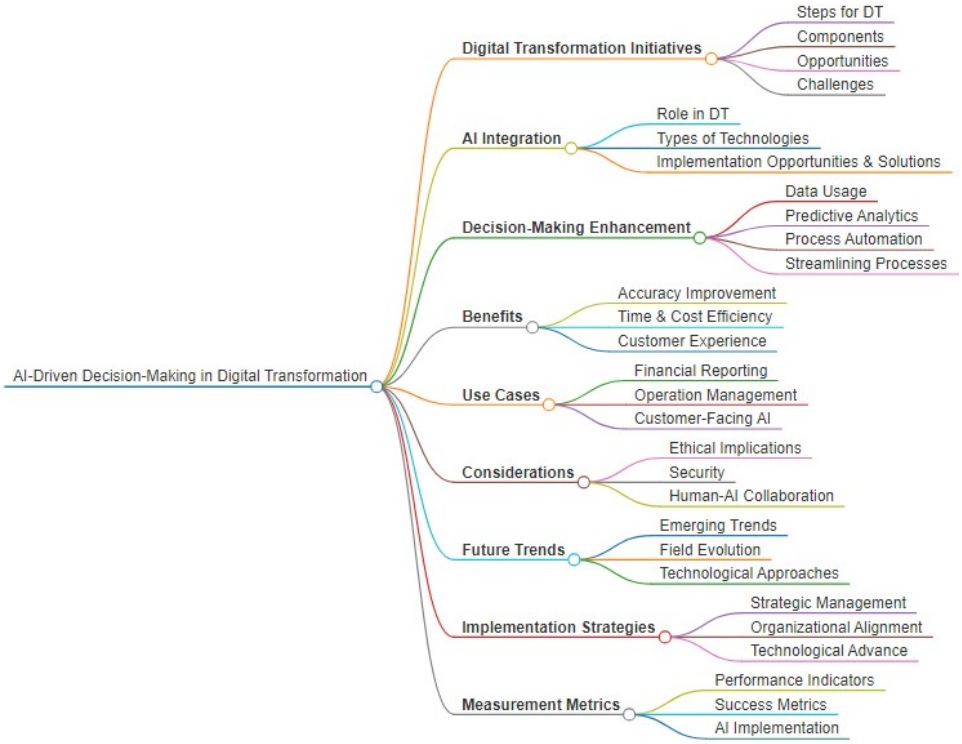

Figure 1. AI driven decision-making mind map.

In a landscape where data-driven insights drive organizational success, the potential benefits of AI—from streamlining processes to discovering actionable intelligence—invite organizations to explore new frontiers in decision-making capabilities. Against this background, this article undertakes an exploration of the transformative role that AI technologies are playing in reshaping the financial reporting decision-making landscape in the age of digital transformation. Delving into the complicated interplay between AI integration and the evolving nature of financial reporting systems, we seek to provide nuanced insights that connect theoretical advances with practical implications. Our goal is to guide organizations to a comprehensive understanding of how AI, when seamlessly integrated, can not only meet but exceed decision-making needs in the dynamic field of financial reporting in the digital age.

2. Literature Review

The integration of artificial intelligence (AI) into financial reporting systems has gained significant attention in the recent literature [4] due to its potential to transform traditional financial processes and unlock business value. The authors of [5] investigate the impact of integrating artificial intelligence into accounting information systems for enhancing non-financial performance in manufacturing companies, revealing significant positive effects on both the efficiency of accounting information systems and overall non-financial performance. Numerous studies have emphasized the role of AI in enhancing financial decision-making processes. Ref. [1] demonstrated the effectiveness of machine learning algorithms in predicting financial trends, optimizing resource allocation, and providing valuable insights for strategic planning. The integration of neural networks, as discussed by [6], has shown promise in automating tasks, improving forecasting accuracy, and supporting decision-makers in the financial domain.

The role of big data and leveraging AI-driven decision-making and digital transformation in financial reporting systems unlocks business value, aligning with stakeholder preferences, and addressing challenges and opportunities in the evolving financial landscape [5]. In the context of the modern economy, the transformative impact of big data extends beyond its common use by economists, prompting a shift in focus toward understanding

how others' utilization of data influences market outcomes [5]. This exploration involves incorporating big data into contemporary economic and financial theories. Notably, one application involves leveraging big data to enhance the decision-making of financial market participants, influencing firm prices, cost of capital, and investment dynamics.

The concept of digital transformation in financial reporting has been explored extensively in the literature. Scholars such as the authors of [7,8] discussed the evolution of financial reporting systems from manual processes to advanced digital platforms. The shift towards cloud-based solutions, the automation of data entry tasks, and the use of advanced analytics tools have been identified as key components of digital transformation in financial reporting [9].

Research by Sorensen [10] investigates the importance of aligning financial decisions with stakeholder preferences. Ref. [10] highlights the need for tools that consider the perspectives of various stakeholders, such as Company Management and Shareholders. The integration of AI-driven decision-making tools, informed by neural networks, offers a mechanism to align strategic choices with the preferences of key stakeholders.

The literature also recognizes challenges associated with the integration of AI and digital transformation in financial reporting. Concerns related to data privacy, regulatory compliance, and the need for skilled professionals capable of navigating the intersection of finance and AI have been discussed [3,11]. However, studies also highlight the opportunities for cost savings, efficiency improvements, and strategic advantages that arise from successful implementation [12]. Numerous studies emphasize the importance of financial KPIs in performance measurement and strategic decision-making within organizations [13] Metrics such as return on investment (ROI), earnings per share (EPS), and profit margin are recognized as critical indicators of financial health. Researchers argue that incorporating these KPIs into neural networks can enhance the accuracy of financial predictions and decision support systems [14,15].

Examining the intersection of game theory and financial decision-making [16] explores how strategic interactions among market participants, influenced by information asymmetry and competition, impact financial outcomes. The study may not directly focus on KPIs but provides insights into decision dynamics. While there might not be an extensive body of literature explicitly combining financial KPIs, decision-making, and game theory, some studies provide a foundation for understanding the interconnectedness of these concepts. Addressing the transparency and interpretability of AI decision models, Ref. [17] discusses the importance of explainability to gain the trust and acceptance of AI tools in decision-making, especially in sensitive domains like healthcare and finance.

The literature review indicates a growing body of research emphasizing the diverse applications, challenges, and ethical considerations associated with the integration of AI tools in decision-making. Understanding the impact of AI across various domains provides a foundation for future developments in creating a more effective, transparent, and ethical decision-support system.

In recent years, accounting and audit companies have tapped into the potential of AI to revolutionize traditional processes within financial institutions and have developed applications of machine learning in finance. JP Morgan Chase, a global leader in financial services, developed the Contract Intelligence, or COiN, platform, an AI-driven tool designed to review legal documents and extract critical data points and clauses, reducing up to 360,000 h annually, consuming significant human resources and enhancing the precision and scalability of operations, setting a new standard for efficiency in financial reporting. Another compelling example comes from Deloitte, a powerhouse in audit and assurance services which employed ACL Analytics, a sophisticated data analytics software, to elevate its audit processes. This tool harnesses the power of AI and machine learning to sift through vast volumes of financial data, identifying anomalies, trends, and patterns that warrant further scrutiny. By integrating neural networks, auditors can concentrate their efforts on high-risk areas, thereby improving the quality and depth of their audits and

providing clients with valuable, data-driven recommendations, fostering more informed decision-making and strategic planning.

3. Materials and Methods

This research paper uses a comprehensive foundational research methodology to unlock business value by integrating AI-based decision-making with digital transformation in financial reporting systems. The logical process described in this methodology serves as a step-by-step road map, guiding the investigation into the intersection between artificial intelligence (AI) and digital transformation in the economy in the context of the digitalization of financial reporting. The main objective is to develop a theoretical framework that improves decision-making processes by assimilating advanced artificial intelligence technologies into existing financial reporting systems. Through this research we went through systematic stages, starting with the identification of the research problem, followed by an extensive literature review to gather relevant information on artificial intelligence, digital transformation, and current financial reporting systems. The theoretical foundation was then mapped by synthesizing existing knowledge and identifying gaps in current understanding. Subsequently, the authors formulated a research design to guide the empirical investigation.

Integrating AI-based decision-making with digital transformation into financial reporting systems requires careful consideration of technological, organizational, and ethical dimensions. The methodology addresses these issues by incorporating a multidisciplinary approach, ensuring a holistic understanding of the challenges and opportunities associated with implementing artificial intelligence in financial reporting.

By navigating through this methodical process, the research aims to provide valuable information to both academia, business, and industry. The expected outcome is a solid theoretical framework that not only clarifies the synergies between artificial intelligence and digital transformation but also provides practical guidance for organizations seeking to improve their financial reporting decision-making capabilities.

This research aims to bridge the gap between theoretical advances and practical implications, thereby unlocking the untapped business value inherent in integrating AI-driven decision-making with digital transformation in financial reporting systems.

4. Digital Transformation Tools for the Decision-Making Process

Digital transformation tools for financial reporting can significantly support the decision-making process within organizations, developing strategies that are resilient to different economic conditions. They play a crucial role in supporting decision-making processes in financial reporting by providing real-time data, advanced analytics, automation, and collaborative features. These tools contribute to more informed, strategic, and data-driven decision-making within organizations. The integration of advanced technologies and digital tools into financial reporting systems offers several benefits that enhance decision-making capabilities. Decision-makers can access up-to-date information on key financial metrics, performance indicators, and market trends, allowing for more informed and timely decision-making [17,18].

Advanced analytics and data visualization tools help transform complex financial data into easily understandable visual representations. This aids decision-makers in identifying patterns, trends, and anomalies, facilitating data-driven decision-making. Digital tools often incorporate forecasting and predictive analytics capabilities. By analyzing historical data and identifying patterns, these tools can assist decision-makers in making more accurate predictions about future financial trends and outcomes. Incorporating artificial intelligence and machine learning (ML) algorithms enhances the capabilities of financial reporting systems. These technologies can provide intelligent insights, identify opportunities, and support decision-making by analyzing large datasets and facilitating collaboration and communication among different stakeholders involved in the decision-making process [14,15].

Decision-makers can assess the financial implications of various decisions, ensuring alignment with regulatory requirements and risk mitigation strategies and enabling scenario planning by allowing decision-makers to model different financial scenarios and assess their potential impact. Analysis of strategic interactions among multiple decision-makers, often in competitive situations, can be employed to support managers and Shareholders in the decision-making process. In business contexts, it can be used to model and analyze decision-making scenarios involving multiple stakeholders, such as competitors, suppliers, and customers [19,20].

Game theory and machine learning provide strategic insights for risk assessment by analyzing diverse sets of data and identifying potential trends or anomalies and by helping managers and Shareholders anticipate the actions and reactions of others [18]. They aid in the making of decisions that consider the likely responses of competitors and collaborators, leading to more informed strategies. Neural networks, a subset of machine learning and AI, are adept at pattern recognition and prediction. In decision-making, neural networks can analyze large datasets, identify patterns, and make predictions based on historical and real-time information. This capability is valuable for managers and Shareholders when evaluating various decision options and their associated risks.

This conceptual map (Figure 2), provides a visual representation of the interconnected concepts, illustrating how game theory and neural networks, when integrated into decision support systems, contribute to strategic decision-making processes and enhance overall decision quality for stakeholders [21]. The combination of game theory and neural networks can be particularly powerful. Neural networks can analyze data to inform decision-makers about the likely outcomes of different strategies, while game theory can help model the strategic interactions and competitive dynamics among stakeholders. By leveraging neural networks to analyze historical data and predict outcomes, decision-makers can use game theory to optimize their strategies based on a deeper understanding of the competitive landscape. AI, including game theory and neural networks, can be integrated into decision-support systems that provide actionable insights to managers and Shareholders.

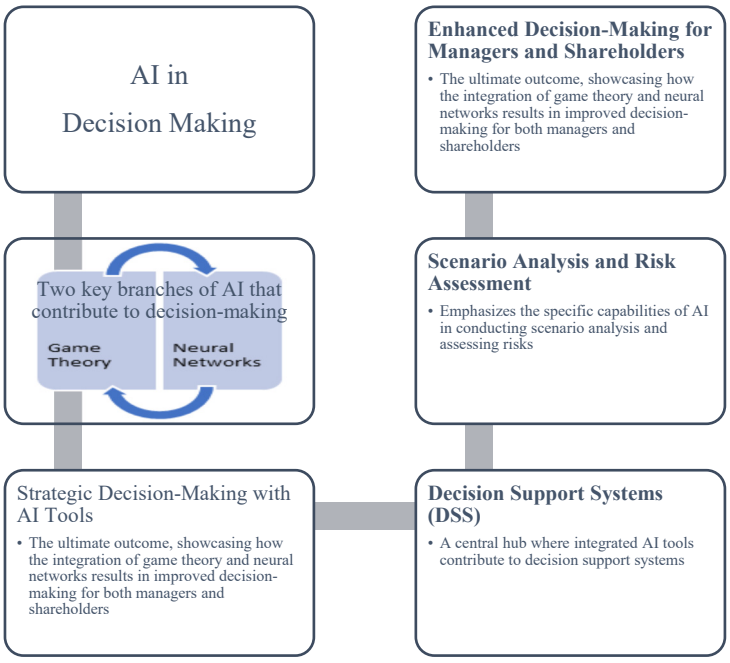

Figure 2. Conceptual map of AI integrated into decision support systems.

These systems leverage advanced analytics to enhance decision-making processes. Managers can use AI tools in the decision-making process to conduct scenario analysis,

assessing the potential outcomes of different decisions under various conditions. This aids in the making of decisions that are more robust and adaptable to different circumstances

4.1. Developing a Neural Network for Integrating AI in Decision-Making Processes

Developing a neural network for integrating AI in financial reporting involves designing a model that can analyze and interpret financial data from balance sheets. The choice of a three-layer neural network for accounting and financial reporting tasks is not an inherent rule, but rather a commonly used architecture that has shown effectiveness in various applications. A three-layer architecture is relatively simple and easier to interpret when we compare it to deeper counterparts. This architecture has fewer parameters and layers, which ostensibly makes it more manageable. However, this should not obscure the reality that even a three-layer neural network can function as a complex black box. The inherent non-linear transformations and the interactions between layers make it challenging to decipher how specific inputs are translated into outputs. In financial reporting, where transparency and accountability are paramount, the opaque nature of neural networks, regardless of their depth, can lead to significant interpretability challenges. Because interpretability is often crucial, and as stakeholders need to understand and trust the results of the model, this complexity is not just a theoretical concern but a practical one that impacts trust and reliability in real-world applications.

Three-layer neural networks are notably powerful due to their ability to approximate a wide range of functions. This capability is rooted in Kolmogorov's superposition theorem, which asserts that a three-layer neural network can represent any multivariate function, whether continuous or discontinuous. This makes such networks versatile for various applications, including financial reporting systems where capturing complex, non-linear relationships within data is crucial [22,23]. One of the primary advantages of a three-layer neural network is its relative simplicity and interpretability compared to deeper networks. While it can be challenging to interpret the decision-making process of very deep neural networks, three-layer models strike a balance by being complex enough to capture intricate patterns while remaining simpler to analyze and debug. This interpretability is particularly important in financial contexts where transparency and accountability are paramount [24,25].

Simpler models are also less prone to overfitting and can be more robust, especially when dealing with limited data. For many accounting and financial reporting tasks, a moderate number of hidden layers can effectively capture the underlying patterns and relationships in the data.

We designed the mathematical model for a neural network with 31 input units, 16 hidden units, and 2 output units as follows:

$$x1, x2, ..., x31 \text{tobetheinputfeatures}$$

$$h1, h2, ..., h16 \text{ tobethehiddenlayerunits}$$

$$y1, y2 \text{ tobetheoutputlayerunits}$$

The mathematical model of the neural network can be expressed as follows:

Hidden layer computation:

$$hj = \text{ReLU}\left(\sum i = 131 wij(1)xi + bj(1)\right), \text{for } j = 1, 2, \ldots, 16$$

where $\text{ReLU}(a) = \max(0, a)$ is the Rectified Linear Unit activation function.

Output layer computation:

$$yk = \text{Softmax}\left(\sum j = 116 wjk(2)hj + bk(2)\right), \text{for } k = 1, 2$$

were

$$\text{Softmax}(a)i = \sum j = \frac{eai}{\sum 1eai} \text{ istheSoftMaxactivationfunction.}$$

The parameters of the model (weights and biases) are learned during the training process to minimize a specific loss function, typically associated with the task at hand (e.g., classification or regression). The training involves adjusting the weights and biases using optimization algorithms such as stochastic gradient descent (SGD).

The model is trained by iteratively performing forward propagation, calculating the loss, and then using backpropagation to update the model parameters. The training process continues until the model converges or until a predetermined number of epochs is achieved. Once trained, the neural network can be used to make predictions on new data by performing forward propagation with the learned parameters. This mathematical approach forms the basis of training using a three-layer neural network for financial reporting tasks, connecting the input layer with the balance sheet structure to the hidden layer, and ultimately predicting financial KPIs in the output layer. Adjustments can be made based on the specific characteristics of your data and task requirements.

In financial settings where data can be limited and computational resources may be constrained, a three-layer architecture strikes a balance between complexity and efficiency. Extremely deep networks may suffer from vanishing or exploding gradient problems during training, making it challenging for the model to learn effectively. A three-layer network is less prone to these issues, especially when using activation functions like ReLU (Rectified Linear Unit) that mitigate the vanishing gradient problem [26].

The input layer should be designed to capture relevant information from the balance sheet. As seen in Figure 3. And further explained in Appendix A. Each node in the input layer corresponds to a specific feature or variable from the balance sheet, such as assets, liabilities, equity, taxes, depreciation, net revenue, etc. Including features related to the balance sheet structure allows the neural network to learn patterns and relationships within the financial data. This information is crucial for understanding the financial health and position of the economic entity. Although this is a proposal model for an economic entity, the effectiveness of our neural network depends on the quality and relevance of the accounting provided. It should be ensured that the selected features in the input layer are meaningful and that there is sufficient data to train the model effectively.

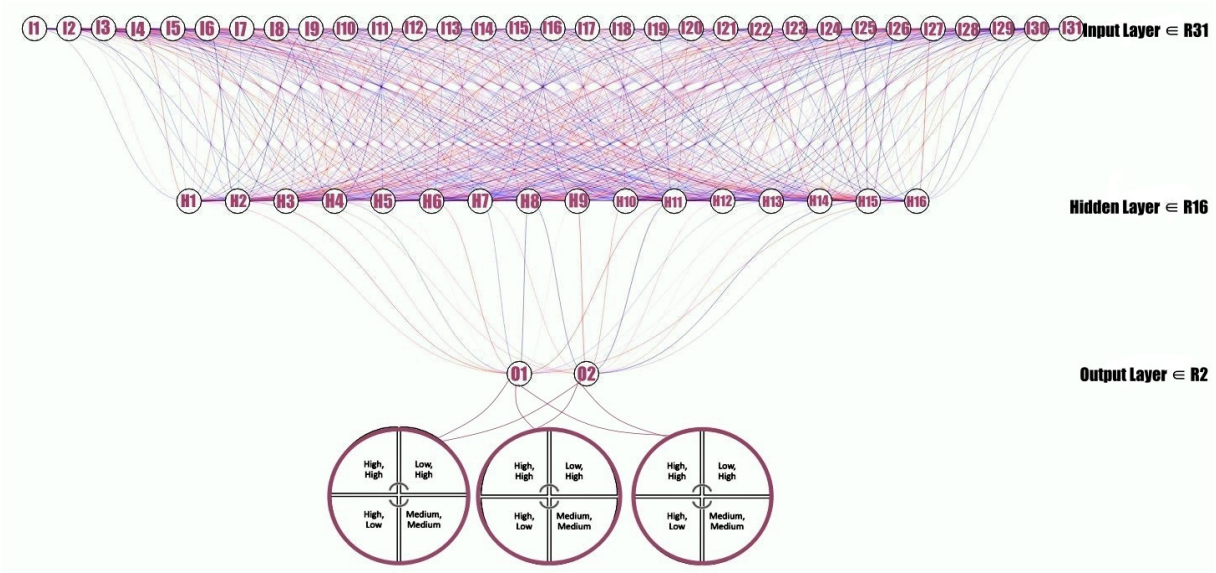

Figure 3. Three-layer neural network for accounting and financial reporting tasks.

The hidden layer is where the neural network learns complex representations and patterns from the input features. By connecting the input layer to the hidden layer, the network can extract meaningful insights and relationships. If the economic entity's goal is to increase business value, it makes sense to correlate the hidden layer with financial KPIs. Financial KPIs often serve as performance indicators that directly impact the overall

value and success of a business. The hidden layer can learn to abstract and combine features from the input layer to identify patterns associated with successful financial outcomes or increased business value. The choice of the two output layers depends on the specific objectives and how the company defines and relates to business value, whether by profitability or revenue growth. The exact KPIs may vary depending on the industry, company goals, and the nature of the business that integrates the neural network AI tool. One of the key indicators of a successful business is its ability to generate increasing revenue over time. The first outcome layer could represent the predicted revenue growth. The neural network would then be trained to learn patterns in the input data that correlate with higher revenue.

The mathematical model would have two output nodes, each corresponding to one of these outcomes. For binary classification, the company might use a sigmoid activation function in the output layer, and for regression tasks, the company might use linear activation [17].

$$(1)\ Y_1 = \sigma(H \cdot {W_1}^{(2)} + {b_1}^{(2)})$$

$$(2)\ Y_2 = \sigma(H \cdot {W_2}^{(2)} + {b_2}^{(2)})$$

where σ is the sigmoid activation function, and Y_1 and Y_2 represent the predicted values for revenue growth and profitability, respectively.

The third output node can be included if the economic entity might be able to account for negative financial KPIs that they want to minimize like operating costs or the expense ratio.

$$(3)\ Y_3 = \sigma(H \cdot {W_3}^{(2)} + {b_3}^{(2)})$$

4.2. Using Game Theory AI Tools in the Decision-Making Process

Game theory is powerful in the era of digitalization [20] and AI because it provides a structured approach to decision-making in complex, dynamic, and uncertain environments. It helps decision-makers navigate strategic interactions, allocate resources efficiently, and adapt to the rapidly changing landscape of technology and business. As we previously mentioned, we encourage economic entities to apply game theory to their business processes to unlock business value through AI-driven decision-making and digital transformation in financial reporting systems and create a payoff matrix that represents the interactions between different decision-makers or stakeholders. In the context of our research, these decision-makers could include the Company Management, Shareholders, AI system, and other relevant entities.

We assume there are two key decision-makers: Company Management (CM) and Shareholders (SH), and there are two strategic choices for each: implement AI-driven financial reporting (AI) or stick to traditional reporting (TR). The payoffs are expressed in terms of business value or utility for each combination of choices.

Explanation of the Payoffs

- High, High: If both Company Management and Shareholders choose to implement AI-driven financial reporting, they both receive high business value or utility.
- Low, High: If Company Management opts for AI while Shareholders stick to traditional reporting, Company Management might experience low value (due to the implementation costs, for example), while Shareholders receive high value (as they may prefer the familiar traditional reporting).
- High, Low: If Company Management sticks to traditional reporting while Shareholders prefer AI-driven reporting, Company Management might achieve high value (as they avoid implementation costs), but Shareholders receive low value (as they desire the benefits of AI-driven reporting).
- Medium, Medium: If both Company Management and Shareholders stick to traditional reporting, they both achieve a medium level of business value or utility.

We can elaborate on the payoffs in terms of increasing value for both Company Management and Shareholders based on two strategic choices: implement AI-driven financial reporting or stick to traditional reporting. The values represent the perceived business value or utility, with higher values indicating higher perceived value. High, medium, and low are qualitative representations of the perceived value, and the actual numerical values would depend on the specific context and preferences of stakeholders. The payoffs are described in Table 1, and the actual values would depend on factors such as the industry, the specific goals and preferences of stakeholders, and the perceived benefits and drawbacks of AI-driven reporting versus traditional reporting in the given context. This matrix provides a structured way to understand how the decisions of each party influence the perceived value for both Company Management and Shareholders:

Table 1. Payoff matrix.

		Shareholders	
Company Management		AI	TR
	AI	High, High	Low, High
	TR	High, Low	Medium, Medium

- High, High (AI):
  - Company Management (CM): High value, as AI-driven financial reporting is expected to enhance efficiency, accuracy, and strategic decision-making, leading to increased overall business performance.
  - Shareholders (SH): High value, as they benefit from improved transparency, better-informed decision-making by management, and potentially increased profits.
- Low, High (TR):
  - Company Management (CM): Low value, as sticking to traditional reporting may result in missed opportunities for efficiency gains, strategic insights, and cost savings offered by AI-driven reporting.
  - Shareholders (SH): High value, as they may prefer the familiarity and stability of traditional reporting, potentially perceiving less risk or disruption to their investments.
- High, Low (AI):
  - Company Management (CM): High value, as the implementation of AI-driven reporting satisfies the management's objective of adopting innovative technologies and staying competitive.
  - Shareholders (SH): Low value, as they might be disappointed with the decision not to stick with traditional reporting, potentially perceiving higher risks or uncertainties.
- Medium, Medium (TR):
  - Company Management (CM): Medium value, as sticking to traditional reporting may provide stability but may not leverage the potential benefits offered by AI-driven reporting.
  - Shareholders (SH): Medium value, as they maintain a sense of stability but may miss out on potential improvements in decision-making and efficiency.

CFOs face both challenges and opportunities in the AI decision-making process within a given industry and regulatory environment. These can vary based on the specific circumstances of each organization. They must navigate complex data privacy regulations to ensure that the use of AI aligns with privacy laws, particularly in industries dealing with sensitive customer information. Another challenge that management faces soon is keeping up with evolving regulations related to AI and ensuring that AI systems comply with industry-specific laws and standards.

Game theory matrices can be tailored to various decision-making scenarios, and when applied to the context of Chief Financial Officers (CFOs) making decisions in the realm of AI, we propose four matrices that can be taken into consideration in the decision-making process: CFOs making AI-related decisions can use game theory matrices to navigate four key scenarios: early vs. late AI adoption, external vendor vs. in-house AI development, data sharing collaboration vs. data protection, and proactive vs. reactive regulatory compliance, balancing benefits, costs, and risks for competitive advantage and innovation.

4.3. Ethical and Privacy Issues in AI-Driven Financial Reporting

In this relatively new AI-driven financial reporting environment, data privacy concerns are paramount. The extensive data requirements of AI systems often encompass sensitive financial and personal information, raising the specter of unauthorized access and data breaches [27]. The very foundation of our work relies on the integrity and confidentiality of the data we handle. As we integrate AI, we must be vigilant in protecting these data through robust encryption methods, ensuring that sensitive information remains secure both in transit and at rest. Stakeholders must be fully informed about how their data are collected, stored, and utilized. This transparency extends to obtaining explicit consent from individuals whose data are being used. By implementing stringent data governance policies, we can delineate clear access controls and ensure that data are only accessible to authorized personnel under appropriate circumstances. Accountability and transparency in AI systems are critical and it is imperative that app developers establish clear accountability frameworks that define the responsibilities of AI users, operators, and decision-makers. When errors occur, there must be a transparent process for identifying and addressing the source of the problem. Implementing explainable AI techniques can significantly aid this process. These techniques allow us to understand and articulate how AI systems make decisions, thereby fostering trust and accountability among stakeholders [28].

With the widespread adoption of international accounting standards, regulatory compliance is an ever-present concern in our profession. AI applications in financial reporting must adhere to a myriad of regulatory requirements, from financial regulations to data protection laws. Engaging in ongoing dialogue with regulatory bodies can provide valuable guidance and help ensure that our AI systems are compliant with current laws. Regular compliance audits are essential to verify adherence and address any gaps in our processes.

Security risks are an inherent aspect of integrating AI into financial reporting. AI systems can be targeted by cyberattacks, potentially leading to data breaches or the manipulation of financial information [29]. To mitigate these risks, we must implement advanced cybersecurity measures and develop comprehensive incident response plans. Regular security assessments will help identify and address vulnerabilities, ensuring the integrity and reliability of our AI systems. In real-life situations, several advanced cybersecurity measures have proven effective in safeguarding AI-driven financial reporting systems, such as multi-factor authentication that significantly enhances security by requiring users to provide two or more verification factors to gain access to a system, end-to-end encryption that ensures data are encrypted from the moment they are created until they are received and decrypted by the intended recipient, or conducting regular security audits and penetration testing that allow organizations to identify and address vulnerabilities in their systems proactively [29].

5. Results and Discussion

Combining a neural network model with game theory, as represented in a matrix, can be a powerful approach, and it is often referred to as game-theoretic machine learning and is used for decision support in companies. The neural network can be used to predict financial KPIs or other relevant outcomes, and the game theory matrix can help analyze the strategic interactions between different entities or stakeholders. It aims to understand how different agents or players, each with their own objectives, make decisions in a competitive or

cooperative environment. We use game theory as a branch of mathematics and economics to monitor the interactions between rational decision-makers, often referred to in the literature as players, in situations where the outcome of one player's decision depends on the decisions of others, and we propose to combine machine learning techniques and integrate them with game theory to model and predict the behavior of players who can gain from positive business value creation. In our game theory, the players represent the Shareholders and the management team, and strategies include increased market capitalization by increasing revenues or profitability and payoffs represented in the matrix. Strategies proposed by the research are the choices available to each player such as choosing the digitalization and incorporation of AI path or sticking to traditional methods of accounting and reporting, and payoffs represent the outcomes associated with specific combinations of strategies chosen by all players. To apply the strategies, predictive models, such as the neural networks with tree layers, can be employed to estimate the likely choices or actions of players based on historical accounting data extracted from the balance sheet and profit and loss data or other relevant features.

Given the specifications of our neural network and the structure of the payoff matrix from game theory, we suggest naming the theoretical model "Decision Harbor AI" a name that reflects the integration of artificial intelligence, financial decision-making, and strategic analysis and symbolizes a safe and informed harbor for decision-making aided by artificial intelligence. Game-theoretic machine learning provides a framework for understanding and predicting strategic interactions [30]. By integrating machine learning models with game theory concepts, we predict it will become possible to gain insights into decision-making processes in complex, dynamic environments. This approach can be valuable for making informed decisions in competitive or cooperative scenarios where multiple stakeholders are involved [31].

In our scenario, we have a game theory matrix with two players: Company Management and Shareholders and the matrix represents the possible outcomes based on the decisions made by these players. We can train the neural network to predict the financial KPIs or outcomes of interest, such as revenue growth, profitability, and cost efficiency as seen in Figure 4. After we trained the neural network to predict positive performance indicators, we used the trained neural network to make predictions for each player (Company Management, AI, and TR) based on the input features and the KPI in the hidden layer.

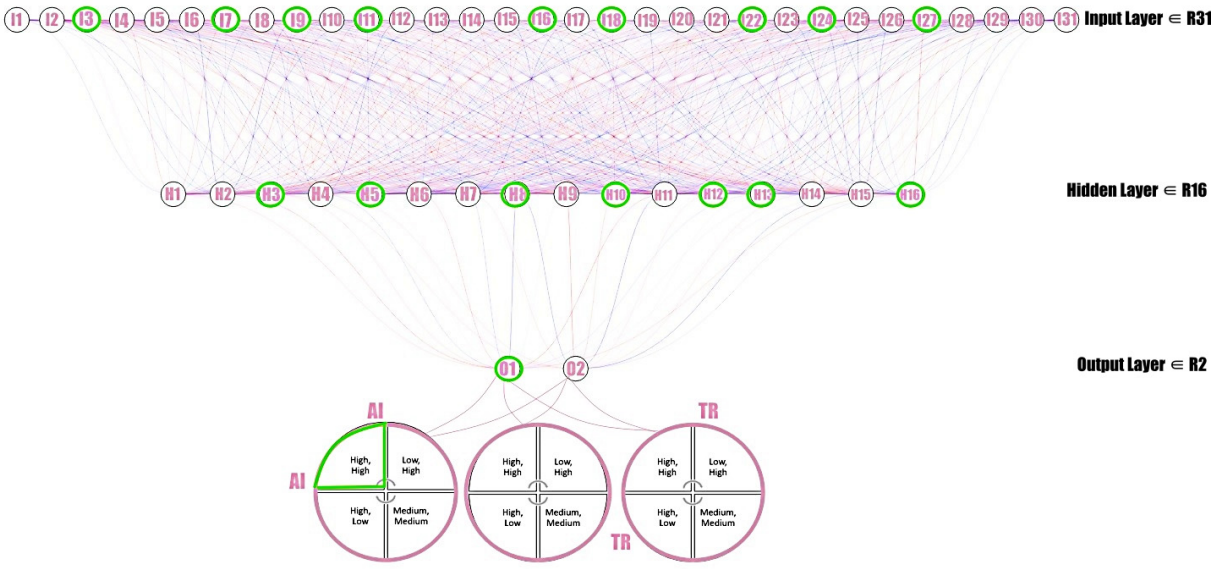

Figure 4. Decision Harbor AI theoretical model—scenario 1.

In bad financial years, the distribution of data may shift. The patterns and relationships between input features and financial outcomes may change, leading to a mismatch between the training and testing data. The neural network, trained on historical data, may struggle to generalize to these new conditions. The model's predictive performance may degrade during bad financial years if the patterns observed during training no longer hold. The model might make inaccurate predictions, especially if it has not encountered similar scenarios in the training data (Figure 5).

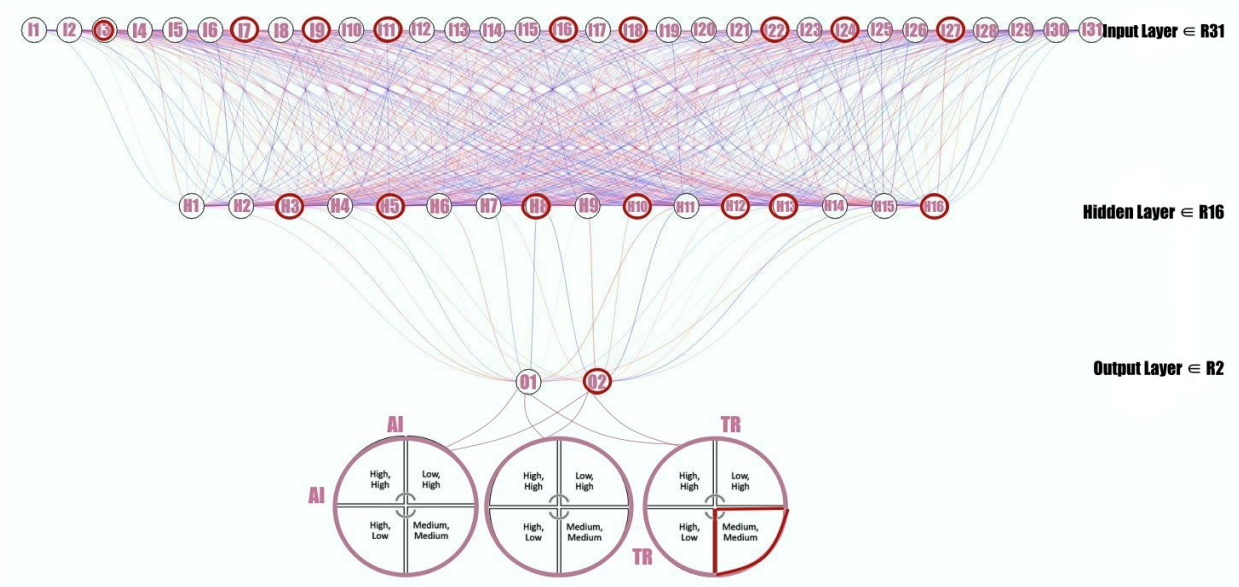

Figure 5. Decision Harbor AI theoretical model—scenario 2.

We suggest that the company implements a strategy for continuous model training to adapt to evolving financial conditions. The model should be regularly updated with new data, especially during periods of financial turbulence, to ensure it remains relevant. For the model to lead to good financial decisions, the management must conduct a scenario analysis to assess the model's performance under various financial conditions. This may involve testing the model against simulated scenarios that represent different economic states, including good and bad financial years. If the neural network performs well during good financial years, it provides validation of the model's robustness. It suggests that the model can adapt to different financial conditions and continues to make accurate predictions when conditions are favorable. Good financial years can positively reinforce the use of the model for decision-making. Reliable predictions in our company during these periods can contribute to effective strategic planning, resource allocation, and other decisions that enhance business value. Decision-makers may gain increased confidence in the model's predictions during good financial years. This confidence can lead to more reliance on the model for guiding decisions.

The Deming Cycle (PDCA) may be used as an iterative four-step management method for continuous improvement. Applying the PDCA cycle to the continuous training and scenario analysis of our neural network model in the context of evolving financial conditions is a sensible and effective approach. We must monitor the training process and assess whether the model's performance improves or remains stable, execute the scenario analysis using the prepared simulation scripts or tools, and assess the model's accuracy, sensitivity, and specificity across different scenarios to identify any patterns of underperformance or overfitting.

If the scenario analysis of our neural network reveals shortcomings, we must consider adjusting the model or the scenario generation process. This may involve redefining features, introducing new features, or modifying the simulation approach. The theoretical

model can incorporate any necessary improvements to enhance the model's ability to handle diverse financial conditions. We can apply stress testing to our model [23], like how banks conduct stress tests to assess the resilience of their financial systems under adverse conditions. In the context of our neural network model and game theory matrix, stress testing can help us understand how well the model performs and how robust decision-making is in the face of extreme or unexpected financial scenarios. Deep learning can be applied to the input layer in our network in the context of dynamic balance sheet stress testing [31,32]. If the balance sheet that generates financial information for the input layer data has a temporal dimension like quarterly or yearly, we can consider recurrent neural networks or Long Short-Term Memory networks (LSTMs) to capture temporal patterns and dependencies in the data. If our input data include diverse sources like financial statements, market data, and economic indicators, we suggest applying architectures that support multimodal data integration. This allows the model to learn from different types of information simultaneously. Overall, it is important to tailor the deep learning approach to the specific requirements and characteristics of our financial data and stress testing objectives. Our theoretical model DecisionHarborAI can be implemented in public organizations as well. The application of AI tools, like this theoretical two-layer model, in the public sector has the potential to bring about significant benefits like assisting in analyzing the impact of different policies, helping policymakers understand potential outcomes and make informed decisions, providing insights into optimizing resource allocation to achieve desired outcomes, evaluating the effectiveness of public programs and initiatives, and enhancing citizen engagement by providing data-driven insights into decision-making processes, fostering transparency and trust between the public and government [33].

To effectively implement such a model, several practical recommendations emerge. Regular updates and retraining of the neural network with new data are crucial to maintaining accuracy and relevance.

The first step is providing a picture or a PDF file of a balance sheet to our API. This will be conducted in a mobile app or a web application. As soon as a picture or PDF is received, it is converted to a TXT file. A parser takes the TXT gained from the OCR and converts it into structured JSON using machine learning. The JSON is then returned as the output from the API. From here, data from the balance sheet can be processed further. The comprehensive dataset is then used to train a neural network, capable of predicting key financial performance indicators such as revenue growth, profitability, and cost efficiency. The DecisionHarborAI model goes a step further by incorporating a game theory framework. This allows for a nuanced analysis of strategic interactions between stakeholders, such as management and Shareholders. By understanding these dynamics, the institution can align its strategic decisions with the interests of all parties involved, thereby maximizing business value.

To ensure robustness, continuous scenario analysis and stress testing are conducted. This practice not only validates the model's predictions under varying conditions but also prepares the institution for potential economic fluctuations. The outcomes are profound: enhanced decision-making capabilities, significant efficiency gains through automation, and a strategic alignment that drives overall business performance.

Limitations must also be considered when implementing AI-driven financial reporting models such as DecisionHarborAI. One of the most significant limitations is the quality of the data fed into the AI models. AI systems require vast amounts of high-quality data to function optimally. However, financial data can often be incomplete, inconsistent, or noisy. Inaccurate or poor-quality data can lead to erroneous predictions and flawed decision-making processes. Organizations must invest considerable effort in data cleansing and validation to ensure that the data used for training and operational purposes is accurate and reliable. This can be resource-intensive and may not always be feasible, particularly for smaller institutions with limited budgets. Like all AI models, DecisionHarborAI will be trained on historical data and may perform well under conditions similar to those present in the training dataset. The ability of our theoretical model to adapt to economic shifts,

regulatory changes, and unforeseen global events such as financial crises or pandemics is a critical concern [34]. The DecisionHarborAI model may fail to generalize effectively to new, unseen scenarios, leading to performance degradation. Continuous model retraining and validation will be necessary to ensure that DecisionHarborAI remains relevant and accurate, but this can be challenging to manage and requires ongoing investment.

6. Conclusions

When implementing a neural network for financial accounting, it is important to consider factors such as data quality, model interpretability, and the specific regulatory environment. The model that this research proposes offers an integrated approach to decision support by combining the predictive capabilities of neural networks with the strategic insights provided by game theory. This integration aims to enhance decision-making processes in complex and dynamic environments and shifts the model's focus to predicting financial indicators and supporting financial decision-making. The neural network component of the new AI tool is designed to provide financial predictions and insights based on historical data. This includes forecasting key financial indicators such as revenue growth, profitability, and cost efficiency. Neural networks can be a valuable tool for calibrating outcomes in the financial accounting environment, and have demonstrated effectiveness in processing complex financial data, identifying patterns, and making predictions. The inclusion of a game theory payoff matrix in this new AI decision-making tool introduces a strategic framework for analyzing interactions among decision-makers. This allows for the consideration of strategic choices and outcomes in a more dynamic and competitive context. AI digital transformation tools have the potential to significantly enhance financial decision-making processes and overall strategic management. These tools can help organizations leverage data-driven insights and automate routine tasks, potentially improving efficiency and decision accuracy. However, it is important to recognize that AI technologies also come with challenges and disadvantages, such as data privacy concerns, the risk of algorithmic biases, and the need for substantial computational resources. Additionally, the complexity of AI models can make them difficult to interpret and trust, which may limit their practical application in certain contexts. Therefore, while AI offers promising advancements, it is essential to approach its integration with a balanced perspective, acknowledging both its benefits and its limitations. All future developing decision-making assistance tools must continuously learn and update their predictions, ensuring relevance and accuracy over time. The model that this paper suggests must be equipped with the capability to undergo stress testing and scenario analysis, allowing it to evaluate its performance under various financial conditions, including both favorable and adverse scenarios, contributing to its robustness.

Neural network payoff matrix fusion represents a comprehensive and adaptive decision support tool that leverages the strengths of neural networks and game theory to provide valuable insights for financial decision-making in both private and public sectors and provides tangible value to businesses. The continuous training, scenario analysis, and strategic framework contribute to its potential effectiveness in dynamic and uncertain environments. The concept of integrating AI-driven decision-making is directly reflected in the conclusions of this paper. The digital tools mixed combine the predictive capabilities of neural networks with a game theory framework, emphasizing the integration of advanced AI techniques for more informed decision-making. The model's success will depend on thorough testing, collaboration with domain experts, and ongoing refinements based on real-world feedback.

Digital transformation tools can significantly aid the financial decision-making process and overall strategic management in a company by analyzing historical financial data to make accurate predictions about future trends and outcomes. These tools can assess and predict potential risks by analyzing various data sources. This enables organizations to proactively identify and mitigate risks in financial decision-making and to automate repetitive and routine tasks, such as data entry, reconciliation, and reporting.

AI digital transformation tools play a crucial role in enhancing financial decision-making processes and overall strategic management. These tools empower organizations to leverage data-driven insights, automate routine tasks, and navigate the complexities of the modern business landscape more effectively.

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Appendix A

Table A1. Description of the layers in the proposed neural model—Decision Harbor AI.

Input Layer $\in \mathbf{R^{31}}$ **I**	**Hidden Layer** $\in \mathbf{R^{16}}$ **H**	**Output Layer** $\in \mathbf{R^{2}}$ **O**
Net revenue	Gross revenue	Revenue Growth
Net Income		
Taxes	Gross income	
Interest expenses	EBITDA	
Depreciation		
Amortization	Profit margins	
Cost of goods sold		
Operating expenses	Cash Flow from operations	
Operating income		
Change in working capital	Free cash flow	
Operating Cahs flow		
Capital expenditure	ROE	
Shareholders' equity		
Average total assets	ROA	
Total liabilities		
Current assets	Debt to equity ration	
Current liabilities		
Cash	Current ratio	Profitability
Cash equivalents		
Net accounts receivable	Quick ratio	
Prepaid expenses		
Share price	Price to earnings ratio	
Earnings per share		
Preferred equity	Book value per share	
Dividend per share		
Value per share	Dividend yield	
Total shares		
Revenue growth	Market capitalization	
Earnings		
Godwill	Growth metrics	
Fixed assets		

References

1. Imoniana, J.O.; Reginato, L.; Junior, E.B.C.; Benetti, C. Stakeholders' perceptions on the adoption of International Financial Reporting Standards by small and medium-sized enterprises: A multidimensional analysis. *Int. J. Bus. Emerg. Mark.* **2025**, *1*. [CrossRef]
2. Radicic, D.; Petković, S. Impact of digitalization on technological innovations in small and medium-sized enterprises (SMEs). *Technol. Forecast. Soc. Chang.* **2023**, *191*, 122474. [CrossRef]
3. Saura, J.R.; Ribeiro-Soriano, D.; Palacios-Marqués, D. Assessing behavioral data science privacy issues in government artificial intelligence deployment. *Gov. Inf. Q.* **2022**, *39*, 101679. [CrossRef]
4. Faccia, A.; Al Naqbi, M.Y.K.; Lootah, S.A. Integrated Cloud Financial Accounting Cycle. In Proceedings of the 2019 3rd International Conference on Cloud and Big Data Computing, Oxford, UK, 28–30 August 2019; ACM: New York, NY, USA, 2019; pp. 31–37. [CrossRef]
5. Allam, K.; Rodwal, A. AI-driven big data analytics: Unveiling insights for business advancement. *EPH-Int. J. Sci. Eng.* **2023**, *9*, 53–58. [CrossRef]
6. Mengu, D.; Luo, Y.; Rivenson, Y.; Ozcan, A. Analysis of Diffractive Optical Neural Networks and Their Integration with Electronic Neural Networks. *IEEE J. Sel. Top. Quantum Electron.* **2020**, *26*, 1–14. [CrossRef]
7. Shengelia, N.S.N.; Tsiklauri, Z.T.Z.; Rzepka, A.R.A.; Shengelia, R.S.R. The Impact of Financial Technologies on Digital Transformation of Accounting, Audit and Financial Reporting. *Economics* **2022**, *105*, 385–399. [CrossRef]
8. Pacurari, D.; Nechita, E. Some considerations on cloud accounting. In *Studies and Scientific Researches. Economics Edition*; Faculty of Economic Sciences, "Vasile Alecsandri" University of Bacau: Bacau, Romania, 2013. [CrossRef]
9. Li, M.; Yu, Y.; Li, X.; Zhao, J.L.; Zhao, D. Determinants of SMEs' Transformation Toward Cloud Services: Perspectives of Economic and Social Rationalities. *Pac. Asia J. Assoc. Inf. Syst.* **2019**, *11*, 65–87. [CrossRef]
10. Sorensen, M.; Yasuda, A. Stakeholder impact of private equity investments. In *Handbook of the Economics of Corporate Finance: Private Equity and Entrepreneurial Finance*; Elsevier: Amsterdam, The Netherlands, 2023; pp. 299–341. [CrossRef]
11. Naik, N.; Hameed, B.Z.; Shetty, D.K.; Swain, D.; Shah, M.; Paul, R.; Aggarwal, K.; Ibrahim, S.; Patil, V.; Smriti, K.; et al. Legal and Ethical Consideration in Artificial Intelligence in Healthcare: Who Takes Responsibility? *Front. Surg.* **2022**, *9*, 862322. [CrossRef]
12. Vo-Thanh, T.; Zaman, M.; Hasan, R.; Akter, S.; Dang-Van, T. The service digitalization in fine-dining restaurants: A cost-benefit perspective. *Int. J. Contemp. Hosp. Manag.* **2022**, *34*, 3502–3524. [CrossRef]
13. Agustí-Juan, I.; Glass, J.; Pawar, V. A Balanced Scorecard for Assessing Automation in Construction. In Proceedings of the Creative Construction Conference 2019, Budapest, Hungary, 29 June–2 July 2019; Budapest University of Technology and Economics: Budapest, Hungary, 2019; pp. 155–163. [CrossRef]
14. Wang, Z.; Wang, Q.; Nie, Z.; Li, B. Corporate financial distress prediction based on controlling shareholder's equity pledge. *Appl. Econ. Lett.* **2022**, *29*, 1365–1368. [CrossRef]
15. Du, G.; Elston, F. RETRACTED ARTICLE: Financial risk assessment to improve the accuracy of financial prediction in the internet financial industry using data analytics models. *Oper. Manag. Res.* **2022**, *15*, 925–940. [CrossRef]
16. Song, Z.; Wu, S. Post financial forecasting game theory and decision making. *Financ. Res. Lett.* **2023**, *58*, 104288. [CrossRef]
17. Murali, M.; Kanmani, S. Modelling game theory applications using network elements to ensure Nash equilibrium through Price of Anarchy and Price of Stability. *Int. J. Syst. Syst. Eng.* **2024**, *14*. [CrossRef]
18. Hamidoğlu, A. A game-theoretical approach on the construction of a novel agri-food supply chain model supported by the government. *Expert. Syst. Appl.* **2024**, *237*, 121353. [CrossRef]
19. Zhuang, Y.T.; Wu, F.; Chen, C.; Pan, Y.H. Challenges and opportunities: From big data to knowledge in AI 2.0. *Front. Inf. Technol. Electron. Eng.* **2017**, *18*, 3–14. [CrossRef]
20. Mahmood, A.; Al Marzooqi, A.; El Khatib, M.; AlAmeemi, H. How Artificial Intelligence can leverage Project Management Information system (PMIS) and data driven decision making in project management. *Int. J. Bus. Anal. Secur. (IJBAS)* **2023**, *3*, 184–195. [CrossRef]
21. Chongcs, J.; Kathiarayan, V.; Chong, J.; Sin, C. The Role of Artificial Intelligence in Strategic Decision-Making Opportunities, Challenges, and Implications for Managers in the Digital Age. *Int. J. Manag. Commer. Innov.* **2023**, *11*, 73–79.
22. Laczkovich, M. A superposition theorem of Kolmogorov type for bounded continuous functions. *J. Approx. Theory* **2021**, *269*, 105609. [CrossRef]
23. Quraisy, A. Data Normality Using Kolmogorov-Smirnov and Shapiro-Wilk Tests. *J-HEST J. Health Educ. Econ. Sci. Technol.* **2020**, *3*, 7–11. [CrossRef]
24. Schmidt-Hieber, J. The Kolmogorov–Arnold representation theorem revisited. *Neural Netw.* **2021**, *137*, 119–126. [CrossRef]
25. Ismailov, V.E. A three layer neural network can represent any multivariate function. *J. Math. Anal. Appl.* **2023**, *523*, 127096. [CrossRef]
26. Elahi, M.; Afolaranmi, S.O.; Lastra, J.L.M.; Garcia, J.A.P. A comprehensive literature review of the applications of AI techniques through the lifecycle of industrial equipment. *Discov. Artif. Intell.* **2023**, *3*, 43. [CrossRef]
27. Habbal, A.; Ali, M.K.; Abuzaraida, M.A. Artificial Intelligence Trust, Risk and Security Management (AI TRiSM): Frameworks, applications, challenges and future research directions. *Expert. Syst. Appl.* **2024**, *240*, 122442. [CrossRef]
28. Cheng, L.; Liu, X. From principles to practices: The intertextual interaction between AI ethical and legal discourses. *Int. J. Leg. Discourse* **2023**, *8*, 31–52. [CrossRef]

29. Humphreys, D.; Koay, A.; Desmond, D.; Mealy, E. AI hype as a cyber security risk: The moral responsibility of implementing generative AI in business. *AI Ethics* **2024**. [CrossRef]
30. Cho, S.; Vasarhelyi, M.A.; Sun, T.; Zhang, C. Learning from Machine Learning in Accounting and Assurance. *J. Emerg. Technol. Account.* **2020**, *17*, 1–10. [CrossRef]
31. Ganaie, M.A.; Hu, M.; Malik, A.K.; Tanveer, M.; Suganthan, P.N. Ensemble deep learning: A review. *Eng. Appl. Artif. Intell.* **2022**, *115*, 105151. [CrossRef]
32. Zhang, Z.; Cui, P.; Zhu, W. Deep Learning on Graphs: A Survey. *IEEE Trans. Knowl. Data Eng.* **2022**, *34*, 249–270. [CrossRef]
33. Chandana Charitha, P.; Hemaraju, B. Impact of Artificial Intelligence on Decision-making in Organisations. *Int. J. Multidiscip. Res.* **2023**, *5*. [CrossRef]
34. Aldoseri, A.; Al-Khalifa, K.N.; Hamouda, A.M. Re-Thinking Data Strategy and Integration for Artificial Intelligence: Concepts, Opportunities, and Challenges. *Appl. Sci.* **2023**, *13*, 7082. [CrossRef]

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The Macroeconomic Implications of the Transition of the Forestry Industry towards Bioeconomy

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Abstract: In a global economic system where essential resources are limited, demand is increasing and environmental degradation is more pronounced, the only viable option to ensure sustainable development is to create an environmentally friendly and efficient economy in order to produce more economic value with the same or fewer resources. The aim of this paper is to provide insight into the macroeconomic implications determined by the transition to a forest bioeconomy, with a focus on the impact on the national gross value added. More specifically, this analysis assesses the relationship between the potential of the macroeconomic value creation on the forestry industry and the measures of progress on the transition towards sustainable forest management and long-term economic growth. The analysis refers to a period between 2013 and 2019, summing-up 133 observations, data that were reported by Eurostat for 23 European Union members. We propose a model that describes a construct of the potential of the value creation that can be generated by each country included in our sample, translated into an efficiency score determined using the Data Envelopment Analysis(DEA)methodology. The results highlighted that the evolution of economic, social, and environmental (ESG) context positively impacted the efficiency score. This positive evolution in time was mainly driven by the higher awareness of governments, companies, and people on the need for a transition to sustainable economic growth and sustainable forest management. Furthermore, this study highlights that the transition to sustainable economic growth implies negative changes to the cost structure of the economies, which lead to higher operational costs and lower gross value added. Moreover, our study provides more insight, from an econometric methodology perspective, regarding the synergy effect as determined by the transformation of business models in the forestry sector towards sustainable forest management.

Keywords: efficient economy; sustainable development; forest management; value creation

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1. Introduction

Considering the evolution of the economy, society, and forestry policies, the transition towards a competitive sustainable economic growth model has always been a challenge, with an important impact on forestry development and the protection of resources. In addition, climate change and environmental degradation are existential threats that highlight the need to amplify interest in sustainable economic development in which natural ecosystems are not ruined by the current, linear way of producing and consuming products. In this sense, in a global economic system where essential resources are limited, demand is increasing, and environmental degradation is more pronounced, the only viable option to ensure sustainable development is to create an environmentally friendly and efficient economy in order to produce more economic value with the same or fewer resources [1].

However, the transition to a green economy does not seem to be an easily process, because it involves fundamental changes in the production and consumption of goods and services so that the needs of the present do not compromise the ability of future generations to meet their own needs [2]. In this context, the actions taken must focus on three fundamental pillars in terms of sustainability, namely, environmental protection and social and economic development. Considered jointly, these pillars point towards a society that fulfils the economic and social requirements needed now and into the future. Based on the idea that sustainable development represents a necessity that can be achieved through the concerted efforts of multiple societal actors and is not just a desideratum of developed countries that have the financial resources and are able to implement environmental conservatism programs that promote sustainable production and consumption patterns, a global commitment to sustainability has been created [3]. This action involves both the significant costs of implementation and compliance [4], which generally translate into various forms of trade-offs between regulatory frameworks, such as the "Paris Agreement on climate change" [5], the "UN 2030 Agenda for Sustainable Development" [6], or the 17 Sustainable Development Goals that were set forth as an urgent call for action in order to create a global vision to address sustainability, and challenges that lead, in the case of most countries, to the prioritization of economic growth, regardless of the value of the long-term environmental costs incurred [7].

The authors of [8,9] state that there is an efficient, resilient, and clean potential for green sustainable development, but the transition is a medium- and long-term process, involving political commitment on the part of states that want a change in the model of economic development.

Our aim in this paper was to fill the gap and provide some new perspectives on the efforts made in order to make easier the transition to a more circular economy, highlighting, at the same time, its impact on macroeconomic output. In this context, the focus of our paper was the analysis of the relationship between the gross value added reported in the forestry industry and a measure of the progress of the transition towards a competitive sustainable economic growth model. Hence, we proposed a model that describes a construct of the potential of the value creation that can be generated by each of the countries included in our sample. Our article comes with additional insights into the literature and fills in the gap through the analysis of the periods of fixed effects, which highlights that the overall evolution in time was mainly driven by structural reforms and action plans, such as that mentioned by the European Green Deal, with all its strategic components.

This paper is structured as follows: In Section 1, we presented the context that determined our study. Section 2 provides the literature regarding actual knowledge in the field and the hypotheses underlying the research undertaken. Section 3 presents the research methodology, Section 4 discusses the obtained results, and the final section, Section 5, summarizes the main findings, conclusions, and avenues for future research.

2. Literature Review

It is known that the future of Europe depends on a healthy planet, and this is why the European Union (EU) makes substantial efforts, proposing holistic and cross-sectoral approaches in which all relevant policy makers contribute to the transition towards a green economy in which renewable biological resources from land and sea are used in order to produce food, materials, and energy [10]. Hence, being a benchmark for all other countries in order to create a climate-resilient society, the European Green Deal, agreed to in 2019, reflects the formalized efforts made by the EU in order to achieve Europe's climate neutrality by 2050, boosting, at the same time, the economy with green technology, ensuring sustainable activities in industry and transport, and reducing pollution [10].

Thereby, the circular economy concept represents an alternative to the current economy of 'take–make–use–dispose' [11], which gains importance for academia, policy makers, and companies, who have become aware of its potential value, which is needed in order to ensure more sustainable economic growth [12], considering the fact that a bioeconomy

will help the EU accelerate progress towards a circular and low-carbon economy. On the one hand, there are studies [13,14] that demonstrate that rule of law, economic freedom, and inflation have a significant long-term relationship with sustainable development, with financial regulations being important in order to obtain a sustainable green economy. On the other hand, some researchers [15–18] concluded that in the implementation of the circular economy, there exist barriers that make process more difficult, especially in terms of implementing a circular business model and changing the way they operate. These barriers may come from a lack of managerial capacity, resources, and corporate knowledge [19] or due to the presence of some regulatory aspects that make the implementation process more difficult [20]. Researchers state that the difficulty in adhering to a circular economy is related to training, changes in behavior, and a lack of interest [21].

It seems that despite all costs, barriers, or obstacles, some companies strive to be circular [22]. One example is in the forest industry, a sector that has considerable potential for applying circular economic practices that can be extended to a "forest-based circular economy", which particularly implies a reduction in the input of virgin natural resources in production systems through the reuse and lifetime extension of wood products and recycling via the optimization of potential wood assortments [23], as wood-based products reduce the carbon footprint and replace nonrenewable products [21]. In the forestry sector, the circular economy can be defined as an economy in which raw materials and their value are used as efficiently as possible, transforming the undervalued forest residues and wood waste into value-generating market forest products [24]. Although based on the population growth rate, there is a tendency to convert land to different types of use, reducing forestry areas [25], efforts made at the manufacturing stage to reduce resource consumption have been acknowledged, but the implementation of other circular economy strategies and the gross value added requires further improvements. Hence, more attention must be paid to end-of-life strategies, with targeted support for the development of new and innovative technologies that allow disassembly and deconstruction. In this sense, environmental degradation related to linear resource exploitation as a result of the growing demand can be mitigated through circular economy best practices [26]. Thus, the existing policy framework needs to be refined and extended in order to promote the recovery and reintroduction of materials in manufacturing processes [27], because education, support of public policies, and cooperation in the market represent the main strategies needed in order to encourage the implementation of the circular economy concept [21] Some studies highlight that the level of education of the population affects the sustainable development of forestry resources, namely, highly educated individuals contributing substantially to the growth of resources in this area [28]. Moreover, it has been stated that only through clear legislative frameworks can circular economy ensure the sustainability of forest ecosystem services [29], although studies still reveal a lack of consistency between circular economy concepts and the forest sector that can be associated and applied [23]. Hence, researchers, through data envelopment analysis (DEA), advocate that long term-sustainability and increased economic efficiency can be obtained through substantial improvements in forest management and much more investments in research and development activities [29].

Therefore, we believe that sustainable development represents a precondition for a successful forest-based bioeconomy, and the hypotheses that were tested in this research were the following:

- **H1.** *The potential for value added creation is influenced by the stage of transition to a sustainable economy;*
- **H2.** *The convergence rate of the value added potential is influenced by the stage of transition to a sustainable economy;*
- **H3.** *The potential for creating added value is more influenced by the economic component than by the social and environmental one.*

The rationale behind our choice for this topic was multiple fold.

First, as noted in [30], forests represent an essential natural resource of EU communities. Currently, the forestry industry provides significant contributions to macroeconomic results,

with more than 7.1% of the gross value added generated by the industrial sector in EU economies. Furthermore, in [31], the authors underlined the fact that the contribution of forest exploitation to macroeconomic results was beyond the wood-processing industry, consisting mainly of the indirect effects as determined by forestry subsectors on the input–output macroeconomic level.

Therefore, the topic of forest management is rather a complex matter that asks for an interdisciplinary approach, including the analysis of forest management through a lens of social, economic, governance, and environmental implications [32–35]. Additionally, we subscribe to opinions that emphasize the negative effects on public policies of the decision-making process, as there are a lack of studies in the area of sustainable forest management that provide a cost–benefits analysis in financial terms, such as the generation and distribution of socioeconomic value and environmental costs [23,33]. All cost elements translate eventually into a decrease in the value added generated by forest exploitation, redesign, and management of the processes of support. Furthermore, such a discussion is essential for policy makers, as studies on the socioeconomic implications of sustainable forest management represent a basis for the justification of the shift from command-and-control forest management to broader governance schemes that seem to be more visible [36]. Therefore, markets expectations and consumers' preferences oriented on more sustainable wood-based products are expected to determine firms to ensure forest legality, alignment to certification systems, or protocols addressing the requirements of sustainable forest management, and forest management strategies and practice aligned with global and regional climate change objectives drawn-up by Sustainable Development Goals (SDG) 13 [37].

Second, the empirical analysis in our study emphasized how important is the adoption of sustainable forest management conceptual models, frameworks, and practice. Forests are not only sources of income but also providers of ecosystem services. As long as there are no existing studies addressing the economics of forest ecosystems services and their contribution to human well-being, public policies will not be properly calibrated to be aligned with the objectives of forests conservation and general sustainable development of the economies [38]. On those circumstances, forestry operations and related supply chains will fail to contribute to the achievement of national, regional, and global strategies concerning sustainable forest management, as long as there is a lack of created incentives for firms to adopt sustainable forest management(SFM)oriented strategies, corporate policies, and governance mechanisms and tools.

Third, we considered relevant our analysis in order to assess if there were any synergies or trade-off affects between the SDG 15 targets related to forest management and the SDGs [37], such as SDG 7 setting-up targets on affordable, reliable, and sustainable energy [39,40], SDG 8 related to targets on sustainable economic growth [7,41,42], SDG 12 related to sustainable consumption and production patterns [7,39,41], or SGD 13 addressing targets aimed to combat climate changes and its impacts [7,39]. All of those sustainable development goals influence the elements of revenue and cost of the value added measures analyzed in this study, and they are a reason why this type of association between the construct of potential value creation and the measures of sustainable development provide us with relevant evidence if there is a trade-off or a synergy effect determined by transformation of business models in forestry sector towards sustainable forest management. As the literature does not provide a clear type of association, as both trade-offs and synergy effects are reported between those SDGs, we expect to provide some more insight but this time from an econometric methodology perspective.

Forth, seems that researchers pay an increasing attention on progress on the technological topics related to forest managements [34], which should be intensified in the actual light of extended intention and decisions to implement in Industry 4.0 emerging technologies with applicability in forestry [43,44]. Therefore, strategic thinking, cooperation, and supply chain optimizations are expected to describe the more recent Forest 4.0 concept, which consists of better calibration of the demand for wood-based products, which

are characterized by higher quality, longer life cycles, and sold together with additional services, such as refurbishment and re-use. Of those circumstances, a high potential for value creation can be generated through cost reduction and product redesign and process optimization in terms of material use, with implications at the level of deforestation, as long as efficient machines, appropriate technical systems, innovative products, and process redesign together with suitable knowledge management and human capital development are financed by corporations over the long term [45].

Fifth, the study highlights how important a governmental, regional, and global approach for sustainable forest management is, in terms of an institutional framework, in this area, as differences at the institutional level could lead to significant incoherencies [46]. All of these incoherencies resumed in the cost–benefits analysis that circle around efforts to adopt sustainable forest management models. The current macroeconomic contribution of the forestry sector can be sustainable, under actual natural resource constraints, and only through smart and feasible public policies, governments, and people's awareness of the need for sustainable forest management strategies and benchmarked international practice. Furthermore, issuing public policies is expected to generate positive returns in terms of sustainable forest management; yet, this is not sufficient, as there must be implemented effective enforcement mechanisms as well and significant incentives offered to corporate decision makers to comply with the government's direction. Otherwise, the heterogeneity in practice would lead to a decrease in the potential synergy effects at the macroeconomic level, and negative externalities would be generated by public policies and regulation in the area of forest management.

Lastly, but not least, we note the essential role that quality plays in the public policies that governments issue in the area of sustainable development, in general, and sustainable forest management, in particular. There are problems regarding how restrictive and qualitative the national or regional regulation is in the area of sustainable forest management, which may differ between countries either because of an insufficient understanding of the conceptual models of sustainable forest management or because of a lack of experience and expertise within the members of the body that sets standards [47]. Those elements lead to policy incoherence, with implications for the implementation of public policies and control of compliance with sustainable forest management practice under national regulation or requirements addressed through different best practice protocols or certification standards, especially in light of the spatial and time varying particularities of forest management processes [46,48]. Unless governments and professional organizations do not provide a robust sustainable forest management model, positive results in sustainable economic development are less likely, except for a situation such as an institutional framework, national regulation, or public policies addressing SFM, which ensures appropriate correlation between the following directives [49]:

- Brings more clarity to the conceptual framework of sustainable forest management, enhancing discourse and understanding of SFM;
- Shapes and focuses the engagement of science to take advantage of innovation and technological advances in SFM;
- Improves the monitoring and reporting on SFM to facilitate transparency and evidence-based traceability and decision making;
- Strengthens forest management practices by market-based and regulatory incentives;
- Facilitates the assessment of progress towards SFM goals;
- Facilitates forest-related dialog and communication.

Therefore, high incoherence in public policy understanding and implementation could lead to nonpredictable patterns in corporate behavior, with negative implications for long-term forest planning, consumers' behavior modeling, waste reduction, and generated value added. If we add the political factor to this equation, the negative effects on the translation of sustainable forest management objectives in public policies and sustainable forest management practice increase [32]. As long as there is no political consensus and there is a lack of ensured clear directions and monitoring tools, the results are expected to

be poor and unpredictable and any changes to be reversible. Relevant to this reality is a comparison between the New EU Forest Strategy for 2030 with the pan-European set of indicators for sustainable forest management, which seem to have significant gaps in terms of the appropriateness of those indicators for the assessment of SFM objectives, goals, or targets [48,50,51].

The progress towards sustainability is visible among all EU member states that have progressed favorably, although not all to the same extent [52]. It seems that huge investments, long-term efforts, and governmental programs can determine real progress in achieving much of the desired sustainable development [53]. In addition, studies highlight that increased economic efficiency can be obtained through permanent improvements in forest management [54], revealing the fact that forest management represents a key issue in any transition towards sustainable societies [4]. Nevertheless, researchers point out the need for additional surveys on optimizing the interaction between forests ecosystems and circular economy, our study fills the gaps, providing more insight, from an econometric methodology perspective, into the synergy effect as determined by the transformation of business models in the forestry sector towards sustainable forest management.

3. Materials and Methods

3.1. Data and Variables Description

Our study aimed to understand the impact of efforts toward the transition to a more circular-based economy on macroeconomic output. In other words, we analyzed the relationship between the gross value added reported in the forestry industry and the measure of progress on the transition towards a competitive sustainable economic growth model. The analysis referred to the period between 2013 and 2019, summing-up 133 observations included in the sample analyzed.

For this purpose, we collected statistical data reported by Eurostat for 23 European Union members: Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden. While the United Kingdom left the European Union, for the rest of the EU members, we did not have a full set of data available for the period analyzed. In Table 1, we define the variables included in our analysis.

Table 1. Description of variables included in this study.

Name	Description	Database Field Name Considered in the Analysis
	DEA Analysis	
Gross value added (GVA)	The natural logarithm of the gross value added (EUR millions) reported to be generated by the forestry sector; the measure describes the contribution of the forestry sector to the GDP of each country.	Eurostat FOR_ECO_CP__custom_3657896
Employees (EM)	The natural logarithm of the number of employees (thousands of annual working units) working in the forestry sector.	Eurostat FOR_AWU_custom_2183481
Fixed capital (FC)	The natural logarithm of the gross fixed capital formation, which reflects mainly the depreciation (consumption) of the assets used in the operations in the forestry sector.	Eurostat FOR_ECO_CP_custom_2183813
Wood consumption (WC)	The natural logarithm of the value of the roundwood material (wood in rough) removals processed and deliver on the market as wood final products.	Eurostat FOR_REMOV_custom_22000886

Table 1. *Cont.*

Name	Description	Database Field Name Considered in the Analysis
	Econometric analysis	
	Dependent variables	
Efficiency score	A measure of efficiency, determined as an output of the Data Envelopment Analysis performed, considering as input variables the number of employees, the depreciation of the fixed assets affected in the daily operations, and the consumption of the natural resource of wood.	Data Envelopment Analysis score output
	Independent variables	
Business sophistication (BS)	An aggregate sub-index of the global competitiveness index that concerns the quality of a country's overall business networks (i.e., supply chains) and the quality of individual firms' operations and strategies that draw-up clusters.	World Economic Forum
KOF index (KOF)	An index of economic globalization disclosed annually by the KOF Swiss Economic Institute, measuring the overall openness of national economies.	KOF Swiss Economic Institute
GSCI index (GSCI)	This reflects an aggregate index that integrates 131 measurable indicators, concerning five main areas: availability of natural resource, the efficiency and intensity use of the natural resources, availability and quality of intellectual capital, the effectiveness of governance mechanisms, or elements of social cohesion.	Solability
	Robustness analysis	
	Dependent variables	
Growth $\Delta GVA_{i,t}(\%)$	The percentual growth of the gross value added created on the forestry sector, as per relationship $\Delta GVA_{i,t}(\%) = \frac{GVA_{i,t}}{GVA_{i,t-1}} - 1$, where $GVA_{i,t}$ is the gross value added reported in year t by country i; it is used to measure the speed of convergence of the speed of growth of the value added, as per the beta convergence classical economic growth econometric model [55].	Eurostat FOR_ECO_CP__custom_3657896
	Independent variables	
Social capital (SC)	A sub-index of the GSCI index, reflecting social aspects concerning health, social stability, public services, crime, or freedom.	Solability social capital dimension
Resource intensity (RI)	A sub-index of the GSCI index, reflecting the efficiency and the environmental effects of using natural resources, concerning consumption and management of energy, water, or waste, with an impact on climate change and environmental pollution.	Solability resource intensity dimentions
Natural capital (NC)	A sub-index of the GSCI index, reflecting the availability of natural resources, concerning forests, energy, agriculture, minerals, or areas of environmental degradation.	Solability natural capital dimension
Governance capabilities (GC)	A sub-index of the GSCI index, depicting rather the involvement, the effectiveness, and the results of national authorities in terms of infrastructure, governments cohesion, business environment, corruption, or financial stability.	Solability governance capabilities dimension
Intellectual capital (IC)	A sub-index of the GSCI index, integrating a multitude of indicators related to both, the infrastructure, the resources of education, the potential of innovation, the effective positive impact of regulation on the business area, or the solutions of financing R&D initiative.	Solability intellectual capital dimension

Source: authors' projection.

Measuring the readiness of each country for sustainability, is an open topic as the methodological issues seem to persist [56]. The complexity of the concept of sustainability is a fundamental issue that is still not solved, as it raises awareness of the fact that decision

makers have to put in balance different relationships, synergies, and trade-offs related to the SDGs, which are reported at the national, regional, and global levels [52,57]. The concept of sustainability, nowadays, leads to bioeconomy, but this suggests as well directs towards economic resilience, both facilitated by continuous improvement and innovation [58]. However, the concept of sustainability concerns not only economic and economic aspects but also social and governance aspects that have become increasingly important in the current context of natural resource constraints.

The forestry industry is not an exception, as it is part of national economies and highly impacted by strengthened and robust networks at the regional and global levels of the economy. Instead, the current literature has brought insufficient insight into the macroeconomic implications of a transition to a bioeconomy for the forestry industry, highlighting a more theoretic approach with irrelevant duplicate results [59]. However, three main concepts have been addressed when talking about a forest bioeconomy: sustainable development, bioenergy production, and climate change mitigation [60].

Those premises have made us determined to find out the aggregate measures of the transition to a sustainable economy, including a bioeconomy. As the concept itself is extremely complex, we appreciated the Solability aggregate sustainability competitiveness index, which was appropriate for our analysis. It is an aggregate measure of five dimensions that are fundamental for a description of transition to bioeconomy and, in general, for transition to sustainable economic growth. This aggregate indicator covers, in a more synthetic way, the essential aspects drawn-up by the UN SDGs, which include, both directly and indirectly, the transition to a forest bioeconomy. Indeed, the forest bioeconomy should represent a key element in each country's strategy for sustainable development, as its contribution is substantial in value creation [61]. The role of the forest bioeconomy, materialized through different channels (e.g., biodiversity, carbon emission mitigation, medical plants, fresh water, and consumers' behavior in the furniture market) is essential [4].

The link between the SDGs and a sustainable forest economy is covered by framework proposed by Solability.

The dimension of natural capital describes the level of natural resource availability. As long as there are constraints on the supply chains related to natural capital, including wood-based products, the process of value creation is negatively impacted. A higher degree of deforestation leads to long-term land degradation, negative impacts on biodiversity, a lower quality of water, pressure on supply chains, increased wood-based products price, and increased levels of environment pollution. Therefore, this dimension incorporates both the synergy effects and trade-offs of different SDGs, such as SDG 1, SDG 6, SDG 7, and SDG 12. That is why we considered it opportune to use this aggregate in our econometric analysis, without isolating the subdimension related strictly related to the forest industry.

A similar approach was considered for the other dimensions as well.

The social dimension is affected by the forestry sector operations along with all of it subdimensions of health, equality, crime, freedom, and satisfaction. The lower the level of deforestation operations, the higher the level of population health, which is in line with SDG 15. In the context of natural resource constraints, the lower the level of deforestation operations for industrial purpose, the higher the chance people can have access to wood resources for personal use (e.g., heating for winter) at affordable prices, which is an aim of SDG 7. Those effects transpose exposure to wood theft, violent conflicts, or even individual happiness.

In the case of intellectual capital and innovation, the subdimensions of education, R&D expenses, or a competitive business environment, described as new comers' influencing the process of gross value creation, are included in forestry. A higher education among the population is expected to lead to opportunities for the more efficient use of natural resources, such as wood, and a higher awareness among the population of the costs and benefits of a model of macroeconomic sustainable growth as well as their willingness to model their consumption behavior in this direction. The higher the level of R&D expenses and investments, it is expected to lead to more intense development of the forestry economy

and be less related to extensive development that would suggest higher consumption of natural resources, with negative implications on the sustainability of economic growth.

The dimension of governance efficiency is designed to provide a rough picture of countries' institutional capabilities to apply the rule of law and ensure high-quality regulation meant to support the business environment. The role of this institutional framework is even more important in cases regarding the forestry economy, as here, there is high awareness regarding the unhappy evolution of the reduction in natural resources, which should be slowed down by mature enforcement mechanisms that are defined by high-quality regulation and that are applied by well-prepared government specialists and supported by innovative solutions of tracking and monitoring wood removals.

Nonetheless, this dimension of resource efficiency represents the dimension of appreciation, describing best the readiness of each country to move towards a forest bioeconomy. The subdimensions of this pillar reflect the effort each country has made to ensure the reduction of waste, intensive economic development, or resilient supply chains, especially in an actual environment characterized by a high risk of disruptions. The most relevant evidence is related to the effects of the recent COVID-19 pandemic, which caused significant changes to the market's structure, consumers' behavior, and the design of operational processes along entities operating in the forestry industry.

We limited our research to the EU region, as the study represents just a starting point to analyze the effects of a transition to a green economy for the potential of value creation in the forestry industry. This choice was mainly driven by the fact that those countries subscribe to similar regulations, driven by European directives and regulations that are mandatory for all EU members. The steps in this direction places the EU region as a benchmark for all other countries, especially starting with the moment all those countries' efforts were formalized and agreed through the European Green Deal document in 2019. The period analyzed describes more appropriately the effects from the changes to the EU regulation promoting a transition to a green economy. Under those circumstances, in our analysis, we looked for period fixed effects, as well as checked the overall evolution during that time, which were mainly driven by structural reforms and action plans, such the European Green Deal with all its strategic components.

3.2. Data Envelopment Analysis (DEA)

Designing an optimal measure of value creation in the forestry sector, our aim was to describe a construct of the potential of value creation that could be generated by each of the countries included on the sample analyzed. Therefore, the gap between the countries with a forestry sector generating the highest gross value added were to be considered as benchmarks. Henceforth, comparing each country included in our sample with the "best" performers allowed us to calculate the gap that needed be covered which, from our perspective, could be perceived as the potential for the growth of value added generated by the forestry sector.

The optimal output identified through the gross value added, in the case of the "best" performers, was conditioned by a series of input factors. Following the philosophy of production functions, we considered as input variables for our benchmarking analysis the number of employees working in the forestry industry, the fixed capital affected by operations in this sector, and the natural resources used (raw wooden and intermediate materials), as reflected in Figure 1. For this purpose, we conducted a data envelopment analysis (DEA).

From a mathematical perspective, the DEA model refers to several core concepts: decision-making units, inputs, and outputs. In this direction, we considered countries as DMUs (decision-making units) in a sample of $j = 1, \ldots, n$, counting for $i = 1, \ldots, m$

inputs (x_{ij}), and producing $r = 1, \ldots, s$ outputs (y_{rj}). The DEA model provides a technical efficiency solution for country j_0 compared with n peer group countries' inputs and outputs.

$$\max \sum_{i=1}^{m} v_i \cdot x_{ij} + v_0^+ - v_0^-$$
$$\sum_{j=1}^{n} \lambda_j \cdot x_{ij} - v_0^- = x_{ij0}\ , \forall i$$
$$\sum_{j=1}^{n} \lambda_j \cdot y_{rj} + v_0^+ = y_{rj0}\ , \forall r$$
$$\sum_{j=1}^{n} \lambda_j = 1$$
$$\lambda_j \geq 0,\ \forall j,\ \varnothing\ free$$
$$\max \frac{GVA}{v_1 \cdot EM + v_2 \cdot FC + v_3 \cdot WC}$$

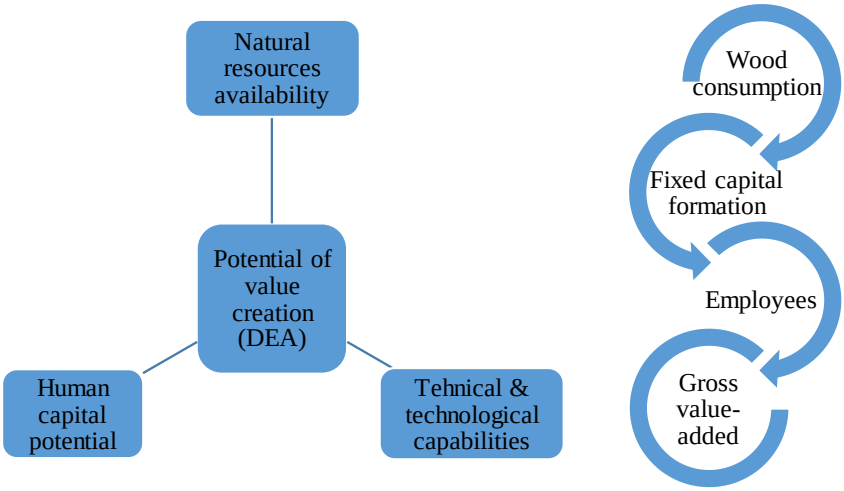

Figure 1. Diagram of the operationalization of potential value creation. Source: authors' projection.

The mathematical model above provides the DEA efficiency measure [62], where λ_j are the related positive weights, while the efficiency ratio function is designed to maximize countries' forestry sector gross value added, considering specific countries' available natural resources and human, technical, and technological capabilities.

This approach is similar to models that are based on the classic production function, which explains the output of a production process based on the consumption of production factors. In this study, the output function variable was related to the gross value added generated by the forest industry, whereas the production factors were resumed to the human capital, fixed capital, and the roundwood removals. However, the DEA provided us the gap score between each country, compared with the best country performer.

3.3. Econometric Models Design

The next step in our analysis consisted of an econometric analysis that described the relationship between the countries' gross value added and the progress towards more sustainable economic growth. It was expected to be a negative relationship, as a transition to a green economy involves significant costs in its implementation and in compliance costs as well [4], which generally translate into various forms of trade-offs among different SDGs, including SDG 15 in relation to the other SDGs [7], which leads, in the case of most countries, to the prioritization of economic growth, no matter the environmental costs incurred over the long-term. However, this could lead to mixed results, as countries have chosen different approaches to address the challenges of sustainable economic growth. A relevant example is the EU region, which can currently be considered a global benchmark in terms of efforts to promote green economies, as they have coordinated their strategic policy efforts through the European Green Deal.

The econometric models estimated in our study are described by the relationships below:

$$Efficiencyscore_{j,t} = \alpha_0 + \alpha_1 \cdot GSCI_{j,t} + \alpha_2 \cdot BS_{j,t} + \alpha_3 \cdot KOF_{j,t} + Period\ effects + \varepsilon_{it}\ (\textbf{Model 3})$$

The notations are described in Table 1. Whereas, ε_{it} is the error term that incorporates the part of the efficiency score that is not explained by the factors included in our econometric models.

The econometric model is designed to reflect the marginal effect of the transition towards a sustainable forest economy on each country's potential to achieve the performance achieved by the country included in the sample with the highest financial results. Therefore, a higher efficiency score translates into closer results of a country to the results reported by the best country performer, with indirect positive impact on the value added, which is expected to be higher in the transition towards a forest bioeconomy and sustainable economic development [4]. Furthermore, we highlighted through this econometric model the role of the globalization phenomenon in the transition towards a forest bioeconomy and directly on macroeconomic output. The more complex and the higher the exposure to international markets of the business models, the higher the production performance and economic results. Therefore, this causal relation suggests a way for countries to achieve financial macroeconomic results closer to that of best performing country as nominated by the DEA results.

The analysis is conducted using panel data sets, checking for fixed or random effects as well, if the relevant statistical tests, such as the Hausman test, the Breusch–Pagan test, or the F tests, confirmed which effects were statistically significant. The models looked only for period fixed effects to reveal trends in the relationship between the potential for value creation and the progress towards a green economy. However, we did not proceed to country fixed effects, as through the DEA we already controlled for countries' economic model specifics.

We included on the estimated econometric models the impact of economic globalization and business sophistication, as those two pillars are expected to represent essential premises for the generation of added value in the context of the role of transnational corporations, which generate significant effects on countries' macroeconomic output by extending and continuously improving complex supply chains. From this perspective, each state should be aware of its contribution to a favorable regulation and enforcement framework that promotes initiatives with a higher potential for added value and discouraging the ones with a lower potential, including in the forestry sector.

3.4. Robustness Analysis

Further, we performed additional robustness analysis. First, we tried to understand if the transition to a sustainable economic growth model has implications on not only the potential of the growth of forestry sectors in terms of value added but also on the absolute value added reported, or if it changed the speed of the convergence of the sector growth between countries with a more developed forestry sector versus countries with a less developed forestry sector. For this purpose, we estimated the models below:

➢ Model assessing the impact of sustainability on the forestry sector's reported added value:

$$GVA_{j,t} = \alpha_0 + \alpha_1 \cdot GSCI_{j,t} + \alpha_2 \cdot BS_{j,t} + \alpha_3 \cdot KOF_{j,t} + Period\ effects + \varepsilon_{it}\ (\textbf{Model 1})$$

➢ Model assessing the impact of sustainability on the forestry sector's speed of β convergence:

$$\Delta GVA_{j,t}(\%) = \alpha_0 + \alpha_1 \cdot GSCI_{j,t} + \alpha_2 \cdot BS_{j,t} + \alpha_3 \cdot KOF_{j,t} + Period\ effects + \varepsilon_{it}\ (\textbf{Model 2})$$

Relevant for our discussion is also the differentiation that should be made between the estimates obtained using either the sustainability-based competitiveness index or the World Economic Forum-developed global competitiveness index. We considered that this comparative analysis provided more insight into the environmental and the social implications of the economic activity on the macroeconomic level, as the GCI incorporated no aspects of environmental protection, whereas the social aspects integrated were rather related to social aspects with a direct impact on the economic activity and output, such as education [63]. Therefore, in relation to **model 3**, we estimated the model below, incorporating the effect of the GCI index instead of the GSCI index:

$$Efficiency\ score_{j,t} = \alpha_0 + \alpha_1 \cdot GSCI_{j,t} + \alpha_2 \cdot BS_{j,t} + \alpha_3 \cdot KOF_{j,t}\ (\textbf{Model 5}) \\ + Period\ effects + \varepsilon_{it}$$

As a last step in our robustness analysis, we estimated an econometric model that provided us with insight into what contribution was determined by each of the five sub-indexes of the GSCI overall index to understand which pillar was significant and generated the highest marginal effect on the potential of countries' value creation in the forestry sector:

$$Efficiency\ score_{j,t} = \alpha_0 + \alpha_1 \cdot NC_{j,t} + \alpha_2 \cdot SC_{j,t} + \alpha_3 \cdot IC_{j,t} + \alpha_3 \cdot GC_{j,t} + \alpha_3 \cdot RI_{j,t} \\ + Period\ effects + \varepsilon_{it}\ \ (\textbf{Model 4})$$

The period effects were analyzed to identify any substantial changes over time in the institutional framework, technological capabilities, resource availability, global economic growth and environmental premises. It is essential from this perspective to understand that the process of convergence is dynamic and that some gaps could still persist, as the best performers do not necessarily stop from evolving as well.

3.5. Sensitivity Analysis

The last part of our study related to further investigations on the consistency of our results, this time from the perspective of the influence of the distribution of the probabilities of the variables included in the econometric analysis. As the efficiency score did not follow a normal distribution, we verified our OLS results with the regression coefficients determined estimating this time a separate quantile regression model.

$$Efficiency\ score_{j,t} = \alpha_0 + \alpha_1 \cdot GSCI_{j,t} + \alpha_2 \cdot BS_{j,t} + \alpha_3 \cdot KOF_{j,t}\ (\textbf{Model 5})$$

Therefore, in **model 6** we included in the econometric quantile regression model only the variables that were included in **model 3** in order to have a proper basis of comparison for the potential effects of the non-normally distributed efficiency score variable. However, in the case of this model, we did not control for the period effects, as in the case of the estimated quantile regression, the scope of our analysis was rather for checking the consistency of the initial OLS econometric analysis, with no purpose to conduct a tendency analysis.

4. Results and Discussions

4.1. Exploratory Statistical Analysis

Our study was designed to provide insight into the implications of the implementation of sustainable economic growth on the macroeconomic level. Specifically, we looked for an association between the level of gross value added generated by the forestry industry and the level of achievement of the core principles and objectives of sustainability on the macroeconomic level.

In Table 2, we provide summary statistics of the main variables related to measures of economic growth and sustainability performance reported at the macroeconomic level in the context of economic globalization and resource constraints.

The gross value added mean (6.581) and standard deviation (1.144) describe a relatively homogenous structure for the national economies included in our sample, as the deviation

explained approximately 17.39% of the mean value. The forestry industry contributed to an overall gross value added of only 0.46%, which did not show a high contribution to the overall GDP. Further, the efficiency of the exploitation of forests land led to higher output that could generate cost-based positive synergy effects in areas such as renewable energy, climate change, public health, or even green tourism [3,4,50].

Table 2. Descriptive statistics.

Variable	Mean	SD	Min.	Max.	Collinearity Statistics		Kolmogorov–Smirnova	
					Tolerance	VIF	Stat.	Sig.
Gross value added	6.581	1.144	4.027	8.340	-	-	0.130	0.000
Efficiency score	0.694	0.250	0.226	1.000	-	-	0.225	0.000
GSCI index	51.49	3.945	42.80	62.10	0.548	1.826	0.059	0.200 *
GCI index	4.868	0.532	3.860	5.845	0.413	2.421	0.514	0.000
KOF index	74.27	18.23	0.077	89.57	0.907	1.103	0.345	0.000
Sophistication	42.82	8.611	27.30	68.80	0.439	2.275	0.138	0.000
Natural capital	48.20	8.253	30.27	67.60	0.979	1.021	0.083	0.058
Social capital	53.44	6.998	37.72	74.60	0.767	1.304	0.053	0.200 *
Intellectual capital	54.27	6.893	34.90	70.78	0.681	1.468	0.042	0.200 *
Governance	55.32	5.906	42.50	69.50	0.905	1.105	0.056	0.200 *
Resource Intensity	48.68	9.332	26.60	69.36	0.784	1.275	0.073	0.186
GDP per capita	12.19	1.437	9.715	14.96	0.794	1.259	0.097	0.012

* This is a lower bound of the true significance. Source: authors' calculation.

However, this contribution varied across countries, depending not only on the area of forests available but also on human capital, techniques, and technologies used along with the industrial processing of wood timber [4]. Essential to this equation is how to ensure intensive economic growth rather than through a model of extensive growth that resumes mainly from the extension of the volume of timber processed from a larger area of forests.

4.1.1. Dynamics on Value Creation Potential from Benchmarking Perspective

The score of efficiency is the measure that provides us with an indication of the potential increase in the gross value added generated by forestry through a combination of all production factors, such as the consumption of timber, the availability of human capital, and the use of modern techniques and technologies to process wood. In Table 2, we can observe the heterogeneity in our sample from the perspective of the efficiency score, as the mean of the DEA calculated score (0.694) was explained by more than 36% of the variation in the sample (0.250). We observed a high widespread on the efficiency score, mainly driven by gaps in terms of the potential of the gross value added between the best performers (1.000) and the lower performers (0.250).

Starting from a sustainable consumption perspective, we understood this gap between countries as capabilities and that economies must generate gross value added in the forestry area by minimizing the use of production factors. Therefore, the 1st quartile (0.482) on this measure suggests that the first 25% of the countries analyzed reported a performance lower than half that of the benchmark countries. In Figure 2, we can see the best performers were Finland, France, Italy, and Netherlands; each economy were considered with a different combination of the production factors. The lower performers were Hungary, Latvia, or Lithuania, who either did not have internal forests areas available or just preferred to follow the model of extensive economic growth, by exploring insufficiently the potential of human capital and emerging technologies, such as IoT, that could bring relevant improvement in terms of planning and monitoring industrial processes.

The information in Figure 3 provide us with relevant insight concerning the association between the efficiency score and the gross value added generated by forestry areas. The representation of both variables suggests a positive relationship from the association, as a

higher efficiency score is related to a higher gross value added. This relationship persisted over time, but the increase in the efficiency deteriorated slightly in the period 2018–2019, mainly driven by governments' awareness of the role of public policies and regulation for achieving targets of the SDGs, with a greater focus on SDG 15 [63–65]. Therefore, awareness by the government produces visible effects on forestry, later than the adoption in 2015 of the UN Sustainable Development Goals (SDGs), showing a lower increase in efficiency starting with results reported in 2018.

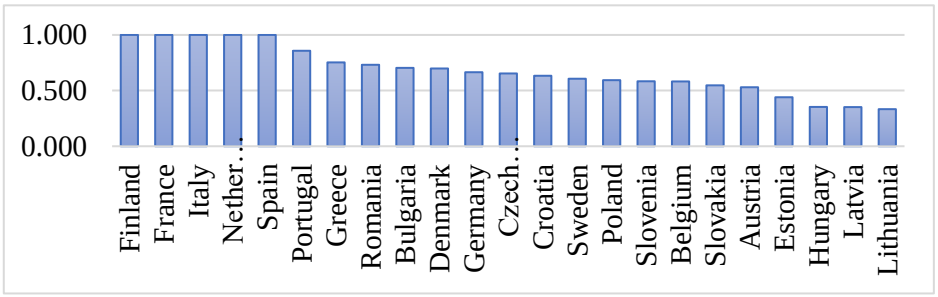

Figure 2. DEA-based efficiency score by country. Source: authors' projection.

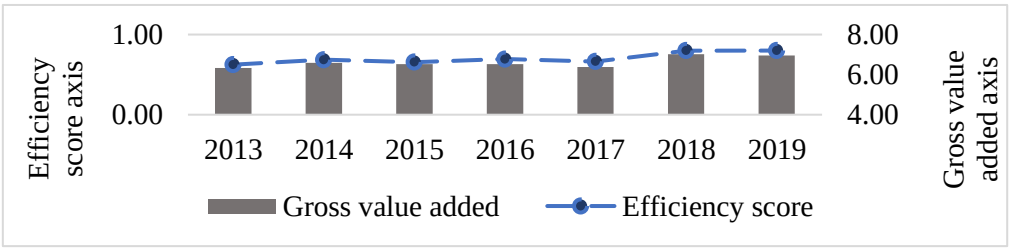

Figure 3. Gross value added (ln) and DEA-based efficiency score. Source: authors' projection.

Starting this year, we observed that the efficiency score slightly decreased, based on additional costs incurred to implement measures of sustainability at the macroeconomic and institutional levels. However, the decrease in the growth of the efficiency score had a lower impact on the increase in the gross value added, as an increasing number of Industry 4.0 emerging technologies were implemented. Therefore, technologies, such as simulation (Sim), geographic information systems (GIS), or radio frequency identification (RFID), generate real positive effects on cost reduction, reduce the complexity of processes, or promote continuous improvement initiatives [44].

4.1.2. Country Based Sustainability Profiles on EU Region

The EU countries included in our sample showed a relatively high level of global sustainability competitiveness index, as the mean value (51.49) was close to the maximum value (62.10). However, there were slight differences across countries, especially from the perspective of some of the sub-indexes included in the GSCI index, particularly concerning the natural capital component and the resource intensity component.

Therefore, a higher variation among countries was shown in the case of those two sub-indexes, as their coefficient of variation was slightly higher: 17.12% for the natural capital component and 19.17% for the resource intensity sub-index. Based on these results, we proceeded to a cluster analysis to group the countries included in our sample using as input criteria the five core pillars of sustainability as proposed by the Solability model. In Figure 4, we represent the mean values of each of the five sub-indexes that were part of the overall sustainability competitiveness index. In this representation, we note the slightly higher difference across the clusters on exactly the pillars placed at the basis of the calculation of this GSCI index.

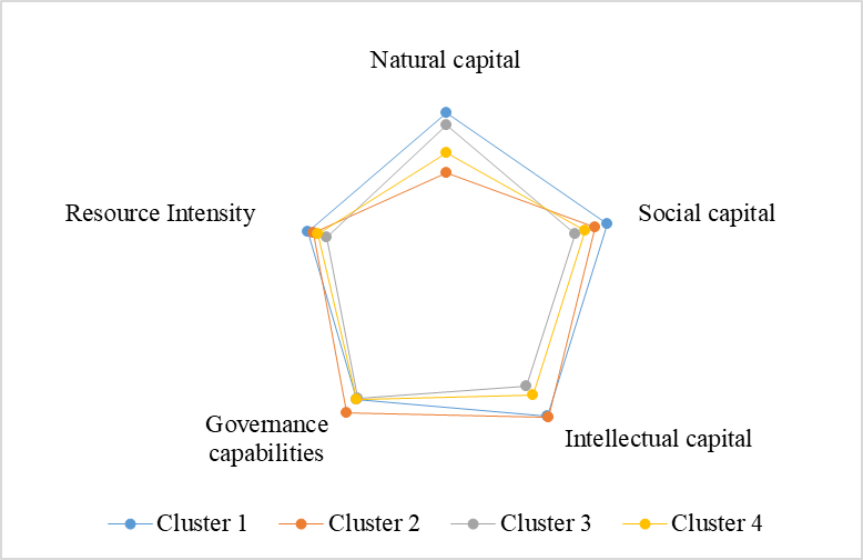

Figure 4. Dendrogram reflecting clusters of the sustainability models. Source: authors' projection.

The highest spread within our sample was recorded with the natural capital sub-index, which reflects a mixture of the availability of natural resources (e.g., population, geography, climate, and biodiversity) as well as the level of depletion/degradation of those resources. Looking at Figure 5, it represents a dendrogram associated with our cluster analysis, note that countries in Northern Europe are clearly delimited in a single cluster, while the fourth cluster includes most of the countries used in our sample. These clusters are similar to the ones estimated in [66–68], where the Northern European countries placed at the top of best performers in terms of sustainability performance.

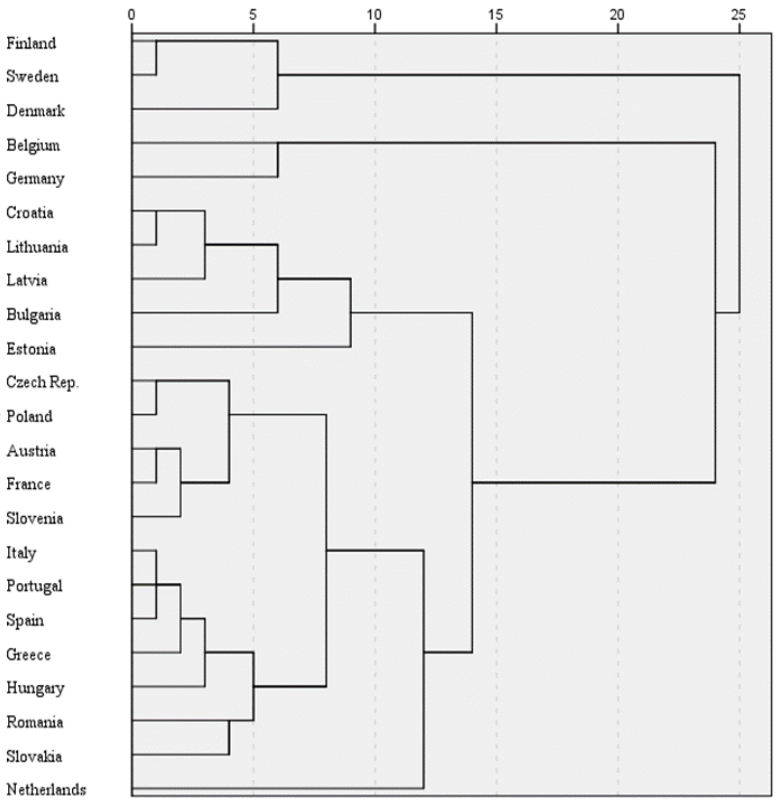

Figure 5. Dendrogram reflecting clusters of sustainability models. Source: authors' projection.

This cluster analysis showed a higher difference between countries in terms of sustainable growth that was indicated by the public policies and institutional frameworks setup in those Northern European countries, which have much more forests land, but they are also on top in terms of countries with higher depletion rate of forests, but their regeneration rates are mainly driven by natural forest regeneration rather than government-driven public policies and projects [69].

In terms of gaps identified concerning the use of the production factors considered in the DEA analysis, we note in Figure 6 that the main gap in forests exploitation across countries was related to fixed capital use, referring to the techniques and technologies used. This result shows us that Northern European countries affect higher amounts of fixed capital for the exploitation of natural resources, mainly driven by higher volumes of wood processed, whereas the other factors considered in the analysis were slightly similar across the countries. Therefore, challenges and opportunities towards better efficiency in forests exploitation obtained by a higher gross value added through minimizing the consumption of natural resources can be found, especially, in the area of implementing emerging technologies.

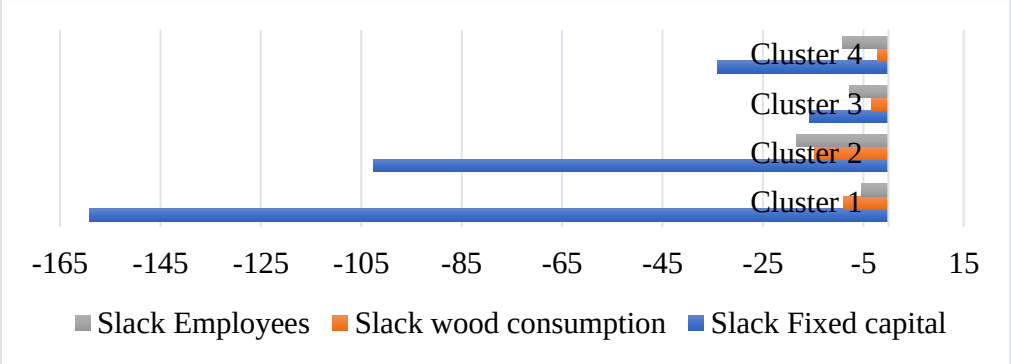

Figure 6. Gaps in the production factors from the perspective of the DEA results. Source: authors' projection.

4.2. Correlation Analysis

In Table 3, we summarize the correlations between the variables considered in the analysis.

Overall, the results suggest statistically significant positive correlations between the efficiency score and the slack on employees working in the forestry industry (0.537). This correlation shows that the gap between the results reported by a country and the results reported by the best performer (slack) positively influences the efficiency score, underlining how important the human factor is within forestry business models, in addition to the technical endowment. Therefore, a higher slack on employees, determined by a higher slack as well on wood consumption (0.509), resulted in a similar one as obtained in [28].

However, the higher correlation between the slack on wood consumption and the slack on fixed capital affected for forestry exploitation (0.781) confirmed again a high level of automation in forestry industrial processes. Instead, a higher endowment with technical capabilities is amplified by the human factor by integration of solutions of emerging technologies that lead to better overall equipment effectiveness (OEE) and higher machine productivity.

Therefore, synergy effects can be achieved by combining equipment, integrating solutions for the implementation of Industry 4.0-based enabling technologies, and using highly qualified human capital. Those synergy effects are suggested as well by the negative correlation between the component of intellectual capital of the GSCI index (−0.419) and slack on fixed capital. This negative correlation shows that countries implementing innovative solutions in the area of operations, lead to better equipment productivity, which place countries closer to the best performers.

Table 3. Pearson correlation matrix.

	Efficiency Score	Slack Employees	Slack Fixed Capital	Slack Wood Consumption	Growth Gross Value Added	Gross Value Added
			DEA-based slacks calculated			
Employees	0.537 **	1	0.323 **	0.509 **		
Fixed capital	0.344 **	0.323 **	1	0.781 **		
Wood consumption	0.406 **	0.509 **	0.781 **	1		
			Aggregate country indexes			
GSCI index	0.016	0.047	−0.531 **	−0.391 **	−0.232 **	0.398 **
KOF index	0.035	0.084	−0.101	−0.114	−0.037	−0.005
GCI index	−0.104	−0.018	0.028	0.089	0.117	−0.009
Business sophistication	0.192 *	0.188 *	−0.477 **	−0.350 **	−0.152	0.429 **
			Sustainability competitiveness pillars country sub-indexes			
Natural capital	−0.064	0.137	−0.252 **	−0.103	−0.022	0.102
Social capital	0.087	0.119	−0.242 **	−0.072	0.035	0.232 **
Intellectual capital	0.084	0.143	−0.419 **	−0.281 **	−0.143	0.336 **
Governance capabilities	−0.210 *	−0.330 **	−0.206 *	−0.291 **	−0.201 *	0.198 *
Resource Intensity	0.128	0.07	−0.207 *	−0.197 *	−0.110	0.191 *

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed). Source: authors' calculation.

Despite the expectation that the gap between countries and best performers, in terms of the fixed capital used in operations, is higher in the case of more complex business models, our results show a negative correlation (−0.477). This negative association suggests rather information concerning the impact of the integration of multiple levels of types of operations on the business model. Higher vertical integration of operations that lead to a higher proportion covered on the entire supply chain, requires a more diverse portfolio of equipment and technologies, which leads to higher gross value added (0.429), if the technological capabilities effectiveness is sufficiently high.

Even if at the lower level (−0.210) but statistically significant, a negative correlation between the efficiency score and countries' governance capabilities indicates the role of the institutional framework at the country level. As long as there is proper regulation in place to promote sustainable forests management and effective monitoring and control mechanisms are implemented, governments strategies through public policies concerning forests management can be successfully achieved at lower compliance costs [67].

4.3. Econometric Analysis

4.3.1. Marginal Analysis of the Impact of Sustainability on Value Creation

The potential for value creation generated in forestry areas has become a continuous debate over the last decades, especially in light of the UN adopting the SDGs, which have placed forestry operations as a key element for strategic sustainable economic growth, reflected in SDG 15. Instead, as the authors of [4] noted, public policies in the forestry area as well several trade-offs lead to a decrease in economic performance because of the additional costs implied by the implementation of sustainable policies on forestry operations. The results in Table 4 indicate the impact of these trade-offs on the economic output. However, the results suggest several synergies, such as sustainable economic growth, led to sustainable management of forests, with direct and indirect implications for public health, economic output, or even quality of life.

The econometric models estimated and described in Table 4 were all statistically significant, as the *p*-values of the F statistic were under the threshold of 0.05, with the exception of models 3 and 5, which still had *p*-values under an acceptable threshold of 0.10.

Table 4. OLS estimated econometric models.

Models	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Dependent variable	GVA	Growth		Efficiency score	
Constant	2.271 *** (1.316)	0.3198 * (0.127)	1.614 * (0.362)	1.048 * (0.335)	0.595 * (0.151)
Global sustainability competitiveness index	0.056 *** (0.03)	−0.007 * (0.003)	−0.028 * (0.008)	-	-
Business sophistication	0.044 * 0.014	-	0.012 * (0.003)	-	0.0062 ** (0.003)
KOF index	−0.006 0.005	-	−0.0001 (0.001)	-	−0.0019 (0.002)
Global competitiveness index	-	-	-	-	−0.0021 (0.001)
Gross value added	-	0.012 *** (0.007)	-	-	-
Social capital	-	-	-	0.008 *** (0.005)	-
Resource intensity	-	-	-	0.007 ** (0.003)	-
Natural capital	-	-	-	−0.005 *** (0.003)	-
Governance capabilities	-	-	-	−0.011 * (0.004)	-
Intellectual capital	-	-	-	−0.0035 (0.004)	-
Control on year effects	N	N	Y	N	N
Model validation					
Sample size	132	170	132	113	132
R^2 adjusted	0.201	0.036	0.033	0.095	0.033
F stat	11.98	4.158	2.475	3.353	2.509
p	0.000	0.017	0.064	0.007	0.062
Durbin–Watson stat	0.047	1.614	0.362	0.490	0.359
Period F test	0.651 0.690	2.219 0.044	2.762 0.015	1.815 0.117	1.068 0.385
Hausman test	0.420 0.936	2.550 0.280	12.46 0.006	9.074 0.106	2.886 0.410
Breusch–Pagan test	0.581 0.446	1.588 −0.208	0.539 0.463	0.098 0.755	0.182 0.670

* Significant at the 1% significance level; ** significant at the 5% significance level; *** significant at the 10% significance level. Source: authors' calculation.

Instead, the R^2 was low, varying between 3.3% and 20.1%, which shows that either the efficiency score aimed to reduce forest resources to obtain fixed gross value added, or the gross value added reported in the forestry area were less influenced by the countries' progress to more sustainable-oriented economic growth framework.

However, coefficients related to the GSCI index and business sophistication proved to be statistically significant. Therefore, despite the low influence on the macroeconomic output, the transition to sustainable economic growth was slightly influenced by the measures of the countries' sustainable competitiveness.

4.3.2. Marginal Analysis of Transition to Sustainability on Operations Efficiency

The efficiency score was negatively impacted by a higher level of progress to sustainable economic growth ($Coef. = -0.0028,\ \ Sig. < 0.01$). To our knowledge, we did not find any study addressing the impact of a transition to sustainable economic growth on an operation's efficiency in the forestry area. However, studies (e.g., [7] or [41]) have underlined

the trade-offs between SDG 15 and other SDGs, including SDG 8 and SDG 9, which have become more visible over time. Therefore, environmental protection leads to conflicting relationships with strategies that concern short-term economic growth, implementation of emerging technologies, and the development of infrastructure, which persist along the entire life cycle assessment framework [68].

Instead, if we looked at the marginal effects of the GSCI score sub-indexes on the efficiency score; we noted that the negative effect was mainly driven by the progress towards sustainable economic growth related to the availability of natural resources ($Coef. = -0.005,\ Sig. < 0.10$) and governments' capabilities to design and implement national strategies on sustainable growth [36,49], and through public policies and effective regulation ($Coef. = -0.011,\ Sig. < 0.01$) [32,46,49]. Moreover, the results show a higher negative impact of governance capabilities, which supports our position that governments should be more involved in drafting national regulation, implementing monitoring and control mechanisms, and promoting sustainable consumption and sustainable forests management best practices by granting incentives in various financial and nonfinancial forms [49].

Countries with plenty of natural resources are constrained by the same pressure as those with less abundant natural resources. Therefore, the countries with plenty of natural resources seem to be more relaxed concerning the need to transition towards a more sustainable consumption function. However, the positive marginal effect of resource intensity ($Coef. = 0.007,\ Sig. < 0.01$) suggests that there are regional efforts made for the optimization of the use of resources among all countries, depending on the constraints each country face in terms of the lack of resources and high dependence on technical advances and Industry 4.0-based emerging technologies, leading to a new perspective of SFM—the Forest 4.0 [34,43,44]. Instead, this result emphasizes the opportunity for public policies government should adopt: must promote sustainable consumption, transition to a more bioeconomy-oriented output [69], or initiatives in sustainable forests management, such as the implementation of Industry 4.0-based smart solutions [44]. In the European Union region, there is much attention paid to sustainable growth through the European Green Deal commitments. However, governments' public policies concerning the forestry industry prove to be discretionary across countries, lacking coherence at regional level, and affecting the regional supply chain's sustainable performance, despite the significant compliance costs recommended for forest-based industries [67]. Moreover, even the New EU Forest Strategy for 2030 cannot yet be fully monitored through a comprehensive and robust system of indicators because of the lack of data and insufficient clarity on the mapping of pan-European indicators, with the strategies they are aiming for [50].

Nonetheless, we observed a positive marginal impact of the social components of the GSCI index ($Coef. = 0.008,\ Sig. < 0.01$)), which suggests that better efficiency on forestry operations can be determined by human factor, influencing community involvement, promoting sustainable wood-based products' consumption, or improving labor practices [4,28]. Additionally, we highlight the essential role of the human factor in the design of business models and national economies, especially through their impact on knowledge management, coordinating activities, searching for opportunities, configuring, and reconfiguring resources or the development of adaptability as dynamic capability under an uncertain economic and environmental regional context [70].

In Figure 7, we illustrated the time fixed effects related to the third model estimated. The trend of the increasing marginal effect over time of the evolution of the economic, social, and environmental context impacted positively on the efficiency score. This positive evolution over time was mainly driven by the greater awareness by governments, companies, and people on the need to transition economies to sustainable growth models. It is essential to observe that the positive significant time fixed effects were recorded, especially, in the period 2018–2019, which coincides with the period that shows the most recent effects of the transition towards the sustainable growth of economies since the adoption of the European Green Deal.

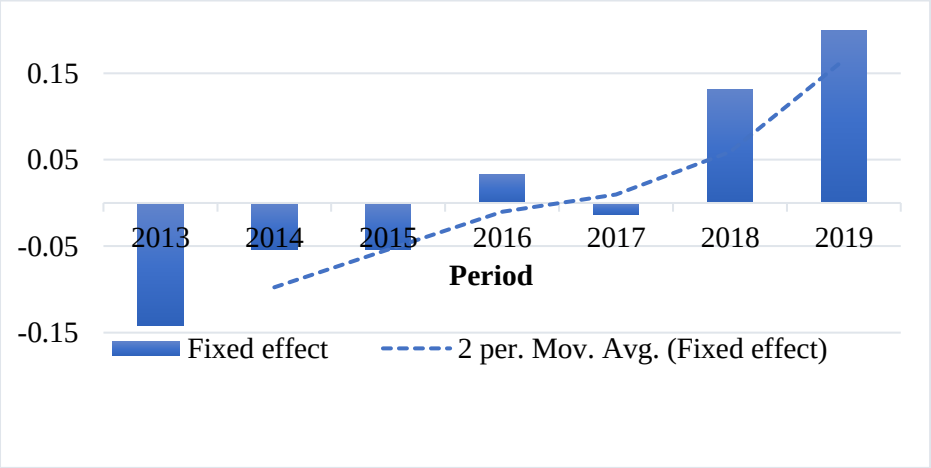

Figure 7. Fixed effects generated by evolution over time. Source: authors' calculation.

We highlighted that the increase in awareness concerning the need for sustainability was possible mainly because of the higher involvement of the EU Commission and national EU members' authorities that had adopted the European Green Deal and further developed more comprehensive specific directions of action, including orientation of EU policies and directing EU grants to initiatives on the circular economy, bioeconomy, or forest sustainable management. However, the transition to sustainable growth and the successful achievement of targets in terms of the globally agreed SDGs had determined disproportionate evolutions across EU countries [71] because of insufficient coherence in public policies and robust monitoring instruments across national economies concerning the transformation of national economies towards sustainable economies [50,58].

4.4. Robustness Analysis

4.4.1. Sustainable Growth's Impact on the Speed of Convergence of the Potential of Value Creation

To check for the robustness of our results presented in the previous section, we proceed to estimate additional econometric models to replace the efficiency score, as a dependent variable, with the level of gross value added reported for the forestry industry. Additionally, we assessed the speed of convergence of the potential of the gross value added by analyzing the effect of the global competitiveness sustainability index on the change rate of the gross value added.

The marginal effect, as determined by the GSCI index, on the gross value added reported for the forestry industry was described by the first model, and it is estimated and presented in Table 4. The results confirmed a positive statistically significant effect ($Coef. = 0.056$, $Sig. < 0.10$)), which demonstrates that a transition to a sustainable economic growth leads to an increase in the absolute value of the gross value added.

However, this relationship did not reveal the fact that the impact of the transition to sustainable growth becomes lower each year, mainly because of the trade-offs between different sustainable development goals, such as the conflicting relationship strengthening over time between SDG 15 and SDG 9 [7]. Therefore, environmental protection leads to conflicting relationships with strategies that concern the implementation of emerging technologies and the development of infrastructure, which persist along the entire life cycle assessment framework [68].

The negative effect on the gross value added was rather suggested by the second econometric model, which started from the classical β convergence model of economic convergence [56]. The results from the model estimate showed a positive impact of the gross value added reported from the previous year on the growth rate of the gross value added ($Coef. = 0.012$, $Sig. < 0.01$), which implies a β coefficient of $-\ln(1 + 0.012) = -0.01119$, as the analysis was made on an annual basis. This coefficient indicates a speed of convergence

for the gross value added across countries with a percentage of approximately 1.19%, which means that countries with previous higher reported gross value added in a forestry area record a lower gross value added in the future, whereas the countries with a previous lower reported gross value added are expected to increase their potential of growth for the gross value added in the forestry area, with the same β coefficient.

More interesting with this equation is the role of the transition towards more sustainable growth-oriented economies. The negative effect of the GSCI index on the growth rate of the gross value added ($Coef. = -0.007,\ Sig. < 0.01$) suggests an amplification of the convergence process on the forestry industry. Therefore, the negative regression coefficient showed a decrease on the rate of growth of the gross value added, especially among the countries with an already higher rate of GVA growth. First, we underline that the reduction in the speed of growth could be mainly determined by the limitations of the current stage of implementation of an emerging technologies and the limited qualified human factor enabling the use of such strategies. Second, the negative effect on the rate of GVA growth could be caused by the increasing the costs of environmental protection, which reduces countries competitiveness in terms of production costs.

4.4.2. Sensitivity of the Results on the Efficiency Score Distribution

As the efficiency score was not normally distributed, we reviewed the results' robustness, if choosing an alternative estimation method that controls for the effects of the dependent variable's distribution on the econometric estimates.

In Table 5 we provide statistics related to the same design of the econometric models presented in Table 4, but this time, it estimated following a quantile regression approach.

Table 5. Quantile regression estimated models (2nd quantile).

Model	(6)
Dependent variable	
Constant	1.919 * (0.475)
Sustainability competitiveness index	−0.036 * (0.01)
Business sophistication	0.015 * (0.01)
KOF economic index	−0.0011 (0.001)
Model validation	
Sample size	132
R^2 adjusted	0.04
Sparsity	0.757
Prob (Quasi-LR stat)	0.022
Quasi-LR statistic	9.608

* Significant at the 1% significance level. Source: authors' calculation.

Overall, the results show robust results in the case of the 2nd quantile, concerning the impact of the GSCI index on the efficiency score ($Coef. = -0.036,\ Sig. < 0.01$). Therefore, the impact persists to be negative, showing that the transition to sustainable growth implies negative changes on the cost structure of the economies, which lead to higher operational costs and lower gross value added.

However, based on the data represented in Figure 8, we note that the negative effect of the GSCI index on the efficiency score was rather related to the average performers, better described in the 2nd quantile, whereas the 1st quantile and the 3rd quantile showed a slightly positive impact of the GCSI index on the efficiency score.

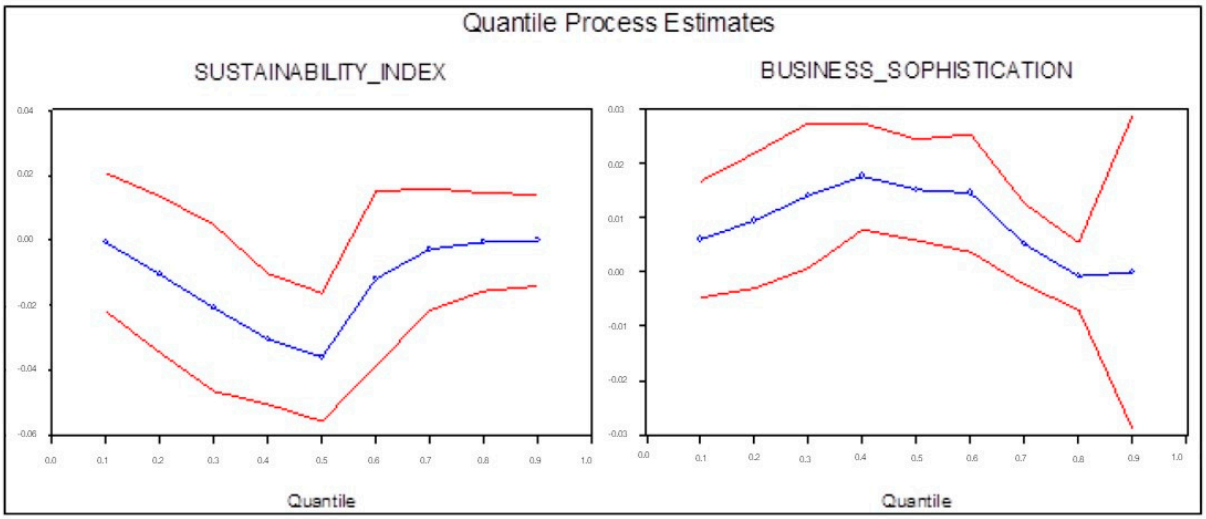

Figure 8. Regression coefficient estimates of the different quantiles. Source: authors' projection.

In the case of the best performers, the most relevant emerging technologies were implemented and the specialization of human capital was already ensured, which means that the current stage of sustainable growth generated benefits which exceeded the costs of sustainability, with direct impact on operational efficiency and indirect positive effects on gross value added generated at the forestry industry level.

Instead, in the case of the worst performers, the positive effect of the GCSI index on the gross value added could be explained by the yet premature stage of the implementation of the sustainability project initiatives, which mainly address the elements of the planning and the processes of the model design, which involve lower cost rates.

5. Conclusions

Nowadays, as we are aware of the effects of climate change and the continuous decrease of natural resources, we notice the need of higher focus on the concept of sustainable development.

Throughout the paper, we aimed to understand how countries' macroeconomic output is influenced by the efforts to change national economies towards circular-based oriented economies. In other words, we analyzed the relationship between the gross value added reported by the forestry industry and a measure of the progress of the transition towards a competitive sustainable economic growth model. We addressed this link between bioeconomy and forestry due to the fact the forest-based sector plays a central role in bioeconomy; it provides materials (i.e., wood and non-wood products), bioenergy, and a wealth of other regulating and cultural ecosystem services [72]. The analysis referred to the period between 2013 and 2019, summing-up 133 observations for 23 European Union members: Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden. We limited our research to the EU region, as the study represents only a starting point in the analysis of the effects of the transition to a green economy on the potential of value creation in the forestry industry. The choice was mainly driven by the fact that those countries subscribe to similar regulations, driven by European directives and regulations, which are mandatory for all EU members. The steps in this direction places the EU region as a benchmark for all other countries, as all those countries' efforts were unanimously agreed and formalized as the document of the European Green Deal document in 2019.

The results of our study highlight that transition to sustainable growth implies negative changes to the cost structure of economies, which lead to higher operational costs and lower gross value added. Our study revealed that for the best performers, namely, Finland, France,

Italy, or the Netherlands, their current stage of sustainable growth generates benefits that exceed the costs of sustainability, with direct impacts on operational efficiency and indirect positive effects on gross value added generated at the forestry industry level. In addition, we underline this gap between countries that exist, as capabilities economies must generate gross value added in the forestry area by minimizing the use of production factors.

Our study has some caveats, given the limitation to the 23 EU member states included in the analysis. However, it would be interesting to perform a comparative analysis between EU countries and countries that do not have a similar SFM framework in order to highlight the importance of public policies and national and regional regulations.

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References

1. Mikhno, I.; Koval, V.; Shvets, G.; Garmatiuk, O.; Tamošiūnienė, R. Discussion: Green Economy in Sustainable Development and Improvement of Resource Efficiency. *Cent. Eur. Bus. Rev.* **2020**, *10*, 99–113. [CrossRef]
2. WCED, UN. Brundtland Report. 1987. Available online: https://www.britannica.com/topic/Brundtland-Report (accessed on 25 August 2022).
3. D'Amato, D.; Korhonen, J. Integrating the green economy, circular economy and bioeconomy in a strategic sustainability framework. *Ecol. Econ.* **2021**, *188*, 107143. [CrossRef]
4. Baumgartner, R.J. Sustainable Development Goals and the Forest Sector—A Complex Relationship. *Forests* **2019**, *10*, 152. [CrossRef]
5. UNFCCC. The Paris Agreement. 2015. Available online: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement (accessed on 25 August 2022).
6. UNGA Reports on Social Development. 2015. Available online: https://www.un.org/development/desa/dspd/publications/united-nations-reports-on-social-development/un-ga-reports-on-social-development-2015.html (accessed on 25 August 2022).
7. Kroll, C.; Warchold, A.; Pradhan, P. Sustainable Development Goals (SDGs): Are we successful in turning trade-offs into synergies? *Palgrave Commun.* **2019**, *5*, 140. [CrossRef]
8. Hu, W.; Wang, D. How does environmental regulation influence China's carbon productivity? An empirical analysis based on the spatial spillover effect. *J. Clean. Prod.* **2020**, *257*, 120484. [CrossRef]
9. Zhao, M.; Liu, F.; Song, Y.; Geng, J. Impact of Air Pollution Regulation and Technological Investment on Sustainable Development of Green Economy in Eastern China: Empirical Analysis with Panel Data Approach. *Sustainability* **2020**, *12*, 3073. [CrossRef]
10. European Commission. 2015. Available online: https://reform-support.ec.europa.eu/what-we-do/green-transition_en (accessed on 25 August 2022).
11. Eberhardt, L.C.M.; Birkved, M.; Birgisdottir, H. Building design and construction strategies for a circular economy. *Archit. Eng. Des. Manag.* **2022**, *18*, 93–113. [CrossRef]
12. Geissdoerfer, M.; Savaget, P.; Bocken, N.M.P.; Hultink, N.J. The Circular Economy—A new sustainability paradigm? *J. Clean. Prod.* **2017**, *143*, 757–768. [CrossRef]
13. Odugbesan, J.A.; Rjoub, H.; Ifediora, C.U.; Iloka, C.B. Do financial regulations matters for sustainable green economy: Evidence from Turkey. *Environ. Sci. Pollut. Res. Int.* **2021**, *28*, 56642–56657. [CrossRef]
14. Bag, S.; Yadav, G.; Wood, L.C.; Dhamija, P.; Joshi, S. Industry 4.0 and the circular economy: Resource melioration in logistics. *Resour. Policy* **2020**, *68*, 101776. [CrossRef]
15. Bjoern, J.; Upadhyay, A. Understanding Barriers of Circular Economy: Cases from the Manufacturing Industry. *J. Enterp. Inf. Manag.* 2019; *ahead-of-print*. [CrossRef]

16. Tura, N.; Hanski, J.; Ahola, T.; Ståhle, M.; Piiparinen, S.; Valkokari, P. Unlocking circular business: A framework of barriers and drivers. *J. Clean. Prod.* **2019**, *212*, 90–98. [CrossRef]
17. Vermunt, D.A.; Negro, S.O.; Verweij, P.A.; Kuppens, D.V.; Hekkert, M.P. Exploring barriers to implementing different circular business models. *J. Clean. Prod.* **2019**, *222*, 891–902. [CrossRef]
18. Bocken, N.M.P.; Short, S.W. Towards a sufficiency-driven business model: Experiences and opportunities. *Environ. Innov. Soc. Transit.* **2016**, *18*, 41–61. [CrossRef]
19. Galvão GD, A.; Evans, S.; Ferrer PS, S.; de Carvalho, M.M. Circular business model: Breaking down barriers towards sustainable development. *Bus. Strategy Environ.* **2022**, *31*, 1504–1524. [CrossRef]
20. Galvão, G.D.A.; de Nadae, J.; Clemente, D.H.; Chinen, G.; de Carvalho, M.M. Circular Economy: Overview of Barriers. *Procedia CIRP* **2018**, *73*, 79–85. [CrossRef]
21. Tedesco, M.; Simioni, F.S.; Sehnem, S.; Soares, J.F.; Moreira Coelho, J.J. Assessment of the circular economy in the Brazilian planted tree sector using the ReSOLVE framework. *Sustain. Prod. Consum.* **2022**, *31*, 397–406. [CrossRef]
22. Michelini, G.; Moraes, R.; Nobre da Cunha, R.; Costa, J.; Ometto, A. From Linear to Circular Economy: PSS Conducting the Transition. *Procedia CIRP* **2017**, *64*, 2–6. [CrossRef]
23. Lazaridou, D.C.; Michailidis, A.; Trigkas, M. Exploring Environmental and Economic Costs and Benefits of a Forest-Based Circular Economy: A Literature Review. *Forests* **2021**, *12*, 436. [CrossRef]
24. Tavares, C.S.; Martins, A.; Graça, M.; Carvalheiro, F.; Duarte, F.D.; Gameiro, J.; Figueiredo, A.; Roseiro, L. Bioproducts from forest biomass II. Bioactive compounds from the steam-distillation by-products of *Cupressus lusitanica* Mill. and *Cistus ladanifer* L. wastes. *Ind. Crops Prod.* **2020**, *158*, 112991. [CrossRef]
25. Place, F.; Otsuka, K. Population, Tenure, and Natural Resource Management: The Case of Customary Land Area in Malawi. *J. Environ. Econ. Manag.* **2001**, *41*, 13–32. [CrossRef]
26. Castellani, V.; Sala, S.; Mirabella, N. Beyond the Throwaway Society: A Life Cycle-Based Assessment of the Environmental Benefit of Reuse. *Integr. Environ. Assess. Manag.* **2014**, *11*, 373–382. [CrossRef] [PubMed]
27. Gagnon, B.; Tanguay, X.; Amor, B.; Imbrogno, A. Forest Products and Circular Economy Strategies: A Canadian Perspective. *Energies* **2022**, *15*, 673. [CrossRef]
28. Han, X.; Geng, Y. Research on the Income Growth of Workers in Northeast State-owned Forest Regions after the Comprehensive Banning. *Acad. Exch.* **2014**, *30*, 135–139.
29. Modolo, R.C.E.; Senff, L.; Ferreira, V.; Tarelho, L.A.D.C.; Moraes, C.A.M. Fly ash from biomass combustion as replacement raw material and its influence on the mortars durability. *J. Mater. Cycles Waste Manag.* **2018**, *20*, 1006–1015. [CrossRef]
30. Lovric, M.; Leskinen, P.; Tuomasjukka, D. How Does Forest Management and the Use Ofwood Contribute to Economic Prosperity and Employment, K2A Knowledge to Action. 2022. Available online: https://efi.int/forestquestions/q10 (accessed on 28 August 2022).
31. Li, Y.; Mei, B.; Juvenal, T.L. The economic contribution of the world's forest sector. *For. Policy Econ.* **2019**, *100*, 236–253. [CrossRef]
32. Lazdinis, M.; Angelstam, P.; Pülzl, H. Towards sustainable forest management in the European Union through polycentric forest governance and an integrated landscape approach. *Landsc. Ecol.* **2019**, *34*, 1737–1749. [CrossRef]
33. Holmgren, S.; D'Amato, D.; Giurca, A. Bioeconomy imaginaries: A review of forest-related social science literature. *Ambio* **2020**, *49*, 1860–1877. [CrossRef]
34. Nummelin, T.; Hänninen, R.; Kniivilä, M. Exploring Forest Sector Research Subjects and Trends from 2000 to 2019 Using Topic Modeling. *Curr. For. Rep.* **2021**, *7*, 267–281. [CrossRef]
35. Klinger, S.; Bayne, K.M.; Yao, R.T.; Payn, T. Credence Attributes in the Forestry Sector and the Role of Environmental, Social and Governance (ESG) Factors. *Forests* **2022**, *13*, 432. [CrossRef]
36. Sheppard, J.; Chamberlain, J.; Agúndez, D.; Bhattacharya, P.; Chirwa, P.; Gontcharov, A.; Sagona, W.; Shen, H.; Tadesse, W.; Mutke, S. Sustainable Forest Management Beyond the Timber-Oriented Status Quo: Transitioning to Co-production of Timber and Non-wood Forest Products—A Global Perspective. *Curr. For. Rep.* **2020**, *6*, 26–40. [CrossRef]
37. WBCSD. Forest Sector SDG Roadmap. 2021. Available online: https://www.wbcsd.org/Sector-Projects/Forest-Solutions-Group/Forest-Sector-SDG-Roadmap (accessed on 28 August 2022).
38. Garcia, S.; Abildtrup, J.; Stenger, A. How does economic research contribute to the management of forest ecosystem services? *Ann. For. Sci.* **2018**, *75*, 53. [CrossRef]
39. Fuso Nerini, F.; Tomei, J.; To, L.S.; Bisaga, I.; Parikh, P.; Black, M.; Borrion, A.; Spataru, C.; Castan Broto, V.; Anandarajah, G.; et al. Mapping synergies and trade-offs between energy and the Sustainable Development Goals. *Nat. Energy* **2018**, *3*, 10–15. [CrossRef]
40. Vera, I.; Wicke, B.; Lamers, P.; Cowie, A.; Repo, A.; Heukels, B.; Zumpf, C.; Styles, D.; Parish, E.; Cherubini, G.; et al. Land use for bioenergy: Synergies and trade-offs between sustainable development goals. *Renew. Sustain. Energy Rev.* **2022**, *161*, 112409. [CrossRef]
41. Pradhan, P.; Costa, L.; Rybski, D.; Lucht, W.; Kropp, J.P. A Systematic Study of Sustainable Development Goal (SDG) Interactions. *Earth's Future* **2017**, *5*, 1169–1179. [CrossRef]
42. Fonseca, L.M.; Domingues, J.P.; Dima, A.M. Mapping the Sustainable Development Goals Relationships. *Sustainability* **2020**, *12*, 3359. [CrossRef]
43. Feng, Y.; Audy, J.-F. Forestry 4.0: A framework for the forest supply chain toward Industry 4.0. *Gestão Produção* **2020**, *27*, e5677. [CrossRef]

44. He, Z.; Turner, P. A Systematic Review on Technologies and Industry 4.0 in the Forest Supply Chain: A Framework Identifying Challenges and Opportunities. *Logistics* **2021**, *5*, 88. [CrossRef]
45. Schweier, J.; Magagnotti, N.; Labelle, E.R.; Athanassiadis, D. Sustainability Impact Assessment of Forest Operations: A Review. *Curr. For. Rep.* **2019**, *5*, 101–113. [CrossRef]
46. Blattert, C.; Eyvindson, K.; Hartikainen, M.; Burgas, D.; Potterf, M.; Lukkarinen, J.; Snäll, T.; Toraño-Caicoya, A.; Mönkkönen, M. Sectoral policies cause incoherence in forest management and ecosystem service provisioning. *For. Policy Econ.* **2022**, *136*, 102689. [CrossRef]
47. Breuer, A.; Janetschek, H.; Malerba, D. Translating Sustainable Development Goal (SDG) Interdependencies into Policy Advice. *Sustainability* **2019**, *11*, 2092. [CrossRef]
48. Linser, S.; Wolfslehner, B.; Asmar, F.; Bridge, S.R.J.; Gritten, D.; Guadalupe, V.; Jafari, M.; Johnson, S.; Laclau, P.; Robertson, G. 25 Years of Criteria and Indicators for Sustainable Forest Management: Why Some Intergovernmental C&I Processes Flourished While Others Faded. *Forests* **2018**, *9*, 515. [CrossRef]
49. Linser, S.; Wolfslehner, B.; Bridge, S.R.J.; Gritten, D.; Johnson, S.; Payn, T.; Prins, K.; Raši, R.; Robertson, G. 25 Years of Criteria and Indicators for Sustainable Forest Management: How Intergovernmental C&I Processes Have Made a Difference. *Forests* **2018**, *9*, 578. [CrossRef]
50. Lier, M.; Köhl, M.; Korhonen, K.T.; Linser, S.; Prins, K.; Talarczyk, A. The New EU Forest Strategy for 2030: A New Understanding of Sustainable Forest Management? *Forests* **2022**, *13*, 245. [CrossRef]
51. Linser, S.; Wolfslehner, B. National Implementation of the Forest Europe Indicators for Sustainable Forest Management. *Forests* **2022**, *13*, 191. [CrossRef]
52. Carrillo, M. Measuring Progress towards Sustainability in the European Union within the 203Agenda Framework. *Mathematics* **2022**, *10*, 2095. [CrossRef]
53. Wang, H.; He, M.; Ran, N.; Xie, D.; Wang, Q.; Teng, M.; Wang, P. China's Key Forestry Ecological Development Programs: Implementation, Environmental, Impact and Challenges. *Forests* **2021**, *12*, 101. [CrossRef]
54. Neykov, N.; Krišťáková, S.; Hajdúchová, I.; Sedliaciková, M.; Antov, P.; Giertliová, B. Economic Efficiency of Forest Enterprises—Empirical Study Based on Data Envelopment Analysis. *Forests* **2021**, *12*, 462. [CrossRef]
55. Iancu, A. Economic Convergence. Applications—Second Part. *Rom. J. Econ. Forecast.* **2007**, *4*, 24–48.
56. Böhringer, C.; Jochem, P.E. Measuring the Immeasurable—A Survey of Sustainability Indexes. *Ecol. Econ.* **2007**, *63*, 1–8. [CrossRef]
57. Mensah, J. Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review. *Cogent Soc. Sci.* **2019**, *5*, 1653531. [CrossRef]
58. Zupanic, N. Systematic Literature Review: Inter-Reletedness of Innovation, Resilience and Sustainability—Major, Emerging Themes and Future Research Directions. *Circ. Econ. Sustain.* **2022**. [CrossRef] [PubMed]
59. Halonen, M.; Näyhä, A.; Kuhmonen, I. Regional sustainability transition through forest-based bioeconomy? Development actors' perspectives on related policies, power, and justice. *For. Policy Econ.* **2022**, *142*, 102775. [CrossRef]
60. Paletto, A.; Bernardi, S.; Pieratti, E.; Teston, F.; Romagnoli, M. Assessment of environmental impact of biomass power plants to increase the social acceptance of renewable energy technologies. *Heliyon* **2019**, *5*, e02070. [CrossRef] [PubMed]
61. Linser, S.; Lier, M. The Contribution of Sustainable Development Goals and Forest-Related Indicators to National Bioeconomy Progress Monitoring. *Sustainability* **2020**, *12*, 2898. [CrossRef]
62. Lotfi, R.; Kheiri, K.; Sadeghi, A.; Tirkolaee, E.B. An extended robust mathematical model to project the course of COVID-19 epidemic in Iran. *Ann. Oper. Res.* **2022**, 1–25. [CrossRef]
63. Arce, J.J. *Forests, Inclusive and Sustainable Economic Growth and Employment*; United Nations: New York, NY, USA, 2019.
64. Global Competitiveness Report. 2020. Available online: https://www.weforum.org/reports/the-global-competitiveness-report-2020/ (accessed on 25 August 2022).
65. Ricciolini, E.; Rocchi, L.; Cardinali, M.; Paolotti, L.; Ruiz, F.; Cabello, J.M.; Boggia, A. Assessing Progress Towards SDGs Implementation Using Multiple Reference Point Based Multicriteria Methods: The Case Study of the European Countries. *Soc. Indic. Res.* **2022**, *162*, 1233–1260. [CrossRef]
66. Martín, C.J.; Carnero, M.C. Evaluation of Sustainable Development in European Union Countries. *Appl. Sci.* **2019**, *9*, 4880. [CrossRef]
67. Aggestam, F.; Pülzl, H. Coordinating the Uncoordinated: The EU Forest Strategy. *Forests* **2018**, *9*, 125. [CrossRef]
68. Sahoo, K.; Bergman, R.; Alanya-Rosenbaum, S.; Gu, H.; Liang, S. Life Cycle Assessment of Forest-Based Products: A Review. *Sustainability* **2019**, *11*, 4722. [CrossRef]
69. UNECE. State of Europe's Forests. 2020. Available online: https://unece.org/info/Forests/pub/22007 (accessed on 25 August 2022).
70. Cyfert, S.; Dyduch, W.; Zastempowski, M. The Impact of Resources on the Adaptability of State Forest Companies. Some Evidence from the State Forests National Forest Holding. *Forests* **2022**, *13*, 355. [CrossRef]
71. Jędrzejczak-Gas, J.; Barska, A.; Wyrwa, J. Economic Development of the European Union in the Relation of Sustainable Development—Taxonomic Analysis. *Energies* **2021**, *14*, 7488. [CrossRef]
72. Wolfslehner, B.; Linser, S.; Pülzl, H.; Bastrup-Birk, A.; Camia, A.; Marchetti, M. *Forest Bioeconomy—A New Scope for Sustainability Indicators*; From Science to Policy 4; European Forest Institute: Joensuu, Finland, 2016.

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The association between digitalization and mental health: The mediating role of wellbeing at work

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The study aims to measure the mediating relationship of wellbeing at work between digitalization (IT infrastructure, IT business spanning, and IT proactive stance) and their effect on mental health. The study uses primary data collection techniques to gather data and used purposive sampling to analyze the data. The sample size of the study is 349 respondents. The research uses Smart PLS software to measure the relationship through bootstrapping and algorithms. The study finds a significant positive mediating role of wellbeing between digitalization (IT infrastructure, IT business spanning, and IT proactive stance) and their effect on mental health. The study outcomes are helpful for managers and policymakers.

KEYWORDS

mental health, digital health, digitalization, job performance, IT infrastructure, well-being, IT proactive stance

Introduction

In the past decades, technological advancement has profoundly altered global work practices with innovative developments. Significantly, the disruptive digital landscape has become the impetus for novel digitization, substantially overriding traditional digital tools with modern interventions. In recent years, the twenty-first-century modern technological revolution has developed promising digital capabilities to cover humans' personal and professional lives, potentially bringing positive health outcomes (1).

Digitalization is a novel phenomenon that has elevated the use of information technology across various domains. There has been strong demand for its application in the healthcare sector. However, in recent years, the mental health of frontline workers has not received adequate attention despite healthcare being a highly competitive industry in which employees are exposed to significant psychological challenges (2). As such, this literature states that as healthcare psychological problems are accelerating, it has become essential to focus on their impairing impact on employees' overall mental health (3, 4).

Mental health in relation to technology has become a prime interest of current researchers, with some researchers signaling the potential for the use of technology to considerably improve employees' mental health. While in recent years, technology adoption has been shown to bring promising health outcomes in many fields, unfortunately, the value of digital capabilities has not been realized in the healthcare industry (5). One study states that the emerging role of digitalization in the healthcare sector is vital, thus highlighting the need to realize and understand the association between IT capabilities and employees' psychological wellness (6).

The technological solutions implemented across medical domains (e.g., medicine and psychology) are of increasing interest to researchers in terms of novel innovations. Digitalization, a technology-driven notion, has diffused its characteristics into the origin of the healthcare sector. Novel IT capabilities have allowed healthcare organizations to adapt to changing working conditions, thus supporting employees' mental health (7). The real-time access afforded by IT has assisted the hospital industry by optimizing workflow. In fact, in healthcare, the accelerating technological advancement has garnered a tremendous boost to employees' wellbeing. Engaging and involving frontline technical staff in the design and rolling out of new IT infrastructure (ITI) has allowed organizations to understand the value of digital tools in improving employees' mental health.

The ITI alludes to organizations' digital assets such as tools, software, hardware, and applications (8). Significantly, ITI is recognized as a vital tool for fostering employees' mental health (9, 10). Technology is deeply rooted in the health economy, with IT business spanning (ITB) facilities impacting employees' mental health. As such, ITB refers to an organization's ability to adopt novel digital tools, therefore improving firms' operations (11). This novel business capability (i.e., ITB) helps organizations boost employees' mindfulness and productivity (12–14).

In particular, at present, an overwhelming number of technologies are available, meaning organizations need to understand the role of digital innovations in influencing employees' mental health. In this regard, the literature review provides evidence that to ensure the psychological needs of the frontline workers, health institutions should focus on developing technological capabilities for combating the progressing psychological vulnerabilities (15). Therefore, the IT proactive stance (ITP) has become prominent, whereby being forward-thinking about IT is used to achieve the business goal (16). Significantly, to achieve such goals, an organization must ensure its employees' healthy mindset. As a result, the ITP has emerged as a popular tool for ensuring employees' mindfulness.

Significantly, in recent years, occupational digital mental health has played a profound role in eradicating the potential barriers to achieving workplace wellness (17). Numerous factors contribute to elevating workplace problems. However, these increasing psychological vulnerabilities encourage medical institutions to mitigate health issues, thereby ensuring workplace wellbeing (15, 18). A healthy technological environment influences individuals' psychological health and, ultimately, workplace wellbeing and behavior. As a result of IT's increasing significance, organizations are adopting novel IT capabilities for ensuring wellness at work (19).

Undoubtedly, technological abilities have the potential as a global solution to growing psychological vulnerabilities. However, the healthcare sector demands that firms implement digitalization to gain greater attention in the coming decades (20). Technological health interventions provide numerous opportunities to combat the growing health crises. They maximize frontline technical support to establish a healthy environment. However, besides the influential role of technology, the literature shows that current employees are reluctant to adopt digitalization tools (21). In particular, one study states that this fear leads to health organizations lacking technological implementation, adversely influencing employees' psychological wellbeing (22).

However, against this drawback, this study demonstrates a novel conceptual model, presenting a systematic literature review on employees' mental health and workplace wellness. This study consolidates dominant factors that boost employees' mental and workplace wellbeing. Then, to reach a possible conclusion, the study highlights the role of digitalization (e.g., ITI, ITB, and ITP) in influencing employees' mental health. Moreover, it also sheds light on the effect of IT capabilities on workplace wellbeing. In the same vein, the study investigates the mediating role of the wellbeing at work nexus on digitalization and employees' mental health.

Significantly, this study promotes employees' mental health and wellbeing regarding digitalization. In particular, to the best of our knowledge, this study is pioneering in illustrating the role of IT capabilities (e.g., ITI, ITB, and ITP) in influencing employees' mental health. It explains a new concept that highlights the mediating role of wellbeing at work in this context. Therefore, on the scale of digitalization, this study presents valuable knowledge on employees' mental health and wellbeing. The study's findings are targeted toward researchers, policymakers, healthcare institutions, and the medical administration to suggest ways to improve employees' mental wellbeing.

This study comprises six different sections. The next section (i.e., "Literature review") presents a conceptual model highlighting the study background. The "Methodology" section prescribes the methodological tools and techniques needed for study analysis. The "Results" section explains the analysis results, while the "Discussion" section discusses the significant study outcomes. Finally, the "Conclusion" section concludes the study by suggesting the research findings and implications.

Literature review

IT infrastructure and mental health

In recent years, the rapid advancement in digital technologies has altered the nature of work, thereby requiring employees to radically respond to the technological change. Among these developments, the ITI has emerged as an inevitable tool in assisting employees' workplace activities. The ITI has empowered workers to perform to their potential, thus bringing positive healthcare outcomes. In particular, this mental health innovation (e.g., ITI) is a convenient way of overcoming health crises in the workplace setting (17, 23). In recent years, technology has significantly evolved, bringing numerous opportunities for frontline workers. In explaining this notion, the literature states that, in healthcare, the high potential of digital technology fosters employees' psychological wellbeing and performance (10, 24).

In particular, workplace mental health is structured around modern digital developments. Novel IT innovations reduce the growing health ramifications, thereby engendering positive health outcomes (e.g., psychological wellbeing) (25). In fact, technology's rapid transformation of the world has worked as a catalyst, resolving problems across the healthcare ecosystem. As such, prior research states that digital tools have inevitably made healthcare organizations embrace novel technologies, thus promoting employers' positive psychological wellbeing (26). Overall, with the increasing significance of technology in healthcare, medical institutions should ensure proper utilization of technology to foster employees' mental health. Therefore, in light of the previous literature, the current study suggests the following hypothesis:

> ***H1****: IT infrastructure has a positive and significant impact on mental health.*

IT business spanning and mental health

Mental health is a significant part of a person's wellbeing. With the growing number of individuals experiencing mental health crises, understanding the impact of technological change has become vital for ensuring individuals' psychological health. Technology integration helps organizations enhance employees' mental health. In the present digital era, IT-enabled advancements (i.e., ITB) are deeply rooted in firms' structures (27). Therefore, in ensuring positive mental health, ITB integrates preventive health technologies into the firm's structure (28, 29).

In particular, at present, the high pace of disruption (e.g., ITB) has updated and transformed firms' activities, shifting researchers' focus to mental wellbeing. The literature suggests that virtual IT platforms have made employees assess their psychological needs, thereby ensuring a higher degree of mindfulness (13, 30, 31). Those working in the hospital industry face high-level psychological issues (e.g., stress, anxiety, and depression). However, the rapid digital developments have profoundly altered the nature of the work, thereby combating the growing health vulnerabilities. As such, the ITB advances employees' mental health by mitigating the psychological risks associated with the workplace (32). Therefore, rather than just implementing technology, firms should build a clear understanding of its use for promoting employees' mindfulness. Consequently, based on the literature, this study proposes the following hypothesis:

> ***H2:*** *IT business spanning has a positive and significant impact on mental health.*

IT proactive stance and mental health

In the digitization world, IT capabilities have brought numerous opportunities that support a workplace's mental wellbeing environment. Therefore, the workplace changes derived from the IT tools have encouraged the employees to learn novel tools for minimizing the effect of growing psychological vulnerabilities. As such, the literature states that owing to the effectiveness of the ITP, organizations should quickly respond to the changing workplace needs, optimally predicting the new opportunities (33, 34). In this regard, the ITP helps detect the employees' psychological needs, thereby illuminating the signs of health crises. The ITP provides opportunities to present organizations with critical information regarding their employees' health and wellbeing. Prior research shows that, at present, mental health technology enables organizations to respond to growing health challenges (35). Due to the increasing ITP role, the literature suggests making a high investment in disruptive technologies, thus ensuring positive health outcomes (i.e., psychological wellness) (36). Therefore, in light of the literature review, this study suggests the following hypothesis:

> ***H3:*** *IT proactive stance has a positive and significant impact on mental health.*

IT infrastructure, IT business spanning, IT proactive, and wellbeing at work

IT infrastructure and wellbeing at work

In recent years, digitization and the prioritization of ITI have gained firms' attention, thereby nurturing employees' workplace wellbeing. In particular, current focus on employees' wellbeing has profoundly extended beyond just focusing on building a

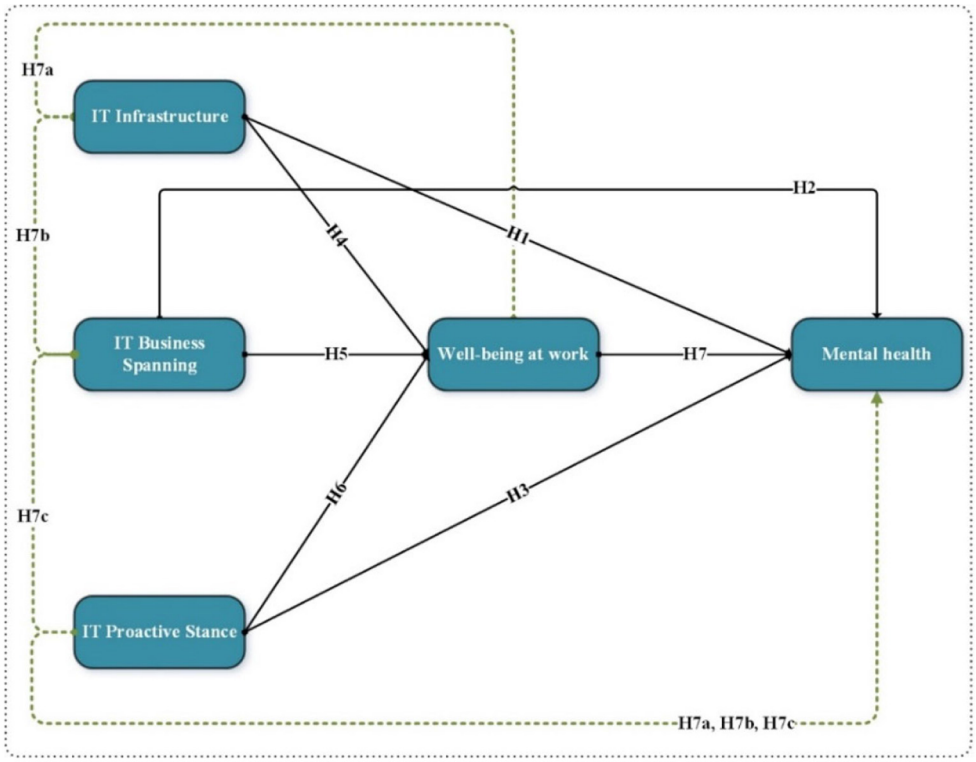

FIGURE 1
Conceptual framework.

healthy workplace environment. ITI is crucial for maintaining optimal wellbeing (37). It increases employees' happiness and workplace wellbeing (38). Numerous tools have been found to support workplace wellbeing, with studies demonstrating that ITI works as an effective means to ensure employees' workplace wellness (39). Undoubtedly, predicting employees' workplace wellbeing has become the top priority of current firms. Due to information communication technologies (ICTs) growing relevance, the intensified role of ICT improves the employees' wellbeing at work. IT acceleration plays a critical role in managing workplace health issues. As such, the research shows that digital transformation focuses strongly on improving workplace wellbeing (40). In fact, ITI is critical to developing workplace wellbeing. Hence, given the literature review, this study proposed the following hypothesis:

H4: *IT infrastructure has a positive and significant impact on wellbeing at work.*

IT business spanning and wellbeing at work

Undoubtedly, advancing globalization has allowed IT developments to open new avenues for improving workplace wellbeing. In the context of digital innovation supporting workplace wellness, one study showed that modern development had fostered a change in the nature of work, thus leading to the health interventions (e.g., ITB) to become the prime determinants of workplace wellbeing (41). The digitalization capability (i.e., ITB) supports the technology used in firms' practices. ITB is a disruptive technological model that has surprised researchers with its transformational aspects (for example, AI-based digital assistants) (42). The ITB capability nurtures the workplace environment by minimizing the workload. In recent decades, intense workloads have caused employees to face severe health repercussions, thus decreasing their workplace effectiveness. In explaining this notion, the study states that the ITB embedded in the firm's processes influences the employees' health, thereby shaping the workplace structure and work demand (43). In particular, technological advancement profoundly alters employees' workplace activities. The ITB elevating the technological change increases individual support for wellness. In this regard, the literature suggests that this novel innovation encourages management to realize the use of digitization to achieve workplace improvements (44). Hence, based on the prior literature, this study proposes the following hypothesis:

TABLE 1 Descriptive statistics.

Items	Frequency ($N = 349$)	(%)
Gender		
Male	161	46.1
Female	188	53.9
Age		
19–30	44	12.6
31–40	95	27.2
41–50	84	24.1
51–60	76	21.8
>60	50	14.3
Education		
Intermediate	67	19.2
Bachelor	113	32.4
Master	124	35.5
MPhil/Others	45	12.9
Marital Status		
Single	59	16.9
Married	290	83.1

H5: *IT business spanning has a positive and significant impact on wellbeing at work.*

IT proactive stance and wellbeing at work

Modern inventions have gradually become popular in ensuring workplace success. In recent years, digital-enabled wellbeing measures have been popularized as an integral initiative for raising awareness regarding wellbeing at work (45). Workplace wellness is a critical development that demands digital tools to improve employees' wellbeing. This technological capability provides solutions to the organization, thus encouraging a healthy workplace (46). The ITP renders tech support to the employees, potentially ensuring workplace wellness. The ITP supports effective IT programs for identifying the opportunities for achieving workplace growth. Additionally, it enhances the organization's internal environment by causing organizations to invest in workplace wellbeing. Prior research states that this health-increasing technology considerably satisfies organizations' needs for workplace wellness (47). These digital technologies minimize the negative impact of the growing workplace problems (48). Since technology has been applied to firms' structures in a widespread manner, it has become important for the organization to effectively utilize IT capabilities to combat workplace challenges, thus ensuring workplace wellbeing (49). Therefore, in light of the past studies, the following hypothesis is proposed:

TABLE 2 Reliability and validity results.

Construct	Items	Loading	α	CR	AVE
IT infrastructure	ITI_1	0.737	0.847	0.848	0.583
	ITI_2	0.703			
	ITI_3	0.779			
	ITI_4	0.830			
IT business spanning	ITB_1	0.676	0.843	0.842	0.572
	ITB_2	0.779			
	ITB_3	0.733			
	ITB_4	0.830			
IT proactive stance	ITP_1	0.704	0.836	0.836	0.560
	ITP_2	0.787			
	ITP_3	0.781			
	ITP_4	0.719			
Well-being at work	WBW_1	0.784	0.929	0.929	0.592
	WBW_2	0.836			
	WBW_3	0.710			
	WBW_4	0.702			
	WBW_5	0.837			
	WBW_6	0.783			
	WBW_7	0.735			
	WBW_8	0.800			
	WBW_9	0.724			
Mental health	MH_1	0.758	0.877	0.877	0.588
	MH_2	0.728			
	MH_3	0.731			
	MH_4	0.825			
	MH_5	0.787			

TABLE 3 Discriminant validity results.

Constructs	1	2	3	4	5
1. IT business spanning	0.757	0.505	0.565	0.569	0.564
2. IT infrastructure	0.507	0.763	0.568	0.547	0.547
3. IT proactive stance	0.562	0.565	0.749	0.556	0.555
4. Mental health	0.570	0.548	0.559	0.767	0.563
5. Well-being at work	0.568	0.548	0.555	0.566	0.770

H6: *IT proactive stance has a positive and significant impact on wellbeing at work.*

Mediating role of wellbeing at work

In the healthcare sector, workplace wellness supports employees' psychological health. Employees with good mental health assist organizations to cope with increasing workplace stressors, thus, in turn, ensuring the employees'

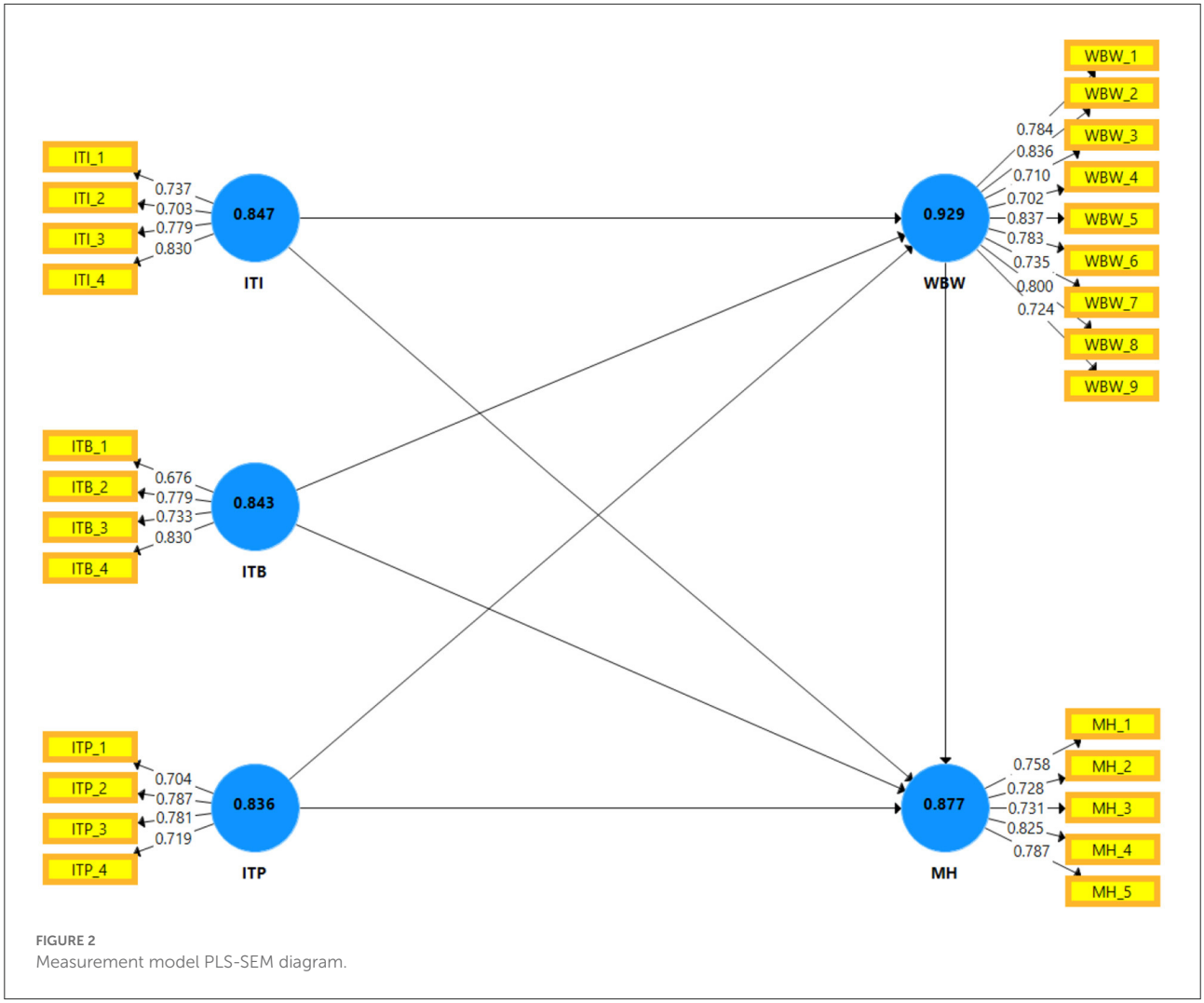

FIGURE 2
Measurement model PLS-SEM diagram.

wellbeing. As such, the research states that workplace wellbeing predicts employees' mental health (50). Mental health is a product of workplace wellbeing. However, understanding this phenomenon involves recognizing the worth of maintaining wellbeing at work. Healthy workplace activities manifest in workers' mindfulness. In this regard, research suggests that organizations tailor their workplace practices to engage individuals in wellness activities, thus facilitating employees' mental health (51). Therefore, at present, creating and building a healthier organizational environment is critical to achieving wellbeing. In explaining this notion, the research states that employees from different domains have recorded workplace wellness as a significant predictor of their mental health (52). Accordingly, this study proposes the following hypothesis:

H7: *Wellbeing at work has a positive and significant impact on mental health.*

Undoubtedly, the massive shift toward technology has fostered numerous opportunities for organizations. It has highlighted how the workplace well-influences employees' mental health. Furthermore, it has been observed that the implementation of novel technologies in the workplace creates a positive wellness culture, thus supporting employees' wellbeing. Employees' mental health highly depends on workplace wellness. Accordingly, the research states that digital capabilities have gained significant popularity by scaling up employees' health outcomes by improving workplace wellbeing (53). In particular, the ITI ensures employees' positive mental health and wellbeing at work. Therefore, ITI increases workplace happiness and wellbeing by minimizing the growing workplace stressors (54). In fact, ITI is a novel phenomenon influencing employee mindfulness and wellness at work (55).

The increasingly demanding nature of work in many industries has led to calls for technology adoption to improve employees' wellbeing. At present, technological changes have

TABLE 4 Results of direct effects.

Hypothesis	Direct relationships	Std. *Beta*	Std. error	*T*-values	*P*-values
H1	ITI → MH	0.202	0.066	3.079	**
H2	ITB → MH	0.239	0.076	3.158	**
H3	ITP → MH	0.192	0.073	2.642	*
H4	ITI → WBW	0.26	0.062	4.186	***
H5	ITB → WBW	0.302	0.069	4.390	***
H6	ITP → WBW	0.239	0.073	3.267	***
H7	WBW → MH	0.213	0.065	3.279	**

*p < 0.05, **p < 0.01, ***p < 0.001.

TABLE 5 Results of mediation effects.

Hypothesis	Indirect relationships	Std. *Beta*	Std. error	*T*-values	*P*-values
H7a	ITI → WBW → MH	0.055	0.025	2.224	*
H7b	ITB → WBW → MH	0.064	0.026	2.481	*
H7c	ITP → WBW → MH	0.051	0.024	2.133	*

*p < 0.05.

enhanced global working conditions, improving the workers' health quality. Digital innovation fundamentally changes the work landscape, thereby yielding the positive effects of IT on employees' wellbeing. Prior research explains that the ITB capability narrows down the pathology of distress by inserting technology into the business process (56). In fact, such digitalization measures significantly enhance the workplace environment by boosting employees' mindfulness. Based on this statement, the research shows that the ITB promotes wellness at work, thereby the ICT aspect can be used to ensure psychological gratification (57). Consequently, to address mental health problems, organizations should consider the prevalence of novel digital measures (e.g., ITB) in ways that can promote work-life balance and positive psychological outcomes (19).

In the present world, employees' wellbeing is a prominent focal point. In achieving this goal, IT capability has opened new avenues, with healthcare institutions being encouraged to embrace novel digital tools for promoting workplace wellness and influencing employees' mental wellbeing. At present, the technical intervention has assisted organizations to improve workplace wellness. In this regard, the ITP has become a dominant capability in fostering workplace wellness. Furthermore, building on this notion, the ITP innovations have helped companies to maintain a healthy working environment, thus boosting employees' mental health. In particular, this ICT measure has enabled organizations to establish a positive workplace atmosphere, thereby promoting employees' psychological wellbeing (47). Overall, digital health technology has contributed to enhancing employees' mental health and workplace wellbeing (19). Therefore, based on the data gathered, this study proposed the following hypotheses (refer to Figure 1):

H7(a): *Wellbeing at work mediates the relationship between IT infrastructure and mental health.*

H7(b): *Wellbeing at work mediates the relationship between IT business spanning and mental health.*

H7(c): *Wellbeing at work mediates the relationship between IT proactive stance and mental health.*

Methodology

The study's primary objective was to analyze the impact of digitalization on employees' mental health while considering the mediating role of wellbeing at work. The study has adopted a quantitative approach for the data collection. The data were collected from the employees working in the service sector of Pakistan. A convenience sampling technique was adopted, and data were collected through questionnaires. We have developed the questionnaire in dual languages (English and Urdu). Back-to-back translation for collecting data was used for "Urdu" language questionnaires as the data were collected from Pakistan, where the mother language is not English. We distributed 420 questionnaires among the employees from November 2021 to December 2021; 349 valid questionnaires were received from the participants. The Statistical Package for the Social Sciences (SPSS) and Partial Least Squares regression (PLS) were used for data analysis.

The measurement scale for the IT infrastructure, IT business spanning, and IT proactive stance consisted of three items and was adapted from the study of Nwankpa and Roumani (58). The sample items include "Data management services and architectures (databases, data warehousing, data availability, storage, accessibility, sharing, etc.)," "Developing a clear vision regarding how IT contributes to business value," and "We are capable of and continue to experiment with new IT as necessary." Wellbeing at work was measured on the nine-item scale adopted from the study of Demo and Paschoal (59). The sample items include "Over the past 6 months, my work made me feel proud" and "Over the past 6 months, my work made me feel active." Employees' mental health was measured on the 5-item scale adapted from the study of Wu et al. (60). The sample item includes "I have everything to look forward to."

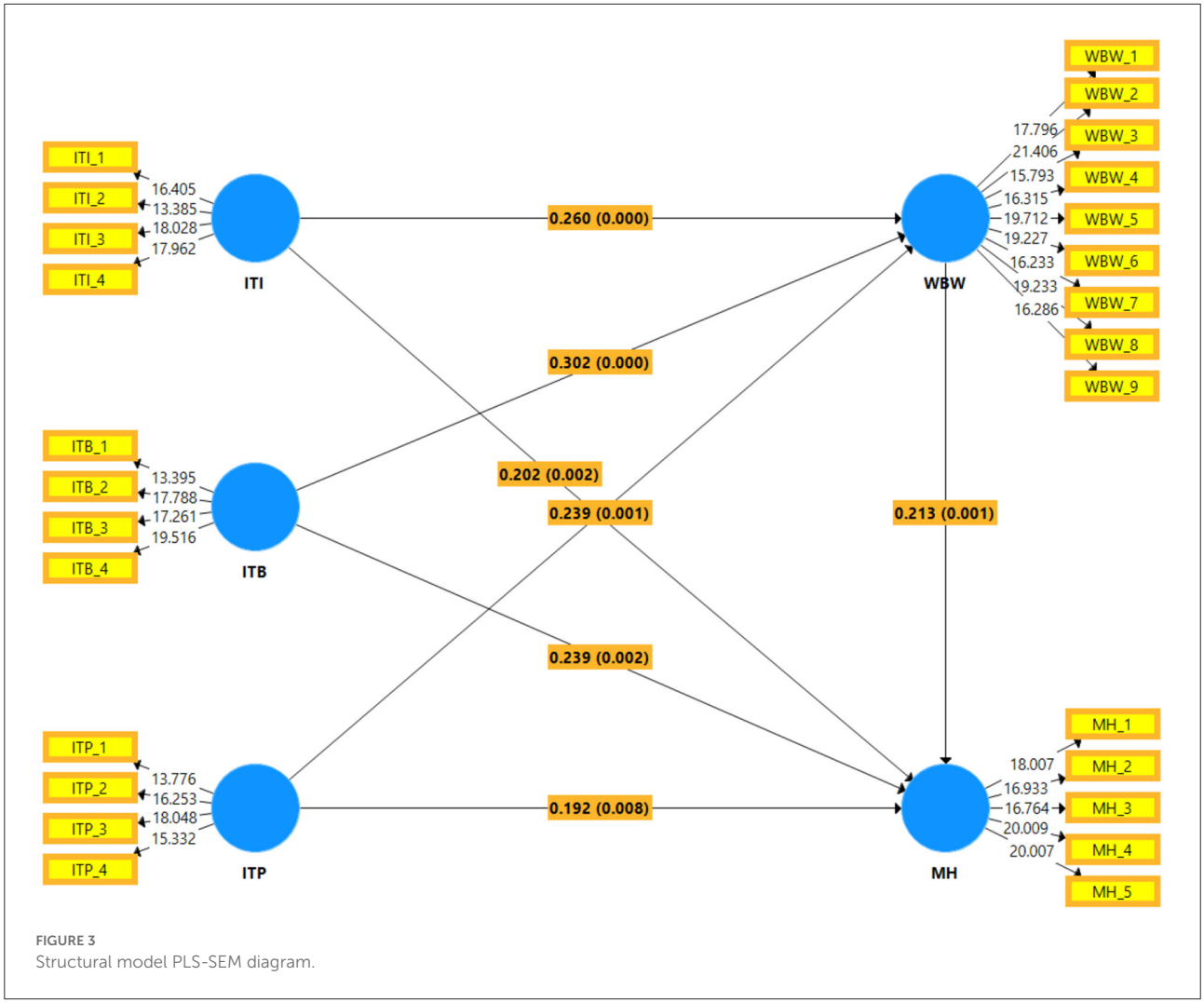

FIGURE 3
Structural model PLS-SEM diagram.

This study applied the common method bias using Harman's single-factor approach. The variance extracted by one single factor is 10.435%, <50%, indicating no common method bias (61).

Results

SmartPLS is used to analyze data in this study using the partial least square structural equation modeling (PLS-SEM) approach. This approach can examine complex models simultaneously, less restrictive to data assumptions. It can handle constructs with few measurement items compared to conventional approaches such as covariance-based SEM or multiple regression (62).

Descriptive analysis

Descriptive analysis results relating to the study participants are reported in Table 1. These results show the frequencies and percentages of the study participants in terms of gender, age, highest qualification, and marital status.

Measurement model

Reliability and validity of the measurements were first ensured through measurement model testing before testing the study's hypotheses. These results are reported in Tables 2, 3. The scores of factor loadings exceeded 0.65, and the average variance extracted (AVE) values were also above 0.50, as reported in Table 2. These factors' loading and AVE scores warranted the convergent validity of the study measures (63). Moreover, as reported in Table 2, the Cronbach's alpha (α) reliability score and composite reliability (CR) of all the variables well exceeded the cutoff value of 0.70 (64), establishing the reliability of the scales.

In addition, Table 3 revealed the discriminant validity scores of the study variables using the Fornell and Larcker (65) criterion and a more robust and advanced approach named the heterotrait-monotrait (HTMT) ratio. According to Fornell and

Larcker's (65) criterion, the square root scores of the AVE of each construct should be more than its correlation values, which was well achieved in the case of this study. Finally, the HTMT ratio score of the construct should be <0.85 to establish discriminant validity. Both these results ensured the discriminant validity of the study scales. Measurement model results are presented in Figure 2.

Hypotheses testing

Table 4 presents the standardized path coefficient scores of all the hypotheses proposed in the direct relationships of the study (H1–H7). The relationship of IT infrastructure with mental health ($\beta = 0.202^{**}$, $t = 3.079$), IT business spanning with mental health ($\beta = 0.239^{**}$, $t = 3.158$), IT proactive stance with mental health ($\beta = 0.192^{*}$, $t = 2.642$), IT infrastructure with wellbeing at work ($\beta = 0.26^{***}$, $t = 4.186$), IT business spanning with wellbeing at work ($\beta = 0.302^{***}$, $t = 4.390$), IT proactive stance with wellbeing at work ($\beta = 0.239^{***}$, $t = 3.267$), and wellbeing at work with mental health ($\beta = 0.213^{**}$, $t = 3.279$) were found to be significant, statistically. Overall, the above results statistically supported this study's first seven hypotheses (H1–H7).

Furthermore, the last three hypotheses (H7a-c) claimed that wellbeing at work mediates the relationship of IT infrastructure, IT business spanning, and IT proactive stance, respectively, with mental health. First, as reported in Table 5, wellbeing at work mediated the relationship between IT infrastructure and mental health ($\beta = 0.055^{*}$, $t = 2.224$), empirically supporting the H7(a) of the study. Next, as claimed in the H7(b) of the study, the mediating role of wellbeing at work for the relationship between IT business spanning and mental health ($\beta = 0.064^{*}$, $t = 2.481$) was also empirically supported. Finally, wellbeing at work also mediated the relationship between IT proactive stance and mental health ($\beta = 0.051^{*}$, $t = 2.133$) and got empirical support for the H7(c) of the study. Figure 3 shows the structural model analysis results.

Discussion

In recent years, novel technological advancement has significantly enhanced employees' mental health irrespective of the industry. IT plays an essential role in ensuring workplace wellness and employees' mental health. As such, many organizations have invested in digital solutions for expanding their services. Organizations are increasingly realizing the value of modern advancements. With the technical developments, healthcare employees have found support to offer best practice care, thereby empowering their mental health and wellbeing at work. In explaining this phenomenon, this section explores the effect of digitalization on employees' mental health and wellbeing at work, considering the previous literature findings.

Traditionally, digital innovations have mainly been the focus on researchers, but now organizations are placing more emphasis on technology as a fundamental part of their structures. The research suggests that technological infrastructure supports employees' mental health (66). ITB has emerged as a solution to resolving employees' mental issues, with one study stating that technology integration (i.e., ITB and ITP) has enabled organizations to modify business activities, thereby ensuring positive mental health (32). Moreover, the growth in ICT has led IT capabilities to emerge as novel tools for fulfilling employees' psychological demands. In fact, our study's findings agree with the previous literature, thereby accepting H1, H2, and H3.

Technology has often represented a disruptive yet positive force in its impact on workplace wellness. IT can be used to solve workplace problems by effectively allowing the institution's technical capability to enhance workplace wellbeing (67). The use of health technology infrastructure has increased in recent years. Prior research shows that good ITI decreases psychological vulnerabilities, ultimately facilitating employees' workplace wellbeing (68). As the global health crisis increases, ensuring workplace wellbeing has become necessary for organizations in this sector. In this regard, a growing body of research states that digital health inventions (i.e., ITB and ITP) bolster employees' workplace wellness (69). In explaining this notion, the existing literature states that to gain long-term benefits in the form of employees' mental health, organizations should create a healthy working environment, thus supporting workplace wellness (70). In fact, our research findings also revealed the same results, thus verifying the research assumptions made in H4, H5, and H6.

Digital technological innovation has brought numerous benefits to healthcare organizations, by facilitating workplace wellbeing and employees' mental health. As such, technology adoption in the healthcare sector reflects the notion that modern tools influence workplace wellbeing (71). In particular, digitalization (e.g., ITI, ITB, and ITP) plays a significant role in enabling positive outcomes in this sector. The findings reveal that digital health capabilities have become increasingly popular as a means to provide employees with a good quality of living (i.e., mental health), thereby supporting their wellbeing at work (68). Hence, our study also supports the prior literature, substantially accepting H7 (a, b, and c). To sum up, our research findings support the previous literature, reiterating the view that technology adoption in the healthcare sector has a positive outcome in terms of employees' mental health.

Conclusion

Undoubtedly, over the years, an overwhelming number of digital innovations has led employees to integrate the digital tools that create a healthy psychological work environment.

Studies show that a poor workplace environment leaves a heavy toll on employees' mental health. Accordingly, to understand the effect of digitization on mental health in the workplace, this study presented a systematic review of how digitalization capabilities in healthcare influence employees' psychological health. The study explored the relationship between IT capabilities and employees' mental health. It drew a link between digitization approaches and employees' mental health concerning the mediating effect of wellbeing at work.

Good IT practices are essential for fostering employees' wellbeing. Our research findings indicate that IT capabilities (e.g., ITI, ITB, and ITP) positively influence employees' mental health and workplace wellbeing. A review of the literature revealed that the technology deployed in the healthcare sector has improved employees' mental health and wellbeing. Altogether, our results are positive, thus supporting the previous studies. In fact, the findings of this study open pathways for future researchers, policymakers, and healthcare institutions, by directing their focus on studying technology and mental health toward the healthcare sector. This study holds valuable knowledge for healthcare organizations regarding the need for a focus on employees' mental health. In fact, the findings of the study are significant in terms of identifying digitization as supporting employee psychological wellness. It recommends that policymakers in healthcare should consider how technology can improve employees' workplace wellbeing and mental health to gain positive health outcomes.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

1. Khan MK. Technological advancements and 2020. *Telecommun. Syst.* (2020) 73:1–2. doi: 10.1007/s11235-019-00647-8

2. Khanal P, Devkota N, Dahal M, Paudel K, Joshi D. Mental health impacts among health workers during COVID-19 in a low resource setting: a cross-sectional survey from Nepal. *Global Health.* (2020) 16:89. doi: 10.1186/s12992-020-00621-z

3. Jansson I, Gunnarsson AB. Employers' views of the impact of mental health problems on the ability to work. *Work.* (2018) 59:585–98. doi: 10.3233/WOR-182700

4. Wu TJ, Li JM, Wu YJ. Employees' job insecurity perception and unsafe behaviours in human–machine collaboration. *Manage. Dec.* (2022). doi: 10.1108/MD-09-2021-1257. [Epub ahead of print].

5. Schueller SM, Torous J. Scaling evidence-based treatments through digital mental health. *Am. Psychol.* (2020) 75:1093–104. doi: 10.1037/amp0000654

6. Timakum T, Xie Q, Song M. Analysis of E-mental health research: mapping the relationship between Inform. technology and mental healthcare. *BMC Psychiatry.* (2022) 22:57. doi: 10.1186/s12888-022-03713-9

7. Farsen TC, Costa AB, Silva N. Resiliência no trabalho no campo da Psicologia: um estudo bibliométrico. *Psicología desde el Caribe.* (2018) 35:81–103.

8. Byrd TA, Turner DE. An exploratory examination of the relationship between flexible IT infrastructure and competitive advantage. *Inform. Manage.* (2001) 39:41–52. doi: 10.1016/S0378-7206(01)00078-7

9. Khawaja KF, Sarfraz M, Rashid M, Rashid M. How is COVID-19 pandemic causing employee withdrawal behavior in the hospitality industry? An empirical investigation. *J. Hosp. Tour. Insights.* (2021) 5:687–706. doi: 10.1108/JHTI-01-2021-0002

10. Naslund JA, Shidhaye R, Patel V. Digital technology for building capacity of nonspecialist health workers for task sharing and scaling up mental health care globally. *Harv Rev Psychiatry.* (2019) 27:181–92. doi: 10.1097/HRP.0000000000000217

11. Elbashir MZ, Collier PA, Sutton SG. The role of organizational absorptive capacity in strategic use of Bus intelligence to support integrated management control systems. *Account. Rev.* (2011) 86:155–84. doi: 10.2308/accr.00000010

12. Hallam KT, Peeters A, Gupta A, Bilsborough S. Moving minds: Mental health and wellbeing benefits of a 50-day workplace physical activity program. *Curr Psychol.* (2022) 1–12. doi: 10.1007/s12144-021-02525-6

13. Kersemaekers W, Rupprecht S, Wittmann M, Tamdjidi C, Falke P, Donders R, et al. A Workplace mindfulness intervention may be associated with improved psychological well-being and productivity. A preliminary field study in a company setting. *Front. Psychol.* (2018) 9:195. doi: 10.3389/fpsyg.2018.00195

14. Shah SGM, Sarfraz M, Fareed Z, ur Rehman MA, Maqbool A, Qureshi MAA. Whether CEO succession via hierarchical jumps is detrimental or blessing in disguise? Evidence from Chinese listed firms. *Zagreb Int Rev Econ. Bus.* (2019). doi: 10.2478/zireb-2019-0018

15. Muller AE, Hafstad EV, Himmels JPW, Smedslund G, Flottorp S, Stensland SØ, et al. The mental health impact of the covid-19 pandemic on healthcare workers, and interventions to help them: A rapid systematic Rev. *Psychiatry Res.* (2020) 293:113441. doi: 10.1016/j.psychres.2020.113441

16. Swanson EB, Ramiller NC. Innovating mindfully with information technology. *MIS Q.* (2004) 28:553. doi: 10.2307/25148655

17. Carolan S, de Visser RO. Employees' perspectives on the facilitators and barriers to engaging with digital mental health interventions in the workplace: qualitative study. *JMIR Mental Health.* (2018) 5:e8. doi: 10.2196/mental.9146

18. Alat P, Das SS, Arora A, Jha AK. Mental health during COVID-19 lockdown in India: Role of psychological capital and internal locus of control. *Curr Psychol.* (2021) 1–13. doi: 10.1007/s12144-021-01516-x

19. Schneider, K. R. (2019). *Technological Availability and Employees' Well-Being: A Pathway to Responsible Digitization*. Darmstadt, Germany: Publications of Darmstadt Technical University, Institute for Bus Studies (BWL) 117467, Darmstadt Technical University, Department of Bus Administration, Econ. and Law, Institute for Bus Studies (BWL).

20. Rudd BN, Beidas RS. Digital mental health: the answer to the global mental health crisis? *JMIR Mental Health.* (2020) 7:e18472. doi: 10.2196/18472

21. Diebig M, Müller A, Angerer P. Impact of the Digitization in the Industry Sector on Work, Employment, and Health. In *Handbook of Socioeconomic Determinants of Occupational Health*. Berlin, Germany: Springer International Publishing (2020). p. 1–15.

22. Kilbourne AM, Beck K, Spaeth-Rublee B, Ramanuj P, O'Brien RW, Tomoyasu N, et al. Measuring and improving the quality of mental health care: a global perspective. *World Psychiatry.* (2018) 17:30–8. doi: 10.1002/wps.20482

23. Kindermann B, Beutel S, de Lomana GG, Strese S, Bendig D, Brettel M. Digital orientation: Conceptualization and operationalization of a new strategic orientation. *Eur Manag J.* (2021) 39:645–57. doi: 10.1016/j.emj.2020.10.009

24. Sarfraz M, Ozturk I, Shah SGM, Maqbool A. Contemplating the impact of the moderators agency cost and number of supervisors on corporate sustainability under the aegis of a cognitive CEO. *Front. Psychol.* (2020) 11:965. doi: 10.3389/fpsyg.2020.00965

25. Awasthi S, Yadav A, Medatwal C. Information technology and its effect on occupational mental health: a study of mechanical engineers. *Int J Mech Eng.* (2021) 6:71–6.

26. Bucci S, Berry N, Morris R, Berry K, Haddock G, Lewis S, et al. "They are not hard-to-reach clients. We have just got hard-to-reach services" staff views of digital health tools in specialist mental health services. *Front Psychiatry.* (2019) 10:344. doi: 10.3389/fpsyt.2019.00344

27. Wessel L, Baiyere A, Ologeanu-Taddei R, Cha J, Blegind Jensen T. Unpacking the difference between digital transformation and IT-enabled organizational transformation. *J Assoc Inform Syst.* (2021) 22:102–29. doi: 10.17705/1jais.00655

28. Abdullah MI, Huang D, Sarfraz M, Ivascu L, Riaz A. Effects of internal service quality on nurses' job satisfaction, commitment and performance: mediating role of employee well-being. *Nurs Open.* (2021) 8:607–19. doi: 10.1002/nop2.665

29. Chandrashekar P. Do mental health mobile apps work: evidence and recommendations for designing high-efficacy mental health mobile apps. *MHealth.* (2018) 4:6–6. doi: 10.21037/mhealth.2018.03.02

30. Matt DT, Pedrini G, Bonfant A, Orzes G. Industrial digitalization. A systematic literature Review and research agenda. *Eur Manage J.* (2022). doi: 10.1016/j.emj.2022.01.001. [Epub ahead of print].

31. Sarfraz M, Hafeez H, Abdullah MI, Ivascu L, Ozturk I. The effects of the COVID-19 pandemic on healthcare workers' psychological and mental health: the moderating role of felt obligation. *Work.* (2022) 539–50. doi: 10.3233/WOR-211073

32. Borle P, Boerner-Zobel F, Voelter-Mahlknecht S, Hasselhorn HM, Ebener M. The social and health implications of digital work intensification. Associations between exposure to Inform. and communication technologies, health and work ability in different socio-economic strata. *Int Arch Occup Environ Health.* (2021) 94:377–90. doi: 10.1007/s00420-020-01588-5

33. Bordi L, Okkonen J, Mäkiniemi JP, Heikkilä-Tammi K. Communication in the Digital Work Environment: Implications for Wellbeing at Work. *Nordic J Work Life Stud*. (2018) 8:29–48. doi: 10.18291/njwls.v8iS3.105275

34. Sun J, Sarfraz M, Khawaja KF, Ozturk I, Raza MA. The perils of the pandemic for the tourism and hospitality industries: envisaging the combined effect of COVID-19 fear and job insecurity on employees' job performance in Pakistan. *Psychol Res Behav Manag.* (2022) 15:1325–46. doi: 10.2147/PRBM.S365972

35. NIMH (2019). *Technology and the Future of Mental Health Treatment*. Bethesda, Maryland: National Institute of Mental Health.

36. Torous J, Wisniewski H, Bird B, Carpenter E, David G, Elejalde E, et al. Creating a digital health smartphone app and digital phenotyping platform for mental health and diverse healthcare needs: an interdisciplinary and collaborative approach. *J Technol Behav Sci.* (2019) 4:73–85. doi: 10.1007/s41347-019-00095-w

37. Chawla S, Sharma RR. Enhancing Women's Well-Being: The role of psychological capital and perceived gender equity, with social support as a moderator and commitment as a mediator. *Front. Psychol.* (2019) 10:1–15. doi: 10.3389/fpsyg.2019.01377

38. Lupșa D, Vîrga D, Maricu?oiu LP, Rusu A. Increasing psychological capital: a pre-registered meta-analysis of controlled interventions. *Appl Psychol.* (2020) 69:1506–56. doi: 10.1111/apps.12219

39. Brassey J, Güntner A, Isaak K, Silberzahn T. *Using Digital Technology to Support Employees' Mental Health and Resilience*. (2021). Washington, D.C.: McKinsey & Company

40. Trenerry B, Chng S, Wang Y, Suhaila ZS, Lim SS, Lu HY, et al. Preparing workplaces for digital transformation: an integrative review and framework of multi-level factors. *Front. Psychol.* (2021) 12:1–24. doi: 10.3389/fpsyg.2021.620766

41. Bostock S, Crosswell AD, Prather AA, Steptoe A. Mindfulness on-the-go: Effects of a mindfulness meditation app on work stress and well-being. *J Occup Health Psychol.* (2019) 24:127–38. doi: 10.1037/ocp0000118

42. Maedche A, Legner C, Benlian A, Berger B, Gimpel H, Hess T, et al. AI-based digital assistants. *Bus Inform Syst Eng.* (2019) 61:535–44. doi: 10.1007/s12599-019-00600-8

43. Wang B, Liu Y, Parker SK. How does the use of inform. communication technology affect individuals? A work design perspective. *Acad Manage Ann.* (2020) 14:695–725. doi: 10.5465/annals.2018.0127

44. Richter A, Heinrich P, Stocker A, Schwabe G. Digital Work Design. *Bus Inform Syst Eng.* (2018) 60:259–64. doi: 10.1007/s12599-018-0534-4

45. Stankov, U, and Filimonau, V. (2020). Technology-assisted mindfulness in the co-creation of tourist experiences. In *Handbook of e-Tourism*. Berlin, Germany: Springer International Publishing. p. 1–26.

46. McAlaney J, Aldhayan M, Almourad MB, Cham S, Ali R. *On the Need for Cultural Sensitivity in Digital Wellbeing Tools and Messages: A UK-China Comparison*. (2020). p. 723–33.

47. Day A, Barber LK, Tonet J. Information communication technology and employee well-being. In: *The Cambridge Handbook of Technology and Employee Behavior*. (2019). Cambridge: Cambridge University Press. p. 580–607.

48. Vanden Abeele MMP. Digital wellbeing as a dynamic construct. *Commun Theor.* (2021) 31:932–55. doi: 10.1093/ct/qtaa024

49. Fisher J. *The Importance of Employee Well-Being and How Technology Can Help*. New York, NY: TechTarget (2020).

50. Haddon J. The impact of employees' well-being on performance in the workplace. *Strategic HR Rev.* (2018) 17:72–5. doi: 10.1108/SHR-01-2018-0009

51. Seaton CL, Bottorff JL, Oliffe JL, Medhurst K, DeLeenheer D. Mental health promotion in male-dominated workplaces: perspectives of male employees and workplace representatives. *Psychol Men Masculinities.* (2019) 20:541–52. doi: 10.1037/men0000182

52. Jnaneswar K, Sulphey MM. A study on the relationship between workplace spirituality, mental wellbeing and mindfulness. *Manage Sci Lett.* (2021) 1045–54. doi: 10.5267/j.msl.2020.9.038

53. Howarth A, Quesada J, Silva J, Judycki S, Mills PR. The impact of digital health interventions on health-related outcomes in the workplace: a systematic review. *Digital Health.* (2018) 4:205520761877086. doi: 10.1177/2055207618770861

54. Zhu Z, Ma W, Leng C. ICT Adoption, individual income and psychological health of rural farmers in China. *Appl Res Qual Life.* (2022) 17:71–91. doi: 10.1007/s11482-020-09879-2

55. Christensen JO, Finne LB, Garde AH, Nielsen MB, Sørensen K, Vleeshouwers J, et al. The influence of digitalization and new technologies on psychosocial work environment and employee health: a literature review. *STAMI-Rapport*. (2021) 1–52.

56. Meske C, Junglas I. Investigating the elicitation of employees' support towards digital workplace transformation. *Behav Inform Technol.* (2021) 40:1120–36. doi: 10.1080/0144929X.2020.1742382

57. Elsbach KD, Stigliani I. New information technology and implicit bias. *Acad Manage Perspect.* (2019) 33:185–206. doi: 10.5465/amp.2017.0079

58. Nwankpa JK, Roumani Y. *IT Capability and Digital Transformation: A Firm Performance Perspective*. Dublin: Thirty Seventh International Conference on Information Systems (2016).

59. Demo G, Paschoal T. Well-being at work scale: exploratory and confirmatory validation in the united states comprising affective and cognitive components. *Proceeding XXXVII Encontro Da ANPAD.* (2013) 7:1–16. doi: 10.1590/1982-43272663201605

60. Wu J, Mei W, Liu L, Ugrin JC. The bright and dark sides of social cyberloafing: effects on employee mental health in China. *J Bus Res.* (2020) 112:56–64. doi: 10.1016/j.jbusres.2020.02.043

61. Podsakoff PM, MacKenzie SB, Lee JY, Podsakoff NP. Common method biases in behavioral research: A critical Rev of the literature and recommended remedies. *J Appl Psychol.* (2003) 88:879. doi: 10.1037/0021-9010.88.5.879

62. Hair JF, Ringle CM, Sarstedt M. Partial least squares structural equation modeling: Rigorous applications, better results and higher acceptance. *Long Range Plann.* (2013) 46:1–12. doi: 10.1016/j.lrp.2013.01.001

63. Henseler J, Ringle CM, Sinkovics RR. The use of partial least squares path modeling in international marketing. In: *New Challenges to International Marketing*. (2009). Bingley, United Kingdom: Emerald Group Publishing Limited.

64. Hair Jr J, Hult GT, Ringle C, Sarstedt M. A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM) - Joseph F. Hair, Jr, G. Tomas M. Hult, Christian Ringle, Marko Sarstedt. (2016) Newcastle upon Tyne, UK: Sage.

65. Fornell C, Larcker DF. Evaluating structural equation models with unobservable variables and measurement error. *J Mark Res.* (1981) 18:39–50. doi: 10.1177/002224378101800104

66. Ma W, Nie P, Zhang P, Renwick A. Impact of Internet use on economic well-being of rural households: Evidence from China. *Rev Dev Econ.* (2020) 24:503–23. doi: 10.1111/rode.12645

67. Weerasekara M, Smedberg Å, Sandmark H. ICT supported occupational stress management: the views of HR managers in Sri Lankan software companies. *Int Conf E-Health.* (2020).

68. Jabra NW. *Using IT Infrastructure to Fuel Employee Well-Being*. Copenhagen: Jabra (2021). Available online at: https://www.jabra.com/blog/using-it-infrastructure-to-fuel-employee-well-being/ (accessed April 10, 2020).

69. Armaou M, Konstantinidis S, Blake H. The effectiveness of digital interventions for psychological well-being in the workplace: a systematic review protocol. *Int J Environ Res Public Health.* (2019) 17:255. doi: 10.3390/ijerph17010255

70. Hilton LG, Marshall NJ, Motala A, Taylor SL, Miake-Lye IM, Baxi S, et al. Mindfulness meditation for workplace wellness: an evidence map. *Work.* (2019) 63:205–18. doi: 10.3233/WOR-192922

71. Burton-Jones A, Akhlaghpour S, Ayre S, Barde P, Staib A, Sullivan C, et al. Changing the conversation on evaluating digital transformation in healthcare: Insights from an institutional analysis. *Inform. Organ.* (2020) 30:100255. doi: 10.1016/j.infoandorg.2019.100255

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RESEARCH ARTICLE

New insights into corporate sustainability, environmental management and corporate financial performance in European Union: an application of VAR and Granger causality approach

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Abstract

The paper examines how environmental, social, and governance (ESG), including management incentives, influence a firm's financial performance. The study method is based on an empirical analysis of data describing firm-level information about corporate financial performance and corporate sustainability performance between 2001 and 2020, summing up 6291 observations related to 422 analyzed firms from the European Union (EU). The study findings emphasize that firm size is highly influenced by sustainable economic development and significantly conditioned by a CSR strategy and a capable management team. We also prove a long-term relationship between the measures of corporate financial performance and the scores reflecting corporate ESG performance. Our results show a co-integration relationship between corporate financial performance metrics and corporate sustainability performance scores. ESG corporate performance is highly conditioned by the level of resources affected for this purpose, directly impacting firms' cash flow.

Keywords Corporate sustainability · Financial performance · Corporate social responsibility · European Union · Environmental management

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Introduction

Non-financial reporting represents a fundamental concept through which companies reveal their attitude toward the community, environment, and governance, often referred to as environmental, social, and governance (ESG) or corporate social responsibility (CSR) actions. Over time, sustainability reports have become increasingly important, completing financial statements in substantiating investment decisions and long-term sustainable development goals. However, they were first seen as an obligation to comply with legal requirements (PwC 2021), with ESG compliance being more pronounced in European companies than in other parts of the world (Shaikh 2022).

Sustainability is a broad and complex concept. It seems that CSR tends to add value only under certain conditions. Researchers reveal that there may also be an indirect relation between CSR and firm performance (Servaes and Tamayo 2013) rather than a direct relation in which CSR improvements are positively related to companies' future profitability (Shah et al. 2019; Sarfraz et al. 2020a; Maury 2022). In this context, managers play a crucial role as more and more companies start to include indicators on

meeting environmental, social, and corporate governance objectives in their directors' remuneration packages.

Managers are responsible for directing resources to implement effective monitoring processes and controls that aim to achieve firms' targets in terms of ESG actions (Ajaz et al. 2020; Velte 2021). The effectiveness of those processes is crucial for firms. Through CSR/ESG strategies, managers search for solutions to develop and consolidate firms' dynamic capabilities, increasing their resilience in the current context of extremely high economic uncertainty. Those capabilities reflect firms' capacities to redesign, adapt, and change processes and direct resources in volatile economic, social, and environmental circumstances. Therefore, firms can gain a significant competitive advantage on the market through more agile processes, creative and innovative solutions addressing ESG problems, or the facilitation of human capital development (Babasanya et al. 2018).

Furthermore, a top-down approach to ESG strategy implementation is essential. The moderating effect of CSR on corporate financial performance is conditioned by the CEO's power (Velte 2021) or the board characteristics (Rossi et al. 2021). Top management decides on a CSR strategy that has to consider several mechanisms that significantly influence the relationship between CSR and corporate financial performance (Vishwanathan et al. 2020; Naseem et al. 2021). Therefore, managers should build a relationship with both shareholders and stakeholders, based on trust and long-term cooperation, in line with the legitimacy theory and stakeholder theory.

Managers must also have enough experience and expertise to cope with industry-specific challenges (Zaiane and Ellouze 2022) or county regulatory framework and enforcement mechanisms (Christensen et al. 2021), especially in the case of mandatory adoption, to avoid the deterioration of CSR's positive long-term moderating effect on corporate financial performance. Industries such as the energy or manufacturing sector are more sensitive to environmental concerns, so managers should integrate economic and environmental dimensions into the day-to-day decision-making process. Otherwise, the compliance costs will be significantly high and drastically affect corporate financial performance. Nonetheless, we emphasize the moderating role of the national regulation and the monitoring and control mechanisms that look for compliance with environmental, social, and economic regulations. Additionally, the transition to sustainable growth models on a macroeconomic level creates distinct paths, even when common understanding is achieved. For example, European Union economies have subscribed to the Green Deal but plan to reach the targets in different ways, through relatively customized public policies aimed to cope with the local characteristics of their economies.

This paper aims to offer some insights into the relationship between ESG/CSR practices and financial performance. The literature emphasizes a positive but small impact of corporate ESG practice on corporate financial performance (Grewatsch and Kleindienst 2017; Shehzad et al. 2020). The link between ESG performance and corporate financial performance has been generalized among people involved in ESG practices, whether they be researchers, ESG implementation experts, or non-practitioners responsible for the processes scoped to become green (Bergmann 2016; Sarfraz et al. 2020b). In this context, the focus of our paper is an empirical analysis of data describing firm-level information about corporate financial performance and corporate sustainability performance between 2001 and 2020, summing up 6291 observations related to 422 analyzed firms, covering most of the European Union members. The study is oriented on a firm-level analysis as the sample analyzed consists of firms that are more or less subject to similar country regulation in terms of sustainability, as they are originated from European Union members.

Our paper attempts to fill the gap in the literature, including in the sample analyzed companies from developing countries as well, such as Poland, the Czech Republic, and Hungary (Goyal et al. 2013; Alshehhi et al. 2018). We proceed to a long-term analysis, as the literature highlights that a link between corporate sustainability performance and corporate financial performance is more likely to be visible over a longer period (Lu and Taylor 2016; Alshehhi et al. 2018). The research is oriented toward accounting-based metrics of corporate financial performance, rather than market-based performance, as long-term behavior can be better reflected by accounting-based financial measures, while market-based proxies better reflect short-term causality with ESG performance (Lu and Taylor 2016; Atz et al. 2021).

Additionally, our study addresses the role of ESG strategies, rather than ESG practice on corporate financial performance, providing insights on the essential place of the top-down ESG approach. Management contributes to the efficient use of organizational resources and thus these resources are efficiently allocated to ESG activities. ESG activities contribute to sustainable development and increase the level of competitiveness (Grewatsch and Kleindienst 2017; Atz et al. 2021).

This paper is structured as follows: the "Literature review" section presents the literature review and the hypothesis development, testing how ESG/CSR and management efficiency on implementing firms' strategy influence financial performance; the "Research methodology" section presents the research methodology; the "Results and discussion" section discusses the results obtained; and the "Conclusion" section summarizes the main findings, conclusions, and avenues for future research directions.

Literature review

Non-financial reporting, defined as the disclosure of a company's ESG information. Today, ESG reporting has become a topic of real interest, with environmental, sustainability, and governance policies alongside CSR practices being the real drivers of business development and among the main factors that promote green innovation and environmental management (Pan and Fan 2021).

We are thus moving toward the moment when a company's non-financial performance can compete with its financial performance, greatly influencing investment decisions (PwC 2021). This is because managers and stakeholder believe that significant ESG disclosures yield better operating performance, higher returns, and lower firm-specific risk (Shaikh 2022).

In this context, the identification of the impact of non-financial reporting expressed by ESG and CSR strategies on financial performance, particularly the correlation of KPI indicators with financial performance factors, is of particular importance. This is true from the perspective of, on the one hand, long-term development and value creation, with studies highlighting that social and governance performance significantly affects economic performance (Cek and Eyupoglu 2020; Naseem et al. 2021). On the other hand, new non-financial reporting regulations require companies to have responsible and transparent business models. Hence, investors can evaluate the financial results of various ESG factors from the perspective of changes in cash flows, the impact on earnings, or the cost of capital and asset values.

Authors agreed that sustainability strategies play a crucial role in business development (Amel-Zadeh and Serafeim 2018). However, there is significant gap in the literature regarding a ground theory concerning the causality between corporate ESG performance and corporate financial performance (Grewatsch and Kleindienst 2017). Hence, in this sense, it is interesting to examine how ESG influences firms' financial performance, CSR strategies, and managers' ability to incur expenses on social responsibility projects and maintain, at the same time, positive financial results.

Overall, the literature reflects that firms that integrate CSR strategies into their business model perform better (Bocquet et al. 2017). Maury (2022) stated that CSR improvements are shown to be positively related to higher profits, and Cheng et al. (2014) emphasize that firms with higher CSR ratings have better access to finance and gain competitive advantages (Ruokonen and Temmes 2019). Nevertheless, Masulis and Reza (2014) stated that the stock market can react negatively to the announcement of corporate philanthropic contributions, suggesting that these kinds of CSR activities are not valued by investors mainly because they interfere with the goal of firm value maximization. However, companies are under increasing pressure to "do good" (Huang 2021). Therefore, we believe that CSR practices are key elements of the business model and risk management framework, promoting the image and values with which the company identifies. As such, the first hypothesis that will be tested is:

H1: CSR strategies determine significant changes in a firm's performance.

However, corporate sustainability today implies much more, namely a process that implements a business strategy that focuses on environmental, social, and governance dimensions to improve traditional financial analysis by identifying potential risks and opportunities beyond economic aspects. Kumar (2020) highlighted that ESG compliant firms have better governance, care more for sustainable development and the environment, record less earnings volatility, and have lower-cost funds. Also, high ESG scores have a significant positive impact on firm value (Duque-Grisales and Aguilera-Caracuel 2021). Performance indicators like ROA, ROE, and Tobin's Q generate economic benefits to shareholders (Buallay et al. 2020).

Hence, long-term value creation is not a goal only for investors and management, but also for regulatory bodies, like the United Nations. The latter's involvement can be seen through their recommendation that firms disclose their ESG practices by 2030 to address how severe environmental threats due to climate change can be counteracted in ways that do not affect the financial performance of companies. In addition, studies reveal that when firms undertake strategic actions to improve their ESG performance, they also enhance the firm's reputation in the eyes of its various stakeholders (Kim and Lyon 2015; Abdullah et al. 2018). Therefore, we believe that a firm's ESG score influences its performance and as such the second hypothesis that will be tested is:

H2: A firm's ESG score determines significant changes in its financial performance in the context of environmental change concerns.

Another aspect highlighting the great importance of this topic is whether ESG or CSR performance is the outcome of well-governed managerial decisions, or if they arise when managers are acting in their interests (Gillan et al. 2021). This implies that CSR projects may represent, on the one hand, opulent expenditure made by managers motivated by personal interests, decreasing shareholder value, and worsening financial performance. Managers may be motivated by the remuneration packages received for fulfilling the ESG

objectives; evidently, the largest listed companies set the tone on stock exchanges (PwC 2021). On the other hand, in the case of sensitive industries, managers tend to set higher ESG performance targets and to disclose more corporate social information than other sectors through non-financial reports. This is done out of a desire to mitigate the negative impact of the activity carried out by posing a good image into the market (Garcia et al. 2017). Therefore, we believe that management efficiency in implementing firms' strategy and how shareholders offer incentives to managers to motivate them to obtain an optimal level of corporate performance, are important factors in how CSR/ESG projects influence performance. As such, the third hypothesis that will be tested is:

H3: Managers' ability to cope with environmental, social, and governance issues determines significant changes in a firm's financial performance.

Overall, ESG activities are perceived as a source of explicit costs for firms, with low awareness of the implicit potential positive effects on their performance from a long-term perspective. Incentives in favor of sustainable growth seem too low, discouraging companies from taking the next step toward a green economy. In those circumstances, additional pressure is required, such as more regulation on ESG activities, as the scenario of voluntary adoption of a green business model does not generate sufficient benefits. Also, the widespread practice within countries, industries, and even firms operating in the same field of activity, or at least the information disclosed by them, creates this status quo. The lack of standardization on ESG reporting, despite the common efforts of international standard-setters in the area of ESG practice, may affect the measures of ESG scoring. Therefore, aiming for standardization in disseminating ESG information is a first step to obtain a clearer image of the link between the constructs explored in this paper, as underlined by Christensen et al. (2021). Otherwise, corporate sustainability reports will become highly complex, addressing numerous subjects in a general rather than a relevant and clear manner (Székely and Vom Brocke 2017), leading to higher cost for preparation, higher risk of litigation costs, or just negative reactions on the markets because of insufficient information disclosed on essential topics.

Research methodology

Data and variable definition

Our study represents an empirical analysis of data describing firm-level information about corporate financial performance and corporate sustainability performance. Information analyzed is limited to 2001–2020, summing up 6291 observations related to 422 firms.

The study focuses only on firms with a country of origin as EU members, as they are subject to a common approach in terms of regulation, structural reforms, and financing of projects in sustainable development. The European Union's Green Deal looks at environmental, social issues, innovation, and circular economy and is designed to lead to sustainable development. Countries are supported to provide firms' incentives to achieve targets on SGDs set up by UN members. These targets are transposed into firm sustainability practices related to transformations concerning vision, mission, objectives, policies, and processes that lead to sustainable economic development and create an organizational culture promoting continuous transformation toward sustainability (Khaled et al. 2021).

In Fig. 1, we observe that the number of observations is balanced related to the distribution along the analyzed years. Instead, our sample of observations is mainly related to manufacturing firms originating from the UK, France, and Germany, based on data available on the Refinitiv database. Industry 4.0 has represented an interest in manufacturing firms over the last decade, especially in the case of firms originating from well-developed countries (Czvetkó et al. 2021). We expect that our results show that ESG activities significantly influence firms' corporate financial performance. However, Industry 4.0 leads to SDG achievements, such as SDG 9 related to the industry, innovation, and infrastructure, and SDG 12 concerning responsible consumption and production (Mabkhot et al. 2021). Instead, firms' transformation in achieving those SDGs determines indirect positive effects on human capital-related SDGs, such as SDG1, which leads to poverty elimination through better productivity rates and premises for increases in employees' wages, or SDG 3, which generate improvements in employees' health and well-being. Still, getting benefits from ESG efforts is often referred to as trade-offs made, especially on the objectives of SDG 12, which means that cultural factors influencing people's behavior become even more critical.

In Table 1, we define the variables considered in our model. All data are collected from the Refinitiv database. ESG score, CSR strategy, and management score are calculated based on a percentile rank scoring methodology that generates a score between 0 and 100. Overall, the Refinitiv ESG score focuses more on the social pillar. The weights considered for aggregate score calculation for the environmental pillar is 34%, for the social pillar is 42%, and for the governance pillar, only 24% (Refinitiv 2021). However, we do not analyze separate pillars of the ESG score in our analysis, just the overall ESG score. This way, our results are not affected by the choice of a specific database of ESG information, as Lopez et al. (2020) emphasized that generally, aggregate ESG scores are not

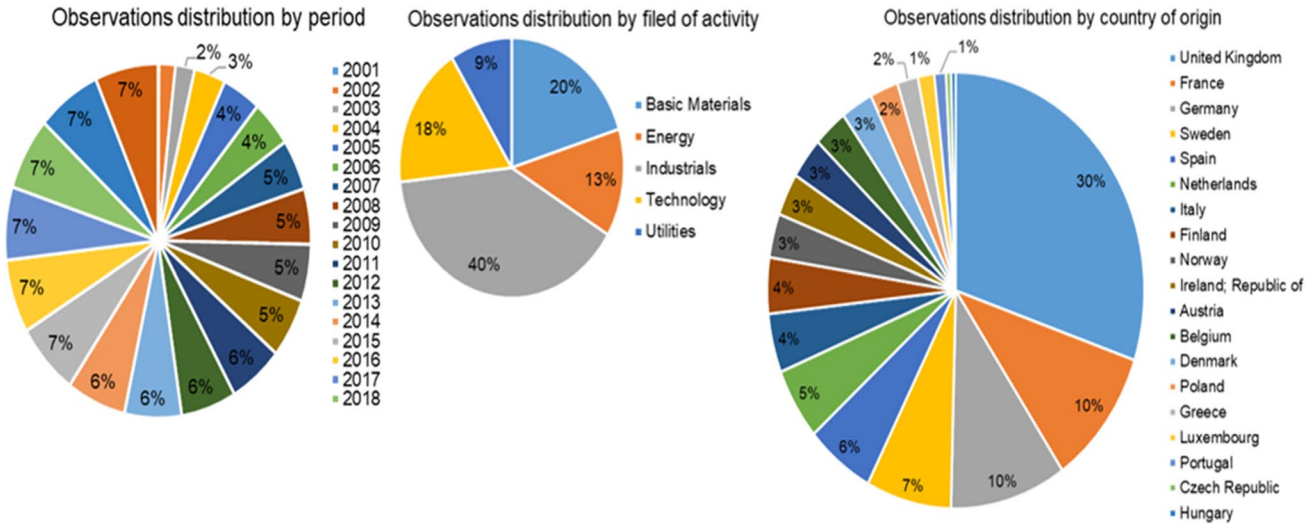

Fig. 1 Sample distribution by different criteria. Source: authors' projection

Table 1 Definition of variables included in the study

Variable		Name	Description
Endogenous variables			
Corporate financial performance **CSP**	Profitability	ROA	It is the return on assets reported by firms at year-end financial reporting;
	Free cash flow	FCF	It is the logarithm of the free cash flow determined as the difference between Net Operating Profit After Taxes (NOPAT) and Net Investment in Operating Capital (NIOC), where $NOPAT = OperatingIncome \bullet (1 - d)$, d is the tax rate, and $OperatingIncome = Grossprofit - Operatingexpenses$;
Corporate sustainability performance **CSP**	ESG score	ESG	It is an aggregate score calculated for each firm yearly by Refinitiv, incorporating numerous aspects of the triple-bottom-line approach, such as environmental (emissions, innovation, resource use), social (community, human rights, product responsibility, workforce), or governance (ESG reporting, governance structures, management compensation, shareholders);
	CSR strategy	CSR	It is an aggregate score calculated for each firm every year by Refinitiv, incorporating various aspects concerning the CSR reporting or strategies in the CSR area designed by firms to obtain corporate social responsibility
Management score		MS	It is a score that looks for management efficiency in implementing firms' strategy and how shareholders offer incentives to managers to motivate them to obtain the optimal level of corporate performance, affecting firms' capitals, respectively financial capital, manufacturing capital, intellectual capital, social capital, human capital, or natural capital
Exogenous variables			
Control variables	Age	A	Number of years since the firm has first been included on the Refinitiv database;
	Size	S	The logarithm of the total assets reported at year-end;
	Business cycle	BC	It is the cash operating cycle used as an alternative proxy for firms' business model cycle, as Dickinson (2011);
	Operating efficiency	OE	It is defined as a percentile rank that reflects the Refinitiv Earnings Quality Model component, which reflects persistence on operating margins reported under optimal asset allocation

Source: authors' projection

influenced by the field of activity or ESG score provider' methodology but rather by market capitalization.

We look as well for CSR impact on corporate financial performance, as an individual component of the sustainable development framework, as it focuses on human capital and social relations within an organization, representing the premises to get benefits from an optimal approach of the knowledge management system and firms' innovation capabilities (Mabkhot et al. 2021).

Management score is included in our analysis to understand the role of management incentives in ensuring firms' sustainable economic development, as motivated managers are more likely to obtain better sustainable economic growth through environmental and social performance (Rezaee 2017).

We consider two measures for corporate financial performance to ensure robustness for our results, as accrual-based firms' profitability differs many times from firms' cash flows. While ROA is considered a critical key performance indicator, firms' free cash flow may be perceived as indicating a realistic self-financing capacity for firms. Additionally, free cash flows represent an essential parameter in the contemporaneous firm valuation models (Damodaran 2007).

Time series analysis and model specification

Earnings sustainable growth represents a current dilemma in the literature, especially from the lens of methodological issues. Those issues have been doubled by the negative effects of earnings management, leading to the deterioration of the value relevance of financial statements over the last decades (Hail 2013; Lev 2018). Monahan (2018) noted that dynamic analysis of corporate financial performance is opportune, bringing insights into the quality of earnings reported. Therefore, we look for a dynamic perspective of earnings evolution by time series analysis considering a panel data approach, where each panel is the firm analyzed.

Panel stationarity testing Testing for stationarity of time series is performed by running a set of panel unit root tests: Levin-Lin-Chu *t*-test, Im-Pesaran-Shin test, ADF-Fisher chi-square test, and PP-Fisher chi-square test. All the methods have a similar principle, representing extensions of the traditional augmented Dickey-Fuller (ADF) unit root test for univariate time series modeling, which was restricted to the assumption of individual cross-sectional independence. Levin-Lin-Chu tested the assumption that all countries in the panel share the same autoregressive coefficient $\alpha_i = \rho - 1$, estimating models below:

$$\Delta CFP_{i,t} = \alpha \bullet CFP_{i,t-1} + \sum_{j=1}^{p_i} \beta_{ij} \bullet \Delta CFP_{i,t-j} + X'_{i,t} \bullet \delta + \mu_i + \theta_t + e_{it}$$

where Δ is the first difference operator of the two measures of corporate financial performance (CFP), $i = 1, \ldots, N$ indicates each firm analyzed, $t = 1, \ldots, T$ indicates the period, p_i is the number of lags, μ_i is the unit-specific fixed effect, while θ_t denotes the time fixed effect and e_{it} is the error terms that follow a stationary invertible autoregressive moving-average process for each unit in the panel but are independently distributed across the panels. If $\rho < 1$, the test confirms that the time series is stationary. Otherwise, the null hypothesis $\rho = 1$ is accepted, showing that each panel has a unit root.

Panel co-integration testing Compared with panel stationarity tests that look for unit root on single time series, co-integration reviews the relationship among a group of variables, each having a unit root (Gujarati 2011). The co-integration test starts from the econometric equation.

$$CFP_{i,t} = \alpha + \sum_{k=1}^{3} \beta_{k,ij} \bullet CSP_{k,i,t} + \mu_i + \theta_t + e_{it}$$

where, by *CSP*, we express the three measures ($k = \overline{1,3}$) concerning sustainability firms' performance, respectively the ESG score, the CSR strategy, and the management score, that follow a stochastic process $CSP_{k,i,t} = CSP_{k,i,t-1} + u_{it}$. Co-integration evaluation involves testing the stationarity of the error term (e_{it}), which translates into the following parametric equation:

$$\hat{e}_{i,t} = \rho \bullet \hat{e}_{i,t-1} + \sum_{j=1}^{p_i} \varnothing_{ij} \bullet \Delta \hat{e}_{i,t-j} + \epsilon_{i,t}$$

If the error term $\hat{e}_{i,t}$ is stationary, endogenous variables analyzed are co-integrated, which means a VAR model is better for our estimation purpose (Pesaran 2015). Instead, suppose the error term is not stationary. In that case, a higher level of co-integration between the analyzed group of endogenous variables asks for unrestricted econometrics models, such as the VECM model in case of endogenous variables with the same order of integration higher than 1 or the ADRL model in case of endogenous variables with different orders of integration.

After all, interpretation of the results supports us in deciding if the model specification has to consider the separation between short-term and long-term variation impact on our corporate financial performance measures. For this purpose, we run the Pedroni panel co-integration battery of tests.

Granger causality test consists of estimating the bivariate regressions of the form below for each possible pair of

variables considered in the analysis, testing for the hypothesis that $\beta_1 = \beta_2 = \beta_3 = \cdots = \beta_l = 0$, for each equation.

$$y_{i,t} = \alpha_0 + \alpha_0 \bullet y_{i,t-1} + \cdots + \alpha_l \bullet y_{i,t-l} + \cdots + \beta_1 \bullet x_{i,t-1} + \cdots + \beta_l \bullet x_{i,t-l} + \varepsilon_{i,t}$$

$$x_{i,t} = \alpha_0 + \alpha_0 \bullet x_{i,t-1} + \cdots + \alpha_l \bullet x_{i,t-l} + \cdots + \beta_1 \bullet y_{i,t-1} + \cdots + \beta_l \bullet y_{i,t-l} + \mu_{i,t}$$

The null hypothesis is that x does not Granger-cause y in the first regression and that y does not Granger-cause x in the second regression. We can reject the null hypothesis if the F statistic is statistically significant, concluding that there is a causality relationship between the two variables but with a clear direction of causality.

This test is essential for our study to provide insights into the direction of causality between the endogenous variables we include in the VAR model to be estimated. There can be bi-directional causality relations or unidirectional causality relations. However, the focus of our paper is on the causality relation between endogenous variables included in the VAR model that shows a significant impact on the CFP measures.

As long as variables included in our analysis are $I(0)$ cointegrated, we estimate a VAR model to review the marginal effect generated by CSP measures on considered CFP measures, looking if there is a positive or negative association. By estimating the VAR model, we overcome the issue of endogeneity in the model specification (Gujarati 2011; Brooks 2019). The $VAR(p)$ process used in our analysis, with a lag of p, can be expressed by the system of relations below:

$$CFP_{i,t} = \alpha + \sum_{j=1}^{p} \beta_j \bullet ESG_{i,t-j} + \sum_{j=1}^{p} \gamma_j \bullet MS_{i,t-j} + \sum_{j=1}^{p} \delta_j \bullet CSR_{i,t-j} + \varepsilon_{i,t}$$

$$ESG_{i,t} = \alpha + \sum_{j=1}^{p} \beta'_j \bullet CFP_{i,t-j} + \sum_{j=1}^{p} \gamma'_j \bullet MS_{i,t-j} + \sum_{j=1}^{p} \delta'_j \bullet CSR_{i,t-j} + \varepsilon'_{i,t}$$

$$CSR_{i,t} = \alpha + \sum_{j=1}^{p} \beta''_j \bullet CFP_{i,t-j} + \sum_{j=1}^{p} \gamma''_j \bullet ESG_{i,t-j} + \sum_{j=1}^{p} \delta''_j \bullet MS_{i,t-j} + \varepsilon''_{i,t}$$

$$MS_{it} = \alpha + \sum_{j=1}^{p} \beta'_j \bullet CFP_{i,t-j} + \sum_{j=1}^{p} \gamma'_j \bullet ESG_{i,t-j} + \sum_{j=1}^{p} \delta'_j \bullet CSR_{i,t-j} + \varepsilon'''_{i,t}$$

where $\varepsilon_{i,t}$, $\varepsilon'_{i,t}$, $\varepsilon''_{i,t}$, and $\varepsilon'''_{i,t}$ denote the stochastic error terms, called innovations. Those innovations are used later for an impulse function analysis to show the effect of changes in the standard deviation of endogenous variables on the other remaining endogenous variables included in the estimated VAR model.

The error terms have to follow a white noise process, known in terms of VAR models as an innovation process, and no autocorrelation between different panel unit residuals, ensuring (i) no dynamic interdependencies, (ii) no static interdependencies, and (iii) no cross-sectional heterogeneities (Schnücker 2016). Therefore, we assess model validation by performing several tests, the autocorrelation LM test and the White heteroscedasticity test, to check for panel errors in autocorrelation and model heteroscedasticity.

Results and discussion

Descriptive statistics

In Table 2, we provide exploratory statistics for the variables used in our study. Looking at the standard deviation, we observed significant heterogeneity in our sample related mainly to ROA and cash cycle, which suggest specific firms' business model particularities. Instead, score-based variables used in the study are more homogenous, most probably because dimensionality reduction purpose of those scores.

Overall, our sample consists of firms with relevant experience in their field of activity (17.14 years) and similar size (22.50). Instead, the cash cycle varies significantly within the sample, with a variation coefficient of approximately 72.59%, highly conditioned by firms' power of negotiation and competitive advantage, with direct implications on firms' cash flow. The return on assets is relatively small, with a mean of 4.70%. However, firms' profitability differs significantly from our sample, with a standard deviation of 13.38%, suggesting significant differences in firms' operation efficiency. Operation efficiency from the perspective of firms' potential to generate cash flows shows a slight variation in our sample, with a coefficient of variation over 41%, which suggests that the variation in ROA is explained by other factors, such as the managerial ability.

Additionally, we observe from Fig. 2 that heterogeneity in our sample related to ROA increases, especially in the period 2014–2018, and reduces slightly during the COVID-19 pandemic, but with an insignificant impact on the overall mean of ROA of our sample. Instead, the evolution is relatively stable in the case of free cash flows, and our sample's heterogeneity is persistent in time. These results indicate that earnings management's measure of profitability is more influenced by cash flow measures, especially through accrual manipulation, as real activity-based earnings management would have affected FCF, not only ROA.

The managerial ability we use in this study shows firms' management teams' modest competencies and abilities to draw up and implement firms' strategies. The mean of 54.2 scores represents only approximately 54.2% of the maximum theoretical value of 100. Similar moderate values are valid for the measures of CSR strategy (47.50) and ESG score (52.39). Instead, those values suggest that firms have understood how important it is to follow the approach of a sustainable economic growth approach. Even there is a small difference between the mean score of CSR strategy and ESG

Table 2 Descriptive statistics

Statistics		ROA	FCF	ESG	Mng	CSR	Size	Eff	Cycle	Age
Sample size		6291	6291	6291	6088	6088	6291	6070	6223	6291
Mean		4.70%	5.498	52.39	54.20	47.50	22.50	57.04	185.7	17.14
Median		4.38%	17.77	53.87	55.61	50.00	22.50	58.00	61.57	17.00
Std. Deviation		13.83%	18.20	20.38	27.81	32.55	1.60	23.43	134.8	9.214
Percentiles	25	1.71%	−18.10	36.84	31.43	16.67	21.43	41.00	14.23	10.00
	50	4.38%	17.77	53.87	55.61	50.00	22.50	58.00	61.57	17.00
	75	7.68%	19.39	68.74	78.20	76.34	23.54	76.00	112.43	24.00
Normality	Stat	21.28%	0.339	0.049	0.065	0.091	0.012	0.059	0.5	0.043
	Sig	0.000[c]	0.000[c]	0.000[c]	0.000[c]	0.000[c]	0.041[c]	0.000[c]	0.000[c]	0.000[c]
Collinearity	VIF	-		3.343	1.391	2.270	1.591	1.012	1.001	1.116

[a]Multiple modes exist. The smallest value is shown

[b]Test distribution is normal, calculated from data

[c]Lilliefors significance correction

Source: author's calculation

score, corroborated with a higher coefficient of variation in the case of CSR strategy $\left(CSR_{var.coef.} = \frac{32.55}{47.5} \approx 68.53\% > ESG_{var.coef} = \frac{20.38}{52.39} \approx 38.90\%\right)$ and 1st quartile of those variables $(CSR_{25thperc.} = 16.67 < ESG_{25thperc.} = 36.84)$, we appreciate that firms run ESG activities without a mature approach based on a robust CSR strategy which may translate into less cost-effective ESG operations and lower net benefits of ESG efforts for the firms. Overall, ESG activities are perceived as a source of explicit costs for the firms, with low awareness of the implicit potential positive effects on firms' performance long-term.

The representation in Fig. 2 of variables included in the study shows that they evolve slightly similar, suggesting a relation of long-term co-integration. In Table 2, we provided results of collinearity tests as well. The results show there is no collinearity issue, as the VIF does not exceed the threshold of 10 (Gujarati 2011).

Correlation analysis

Table 3 provides the associations between variables included in our study. The results show significant correlations only between firm size, ESG score, CSR strategy score, and managerial ability score. Instead, financial performance measures of profitability and FCF are less associated with CSR and ESG measures. Additionally, we observe a small

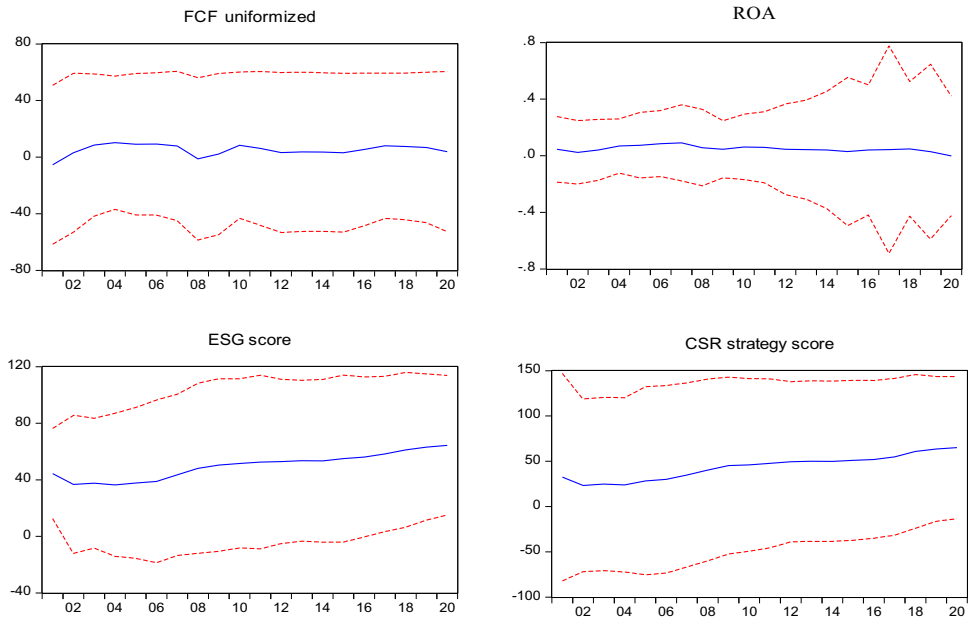

Fig. 2 Evolution in time. Source: author's calculation

Table 3 Correlation matrix

	ROA	ESG	Size	FCF	Mng	CSR	Eff	Age	Cycle
ROA	1								
ESG score	−0.040**	1							
Size	−0.077**	0.575**	1						
FCF	0.292**	−0.011	−0.044**	1					
Management	0.035**	0.510**	0.218**	0.007	1				
CSR strategy	−0.071**	0.739**	0.476**	−0.056**	0.304**	1			
Efficiency	0.194**	−0.005	−0.083**	0.125**	0.025	0.003	1		
Age	−0.079**	0.247**	0.028*	0.065**	0.089**	0.232**	0.054**	1	
Cash cycle	−0.194**	−0.025*	−0.017	−0.004	−0.016	−0.020	−0.009	0.004	1

*Significant at the 0.05 level (2-tailed); **significant at the 0.01 level (2-tailed)

Source: author's calculation

association between ROA and FCF, which confirms that the cash flow measure is less affected by earnings management. At the same time, ROA is highly conditioned by the discretionary decisions of management concerning firms' accounting and financial reporting policies.

Results indicate that sustainable economic development is highly influenced by firm size (0.575) and significantly conditioned by the existence of a CSR strategy (0.739) and a capable management team (0.510). Sustainable economic development does not resume only to isolated ESG projects, or compliance with minimum legal requirements, as it has to be understood beyond those boundaries, such as the design of innovative vision, objectives, and strategies, the creation of concise, clearly defined, and coherent policies, or proper monitoring and control tools. Otherwise, the efforts will translate just in period expenses, negatively impacting firms' future financial performance (−0.40) or even corporate sustainability performance. This approach is influenced by firms' business model (−0.025), firms' experience (0.247), and firms' potential to finance such ESG projects (0.575), the reason why higher focus on ESG activities is confirmed in the case of firms of larger size (Christensen et al. 2021).

Stationarity of time series

In Table 4, we provide panel stationarity test results. As shown in Fig. 2, there is not a significant trend component in the evolution of our endogenous variables, the reason why we consider not looking for individual intercept only. Based on the results, all tests performed are statistically significant, indicating our endogenous variables are stationary on their levels. Therefore, relevant for our regression analysis are the levels of our endogenous variables.

Panel co-integration testing

The choice of VAR or VECM model to assess the link between corporate financial performance and corporate sustainability performance depends on the co-integration between our endogenous variables. Therefore, the next step for our analysis consists of testing for co-integration. Results are provided in Table 5 for both measures of corporate financial performance, respectively, the ROA and FCF variables.

As the results obtained show most of the tests are statistically significant, we conclude that there is a long-term relationship between the measures of corporate financial performance and the scores reflecting corporate ESG performance (Aljandali and Tatahi 2018). In the case of firms' profitability, seven of the eleven tests performed are statistically significant for a significance level of 5%. In comparison, in the case of firms' potential to generate cash flow for self-financing (FCF), eight tests performed are statistically significant.

Therefore, there is a co-integration relationship between corporate financial performance metrics and corporate sustainability performance scores. However, variables considered in our analysis are of $I(0)$ order of integration, with no significant trend component emphasis, the reason why we consider proper a VAR model estimation (Pesaran 2015), a model which looks only for long-term effects, without incorporation of short-term effects as well.

VAR model estimation

Table 6 provides a battery of tests performed to validate estimated VAR models. The Lagrange multiplier test indicates there is no autocorrelation of residuals on the models, as the p value of each model estimates exceeds the significance level of 5%, which rejects the null hypothesis autocorrelation of residuals (Aljandali and Tatahi 2018).

The results also show joint normality Jarque–Bera test results that are statistically significant, which indicates that the variables are not multivariate normally distributed. Similar results are obtained for assessing model heteroscedasticity, as White test statistics are statistically significant with a significance level of 1%. Regression coefficients are not affected

Table 4 Unit root test results

Method	ROA	FCF	ESG score	Management	CSR strategy
	Individual intercept				
	Statistic				
Levin, Lin, and Chu *t*	−11.24*	−134.0*	−16.06*	−16.30*	−31.55*
Im, Pesaran, and Shin W-stat	−8.431*	−26.92*	−4.490*	−8.395*	−6.468*
ADF-Fisher chi-square	1277.0*	2312.6*	1198.1*	1142.5*	1190.4*
PP-Fisher chi-square	1880.6*	2708.7*	1593.1*	1580.3*	1745.8*

*Rejection of the null hypothesis of the existence of a unit root at a 1% significance level

Source: author's calculation

in the presence of heteroscedasticity. We estimate the model using the White-Huber standard error regression procedure to correct this estimation bias to ensure efficient regression coefficient estimates concerning standard errors. Additionally, we highlight that estimated VAR models are stable, as there is not any root of the related polynomial that exceeds the absolute value (Aljandali and Tatahi 2018). Model stability emphasizes that estimated coefficients are relevant from the long-term analysis perspective and shows that estimated VAR models can also be used for forecasting purposes.

In Table 6, we summarize the results of the VAR estimated model, resuming the information provided only to the OLS equations describing the effect on corporate financial performance if the other endogenous variables are considered in model estimation.

The optimal lag of the VAR model was chosen based on the Schwartz criterion as it was lower than the Akaike information criterion (Aljandali and Tatahi 2018). Based on the Schwartz criterion, we have considered a lag of two for all VAR models estimated and presented in Table 6.

Table 5 Panel co-integration test results

Test	*Statistic*		*Weighted statistic -*	
	ROA model	*FCF model*	*ROA model*	*FCF model*
Alternative hypothesis: common AR coefs. (within-dimension)				
Panel v-statistic	3.970*	−2.042	−5.903*	−8.839
Panel rho-statistic	2.648	−2.128*	−0.252*	−1.856*
Panel PP-statistic	−21.93*	−29.26*	−22.28	−32.41*
Panel ADF-statistic	−3.352*	−12.35*	−11.22	−16.44*
Alternative hypothesis: individual AR coefs. (between-dimension)				
	Statistic			
	ROA model	*FCF model*		
Group rho-statistic	8.887	7.354		
Group PP-statistic	−26.49*	−46.42*		
Group ADF-statistic	−7.134*	−13.88*		

*Rejection of the null hypothesis of no co-integration at 5% significance level

Source: author's calculation

Table 6 VAR model validation

Model validation			*ROA model*	*FCF model*
Residuals diagnostic	Joint normality test	JB test	9246.8	3213.5
		p value	0.000	0.000
	Autocorrelation test	LM-Stat	18.14	15.02
		p value	0.316	0.523
	White heteroscedasticity test	Chi-sq	7506.3	1661.7
		p value	0.000	0.000
Model stability	The root of characteristics polynomial-maximal modulus		0.936	0.933

Source: author's calculation

Models incorporated on the VAR estimated model are statistically significant. The p value of each F test performed for the OLS estimated models does not exceed the significance level of 1%. Also, the individual estimated OLS models we have presented in Table 6 have the adjusted R^2 varying between 22.7%, in model 4, and 60.2% in model 2.

Adjusted R^2 illustrates higher value relevance of ESG- and CSR-related scores for free cash flow forecasting, compared with the ROA, as $R^2_{model1} = 43.5\%$ is significantly lower than $R^2_{model3} = 57.6\%$. Those results show the negative perspective on the efforts firms make for sustainable economic development, as ESG activities are mainly seen as expenses without immediate benefits for the firms, with a direct impact on firms' cash flow and lower effect moderated by earnings management on ROA.

Instead, the situation changes when controlling the results for firms' characteristics, as $R^2_{model2} = 60.2\%$ is significantly higher than $R^2_{model4} = 22.7\%$; the results suggest that firms' operation efficiency, business model complexity, or experience in the industry are more relevant. This statement is also confirmed by the higher absolute value of estimated coefficients related to control variables than the coefficients corresponding to corporate sustainability performance measures.

Results presented in Table 7 emphasize the persistence (predictability) of ROA when controlling for one lag ($Coef. = 0.427, Sig. < 0.01$) and two lags ($Coef. = 0.341, Sig. < 0.01$) as well. Those results indicate significant effects of earnings management, showing managers smooth reported earnings. Similar results are identified in the case of FCF when controlling for one lag ($Coef. = 0.401, Sig. < 0.01$) and two lags ($Coef. = 0.389, Sig. < 0.01$) as well. As the correlation between ROA and FCF is only 0.292, those results indicate managers prefer accrual-based earnings management, as cash flow persistence is less related to structural concerns about firms' operations and more related to reported profitability.

All four models incorporated into the estimated VAR model present a significant marginal effect of ESG score on ROA and FCF. However, the effect differs based on the lag considered in the model. The ESG score reported for the prior year negatively affects both corporate financial performance measures considered in our study. In contrast, the ESG score reported 2 years prior generates positive effects on firms' financial performance. In the case of model 1 and model 2, the ESG factor effect is compensated for 2 years, showing a cumulative neutral effect on firms' profitability. Our results are similar to Chen et al. (2021), who have again underlined that in the short run, the costs of ESG activities are to be compensated by the future benefits. From a long-term perspective, it is expected that net positive effects are generated by higher firms' corporate ESG responsibility (Friede et al. 2015; Lu and Taylor 2016; Vishwanathan et al. 2020).

Instead, the situation is slightly different based on results from model 3 and model 4 estimation, as the cumulated effect of the ESG factor over a period of 2 years leads to a slight positive impact. Therefore, FCF is significantly positively affected by ESG score both in the case of model 3 ($Coef_{lag1} = -0.0768, Sig. < 0.01$, lower in absolute value than $Coef_{lag2} = 0.1071, Sig. < 0.01$) and model 4 ($Coef_{lag1} = -0.0613, Sig. < 0.01$, lower in absolute value than $Coef_{lag2} = 0.1016, Sig. < 0.01$). Chen et al. (2021) suggested that the impact of ESG-related project costs is observed on the next year's level of firm reported free cash flow, while positive effects of those costs are observed only 2 years later, as the value creation generated through lean managements, cost improvements initiatives, productivity increase, employees' motivation, or even reputational benefits are potential on short term. Those latent gains can be valorized from a longer perspective, and once they are confirmed, they affect firms' cash flow. The state has an essential role in this equation, as regulatory and legal interventions configure the basis of assumptions managers work with concerning possible non-compliance costs. Investors also have an essential place in this framework, as they negatively perceive any potential non-compliance costs and increase the pressure on managers raising awareness on managers' side about possible future litigation costs generated by commitments on ESG objectives not met. Therefore, based on those results, we can confirm our second hypothesis *H2: ESG score determines significant changes in firms' financial performance in the context of environmental change concerns*.

Results also show a significant effect of CSR strategy score on corporate financial performance along the models incorporated into the estimated VAR model. However, marginal effects generated by CSR strategy score are statistically significant only for 1-year lag, with a lower impact on ROA ($Coef_{lag1} = -0.0001, Sig. < 0.01$), compared with the marginal effect on the free cash flow reported ($Coef_{lag1} = -0.025, Sig. < 0.01$). The marginal effect is lower than the one generated by the ESG score. Therefore, sustainable strategies determine a short-term negative effect on firms' financial performance. A clear corporate social responsibility strategy disclosed by sustainability reports gives shareholders and stakeholders an indication of what efforts the firm should make to enhance its reputation, improve communication with its stakeholders, improve risk management, or strengthen firms' innovation capabilities (Vishwanathan et al. 2020). The negative results show that investment in human capital, process improvements, and innovation capabilities significantly affect corporate financial performance, especially the free cash flow component of investments in operations. The transition to a sustainable economic growth model represents an essential objective nowadays for firms. However, it asks for significant costs

Table 7 VAR model validation

Variable	Model	Lag	*ROA*		*FCF*	
			(1)	(2)	(3)	(4)
Endogenous variables	*ROA*	1	0.427*	0.4742*	-	-
			(0.014)	(0.014)		
		2	0.341*	0.341*		
			(0.015)	(0.015)		
	FCF	1	-	-	0.4008*	0.3894*
					(0.014)	(0.014)
		2			0.1293*	0.1197*
					(0.014)	(0.014)
	ESG score	1	−0.0006*	−0.0003***	−0.0768*	−0.0613*
			(0.0003)	(0.0002)	(0.0390)	(0.0398)
		2	0.0006*	0.0003***	0.1071*	0.1016*
			(0.0003)	(0.0002)	(0.0385)	(0.0390)
	Management score	1	0.0001	0.0000	0.0185	0.0153
			(0.0001)	(0.0001)	(0.0147)	(0.0148)
		2	−0.0001	0.0000	−0.0303*	−0.0302**
			(0.0001)	(0.0001)	(0.015)	(0.0146)
	CSR score	1	−0.0001*	−0.0001*	−0.025***	−0.027**
			(0.0001)	(0.0001)	(0.017)	(0.0172)
		2	0.0000	0.0000	−0.0033	−0.0005
			(0.0001)	(0.0001)	(0.0169)	(0.0170)
Exogenous variables	*Constant*		0.0115*	0.0291	2.9214*	8.2259**
			(0.005)	(0.019)	(0.681)	(3.950)
	Age		-	−0.0003**	-	0.0943*
				(0.0001)		(0.027)
	Size			−0.0014***		−0.447**
				(0.001)		(0.182)
	Business cycle			0.000		0.000
				(0.000)		(0.000)
	Operating efficiency			0.0003*		0.0493*
				(0.000)		(0.010)
Model validation	Adj. *R*-squared		0.435	0.602	0.576	0.227
	F statistic		509.4*	650.6*	899.0*	127.0*
	Akaike information criterion		−1.599	−2.290	8.609	8.399
	Schwarz criterion		−1.588	−2.273	8.621	8.416

*1% significance level; **5% significance level; ***10% significance level

Source: author's calculation

instead, especially because of the need to integrate economic, social, and environmental dimensions of the business operations, leading to synergy effects in time. These costs affect corporate financial performance in the short run, especially in the case of firms starting this transition recently. Instead, this effect is insignificant in the medium and long term because of the heterogeneity in practice related to strategic business behavior. Wang et al. (2016) and Boukattaya et al. (2021) stated that the impact of ESG activities on corporate financial performance plays a moderating role. It is highly affected by industry-specific regulatory frameworks and stakeholders' demands concerning firms' social responsibility. If some firms perform ESG activities only based on legal or industry-specific requirements, the costs of implementing sustainability projects will represent short-term costs. Instead, suppose firms adjust their strategies to target long-term benefits from ESG projects by adjusting processes, training people, and implementing supporting systems and controls to monitor clear KPIs addressing ESG strategic objectives. In that case, the outcome is expected to be positive (Friede et al. 2015). Therefore, based on those results, we can confirm that our first hypothesis *H1: CSR*

strategies determine significant changes in a firm's performance is partially confirmed.

Robustness analysis

While firm size is used as a proxy for business model complexity, firm age is used as a proxy for a firm's experience accumulated over time in the area of activity. In model 2 and model 3, we observe a significant negative effect on corporate financial performance metrics generated by the firm size and age. Additionally, we observe that the score of firms' operation efficiency impacts positively corporate financial performance. Those results indicate that the learning curve has already reached the phase of unconscious competence, described by mastery competence, but unconscious awareness of the competencies assimilated. In those circumstances, there is a small room for improvements on firms' processes as firms and employees as well are not able to adjust to the dynamic complexity in the organization because of the lack of a system thinking practices which promote initiative among the employees and generate opportunities for process improvements (Zgrzywa-Ziemak and Walecka-Jankowska 2020). Another explanation could be the higher compensation of experienced employees but lower financial performance improvements than the increase in employees' compensations.

Causality analysis

Results in Table 7 show the association between corporate financial performance metrics and corporate sustainability performance measures. However, those results do not indicate the direction of those associations if the associations are unidirectional or bidirectional. According to the results in Table 7, we observe that the only bidirectional associations appear between ROA and ESG score, respectively between FCF and CSR strategy score, considering a lag of two. We estimate Granger causality models considering different lag scenarios to properly control the effect of lags considered on the causality models (see Table 8).

Figure 3 represents Granger causality relations through a causality loop diagram to better understand the results obtained. As noted, in representation in Fig. 3, we observe only unidirectional significant causality between corporate financial performance and management score. Those results indicate that higher managerial ability is not a moderating factor for higher firms' profitability. Based on those results, we appreciate that managers may decide on approving ESG and CSR activities, mainly driven by minimum legal requirements and guidance provided on the industry level by professional associations. However, the results show a unidirectional causality between managerial ability and firms' cash flow. Considering a lag of 3 periods in the analysis, the results ($Coef. = -0.0303, Fstat. = 2.679, Sig. < 1\%$) show that higher managerial ability leads to lower free cash flow, which is expected considering the impact of costs related to ESG activities. After all, the ESG activities are expected to positively impact the firm's value only in the long term, as investors and stakeholders' perceptions (trust) are essential to understanding firms' behavior and real intentions related to its sustainability vision (Wang et al. 2016). Therefore, based on those results, we can confirm our first hypothesis *H3: Managers' ability to cope with environmental, social and governance issues determines significant changes in firms' financial performance.* The managers are the ones that decide on firms' strategy, objectives, and how they are to be controlled and monitored. As long there are not robust and mature corporate governance mechanisms in place, serious difficulties can appear in the execution and monitoring stages of the implementation process. Also, managers without motivation are not expected to commit to the efforts of transition to a sustainable economic growth model agreed by shareholders and stakeholders. This is why both managers' abilities and governance supporting processes are essential, which leads to costs of managers' incentivization and costs of compliance with the regulatory framework and internal corporate governance mechanisms.

Instead, the results in Table 8 emphasize how vital are the positive effects determined by ESG efforts for management to decide to increase their attention and allocate additional resources for better results on sustainable corporate performance. An increase in ESG score determines a decrease in the firm's profitability due to costs incurred for implementing mentation of planned ESG projects ($Coef. = -0.0006, Fstat. = 4.135, Sig. < 1\%$). Instead, higher profitability determines an increase in the ESG

Table 8 Granger causality *F* statistics

Relation	No. of lags	*Lag = 1*	*Lag = 2*	*Lag = 3*
ROA < – ESG	*F* statistic	12.13*	4.135**	1.960
ESG < – ROA	*F* statistic	7.35*	6.537*	4.844*
ROA < – MS	*F* statistic	0.127	0.051	0.129
MS < – ROA	*F* statistic	6.727*	3.787**	2.255
ROA < – CSR	*F* statistic	16.00*	4.220**	1.766
CSR < – ROA	*F* statistic	0.739	2.949	2.805**
FCF < – ESG	*F* statistic	2.345	2.003	1.331
ESG < – FCF	*F* statistic	4.207**	5.998*	4.559*
FCF < – MS	*F* statistic	1.097	0.836	2.679**
MS < – FCF	*F* statistic	4.256	1.788	1.429
FCF < – CSR	*F* statistic	10.62*	3.599**	1.993
CSR < – FCF	*F* statistic	0.455	2.549**	1.842

*1% significance level; **5% significance level

Source: author's calculation

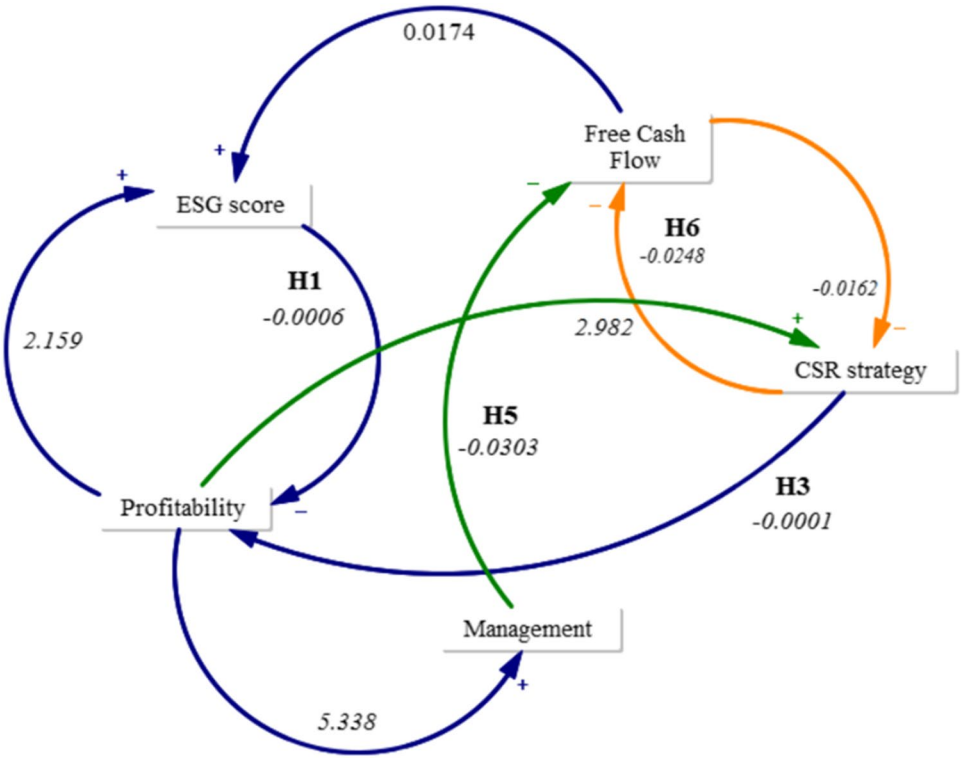

Fig. 3 Causal loop diagram. Legend: blue (lag = 1), green (lag = 2), orange (lag = 3). Note: coefficient from the figure represents the regression coefficient from Table 7. Source: author's projection

score, which might be caused by a higher awareness of the potential benefits of firms' sustainable economic growth ($Coef. = 2.159, Fstat. = 6.537, Sig. < 1\%$).

Moreover, these results indirectly show the increasing role of the human factor in the equation of firms' sustainable economic development. Higher commitment to social and environmental concerns in society increases stakeholders' trust. It leads to higher employee motivation, directly affecting business operations profitability and indirectly affecting firms' innovation capabilities, including digitalization and business process improvements. Therefore, the moderating effect of ESG strategic thinking is highly conditioned by firms' capacity to finance ESG activities, as long as business operation efficiency is positive (Wang et al. 2016; Vishwanathan et al. 2020). ESG strategy and project initiatives are the basis for higher productivity, technological progress and innovation, continuous improvements and processes redesign, or simply optimal knowledge management (Kordab et al. 2020). The impact is higher on the cash flow measure, as employees' motivation and costs with innovation impact directly firms' cash flow. Firms' profitability is not statistically influenced by this component, as a measurement of the return on human capital investments encountered along the time numerous controversies. There is no separate account on the financial statements that report the costs and benefits of CSR projects and current CSR activities.

Between FCF and ESG scores, there is only a unidirectional Granger causality relation, which shows that ESG corporate performance is highly conditioned by the level of resources affected for this purpose, directly impacting firms' cash flow ($Coef. = 2.159, Fstat. = 6.537, Sig. < 1\%$). ESG does not Granger-cause FCF, as benefits from ESG project implementation do not translate into cash inflows but better operation efficiency and improved cost structure, with only an indirect effect on firms' cash flows.

Related to the bidirectional relation between FCF and CSR strategy score, we appreciate that the cause of the negative causality reciprocal relation is determined by management preferences to motivate firms' employees rather with non-cash compensation packages. Also, a productivity improvement can be generated through process improvement and redesign, reducing employee workload or higher satisfaction on the job.

Impulse analysis

Figure 4 represents the impact of shocks on corporate financial performance metrics, expressed through the VAR models' residuals determined. Overall, we observe that impact of earnings management is visible, especially within 4 years, which generally coincide with a full mandate for the CEO and the board of directors.

Instead, shocks of ESG score impact both firms' profitability and free cash flow which are visible in a later period

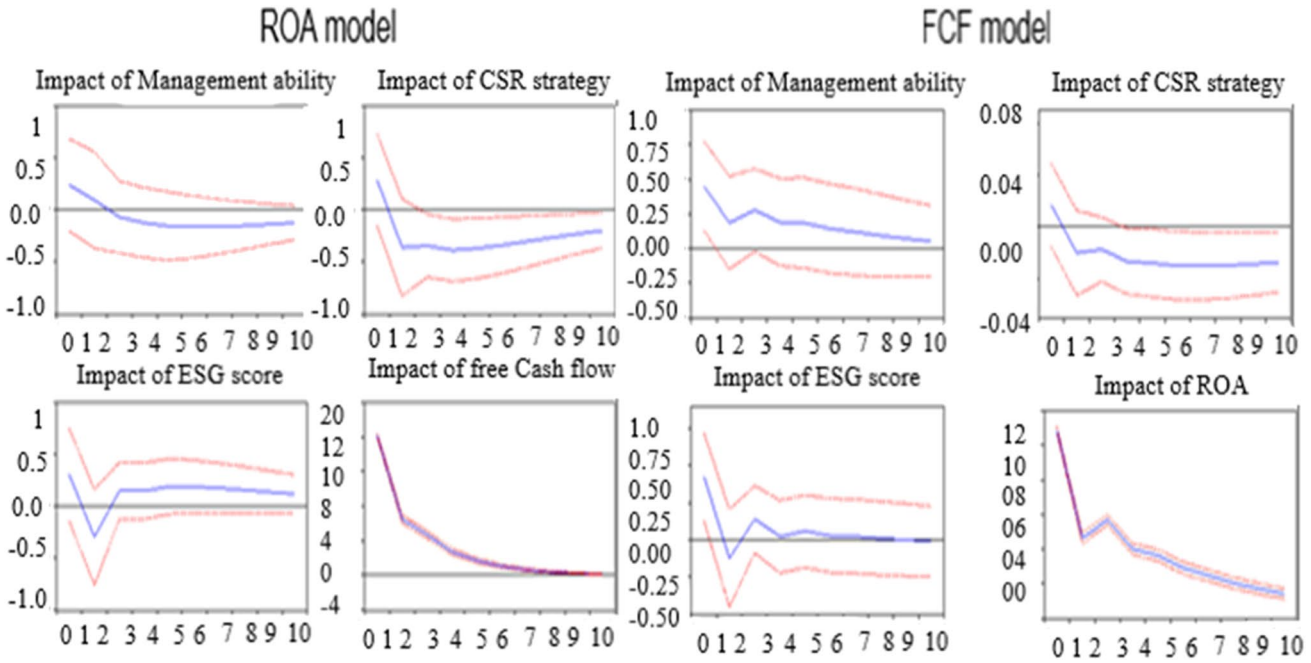

Fig. 4 VAR models' impulse representation. Source: author's calculation

with a lag of 1–2 years, while shocks on CSR strategy score impact the same measures in a later period with a lag of 2–3 years. Generally, social projects and governance improvement initiatives do not take that long time; the reason why we appreciate either firm focus less on environmental projects or they allocate resources for projects that mainly look for compliance with minimum regulatory requirements or investors' expectations and which are estimated with low financial impact for the firms.

Conclusion

This paper discussed the impact of ESG/CSR practices on the financial performance of 422 analyzed firms from the EU, looking for long-term causality. Overall, our study shows that ESG corporate performance is highly conditioned by the level of resources allocated for this purpose, directly impacting firms' cash flow and characteristics, such as industry-specific, managerial ability, investment, and financing strategy. Through empirical analysis, our paper reveals that firms run ESG activities without a mature approach based on a robust CSR strategy, which may translate into less cost-effective ESG operations and lower net benefits of ESG efforts for the firms.

Further research on this topic is planned for the future. First, it would be useful to identify differences in the link between corporate ESG performance and corporate financial performance for developing countries and highly developed ones to see if regulatory and economic externalities act as mediators or moderators between the two constructs. Additionally, an investigation of the evolution of the link between the two constructs along the business model lifecycle would be revealing, as additional expenses accrued by ESG activities are expected to be less likely in the premature stages of a business. Overall, there is a need for a better analysis on the impact of industry-specific aspects on the link between the constructs explored in this paper, especially on the areas that are highly exposed to environmental and social controversies. The focus should be on the redesign of the existing balanced-scorecard solution, by integrating relevant key performance indicators that better reflect the link between financial performance and firms' sustainable development.

Author contribution Conceptualization: Larisa Ivascu, Aura Domil, and Muddassar Sarfraz; methodology: Oana Bogdan, Valentin Burca; formal analysis and investigation: Muddassar Sarfraz and Valentin Burca; writing—original draft preparation: Codruta Pavel, Larisa Ivascu; writing—review and editing: Aura Domil and Muddassar Sarfraz; funding acquisition: Muddassar Sarfraz; resources: Oana Bogdan; supervision: Larisa Ivascu and Aura Domil. All authors approved the current study.

Data availability The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate All procedures performed were in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standard.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

References

Abdullah MI, Sarfraz M, Qun W, Javaid N (2018) Drivers of green supply chain management. LogForum 14:437–447

Ajaz A, Shenbei Z, Sarfraz M (2020) Delineating the influence of boardroom gender diversity on corporate social responsibility, financial performance, and reputation. Logforum 16:61–74

Aljandali A, Tatahi M (2018) Economic and financial modelling with Eviews. Springer Int Publ, Berlin. https://doi.org/10.1007/978-3-319-92985-9

Alshehhi A, Nobanee H, Khare N (2018) The impact of sustainability practices on corporate financial performance: literature trends and future research potential. Sustainability 10:494

Amel-Zadeh A, Serafeim G (2018) Why and how investors use ESG information: evidence from a global survey. Financ Anal J 74:87–103

Atz U, Liu ZZ, Bruno C, Van Holt T (2021) Atz, Ulrich and Liu, Zongyuan Zoe and Bruno, Christopher and Van Holt, Tracy, Online Appendix: Does Sustainability Generate Better Financial Performance? Review, Meta-analysis, and Propositions (August 31, 2021). Available at SSRN, https://doi.org/10.2139/ssrn.3919652

Babasanya AO, Oseni IO, Awode SS (2018) Human capital development: A catalyst for achieving SDGs in Nigeria. Acta Universitatis Danubius. Oeconomica 14:25–41

Bergmann A (2016) The link between corporate environmental and corporate financial performance—viewpoints from practice and research. Sustainability 8:1219

Bocquet R, Le Bas C, Mothe C, Poussing N (2017) CSR, innovation, and firm performance in sluggish growth contexts: a firm-level empirical analysis. J Bus Ethics 146:241–254

Boukattaya S, Achour Z, Hlioui Z (2021) Corporate social responsibility and corporate financial performance: an empirical literature review. Int J Innov Res Publ 35:291–311

Brooks C (2019) STATA guide for introductory econometrics for finance. Cambridge University Press

Buallay A, Fadel SM, Alajmi J, Saudagaran S (2020) Sustainability reporting and bank performance after financial crisis: evidence from developed and developing countries. Compet Rev An Int Bus J 31:747–770

Cek K, Eyupoglu S (2020) Does environmental, social and governance performance influence economic performance? J Bus Econ Manag 21:1165–1184

Chen L, Yuan T, Cebula RJ et al (2021) Fulfillment of ESG responsibilities and firm performance: a zero-sum game or mutually beneficial. Sustainability 13:10954

Cheng B, Ioannou I, Serafeim G (2014) Corporate social responsibility and access to finance. Strateg Manag J 35:1–23

Christensen HB, Hail L, Leuz C (2021) Mandatory CSR and sustainability reporting: economic analysis and literature review. Rev Account Stud 26:1176–1248

Czvetkó T, Honti G, Abonyi J (2021) Regional development potentials of Industry 4.0: open data indicators of the Industry 4.0+ model. PLoS One 16:e0250247

Damodaran A (2007) Valuation approaches and metrics: a survey of the theory and evidence. Foundations and Trends in Finance 1:693–784

Dickinson V (2011) Cash flow patterns as a proxy for firm life cycle. The accounting review, Chicago 86(6):1969–1994

Duque-Grisales E, Aguilera-Caracuel J (2021) Environmental, social and governance (ESG) scores and financial performance of multilatinas: moderating effects of geographic international diversification and financial slack. J Bus Ethics 168:315–334

Friede G, Busch T, Bassen A (2015) ESG and financial performance: aggregated evidence from more than 2000 empirical studies. J Sustain Financ Invest 5:210–233

Garcia AS, Mendes-Da-Silva W, Orsato RJ (2017) Sensitive industries produce better ESG performance: evidence from emerging markets. J Clean Prod 150:135–147

Gillan SL, Koch A, Starks LT (2021) Firms and social responsibility: a review of ESG and CSR research in corporate finance. J Corp Financ 66:101889

Goyal P, Rahman Z, Kazmi AA (2013) Corporate sustainability performance and firm performance research: literature review and future research agenda. Manag Decis 51:361–379

Grewatsch S, Kleindienst I (2017) When does it pay to be good? Moderators and mediators in the corporate sustainability–corporate financial performance relationship: a critical review. J Bus Ethics 145:383–416

Gujarati DN (2011) Econometrics by example. Palgrave Macmillan New York USA

Hail L (2013) Financial reporting and firm valuation: relevance lost or relevance regained? Account Bus Res 43:329–358

Huang DZX (2021) Environmental, social and governance (ESG) activity and firm performance: a review and consolidation. Account Financ 61:335–360

Khaled R, Ali H, Mohamed EKA (2021) The Sustainable Development Goals and corporate sustainability performance: mapping, extent and determinants. J Clean Prod 311:127599

Kim E-H, Lyon TP (2015) Greenwash vs. brownwash: exaggeration and undue modesty in corporate sustainability disclosure. Organ Sci 26:705–723

Kordab M, Raudeliūnienė J, Meidutė-Kavaliauskienė I (2020) Mediating role of knowledge management in the relationship between organizational learning and sustainable organizational performance. Sustainability 12:10061

Kumar PC (2020). ESG compliant companies provide superior returns. https://www.thestar.com.my/business/business-news/2020/02/29/esg-compliant-companies-provide-superior-returns. Accessed 20 Nov 2021

Lev B (2018) The deteriorating usefulness of financial report information and how to reverse it. Account Bus Res 48:465–493

Lopez C, Contreras O, Bendix J (2020) ESG Ratings: The Road Ahead (October 6, 2020). Available at SSRN. https://doi.org/10.2139/ssrn.3706440

Lu W, Taylor ME (2016) Which factors moderate the relationship between sustainability performance and financial performance? A meta-analysis study. J Int Account Res 15:1–15

Mabkhot MM, Ferreira P, Maffei A et al (2021) Mapping industry 4.0 enabling technologies into united nations sustainability development goals. Sustainability 13:2560

Masulis RW, Reza SW (2014) Agency problems of corporate philanthropy. Rev Financ Stud 28:592–636

Maury B (2022) Strategic CSR and firm performance: the role of prospector and growth strategies. J Econ Bus 118:106031

Monahan SJ (2018) Financial statement analysis and earnings forecasting. Found Trends® Account 12:105–215

Naseem S, Mohsin M, Zia-UR-Rehman M et al (2021) The influence of energy consumption and economic growth on environmental degradation in BRICS countries: an application of the ARDL model and decoupling index. Environ Sci Pollut Res 29:13042–13055

Pan D, Fan W (2021) Benefits of environmental information disclosure in managing water pollution: evidence from a quasi-natural experiment in China. Environ Sci Pollut Res 28:14764–14781

Pesaran MH (2015) Time series and panel data econometrics. Oxford University Press

PwC (2021) Paying well by paying for good. https://www.pwc.co.uk/services/human-resource-services/insights/environmental-social-governance-exec-pay-report.html. Accessed 25 Nov 2021

Refinitiv (2021) Environmental, social and governance scores from Refinitiv. https://www.refinitiv.com/content/dam/marketing/en_us/documents/methodology/refinitiv-esg-scores-methodology.pdf. Accessed 10 Jan 2022

Rezaee Z (2017) Corporate sustainability: Theoretical and integrated strategic imperative and pragmatic approach. J Bus Inq 16:1–28

Rossi M, Chouaibi J, Chouaibi S et al (2021) Does a board characteristic moderate the relationship between CSR practices and financial performance? Evidence from European ESG firms. J Risk Financ Manag 14:354

Ruokonen E, Temmes A (2019) The approaches of strategic environmental management used by mining companies in Finland. J Clean Prod 210:466–476

Sarfraz M, Shah SGM, Ivascu L, Qureshi MAA (2020b) Explicating the impact of hierarchical CEO succession on small-medium enterprises' performance and cash holdings. Int J Financ Econ. https://doi.org/10.1002/ijfe.2289

Sarfraz M, Ozturk I, Shah SGM, Maqbool A (2020a) Contemplating the impact of the moderators agency cost and number of supervisors on corporate sustainability under the aegis of a cognitive CEO. Front Psychol 11:1

Schnücker A (2016) Restrictions search for panel VARs . DIW Berlin Discussion Paper No. 1612, Available at SSRN. https://doi.org/10.2139/ssrn.2865627

Servaes H, Tamayo A (2013) The impact of corporate social responsibility on firm value: The role of customer awareness. Manage Sci 59:1045–1061

Shah SGM, Sarfraz M, Fareed Z, et al (2019) Whether CEO succession via hierarchical jumps is detrimental or blessing in disguise? Evidence from Chinese listed firms. Zagreb Int Rev Econ Bus. https://doi.org/10.2478/zireb-2019-0018

Shaikh I (2022) Environmental, social, and governance (ESG) practice and firm performance: an international evidence. J Bus Econ Manag 23:218–237

Shehzad K, Xiaoxing L, Sarfraz M, Zulfiqar M (2020) Signifying the imperative nexus between climate change and information and communication technology development: a case from Pakistan. Environ Sci Pollut Res 27:30502–30517

Székely N, Vom Brocke J (2017) What can we learn from corporate sustainability reporting? Deriving propositions for research and practice from over 9,500 corporate sustainability reports published between 1999 and 2015 using topic modelling technique. PLoS ONE 12:e0174807

Velte P (2021) Meta-analyses on corporate social responsibility (CSR): a literature review. Manag Rev Q 1–49

Vishwanathan P, van Oosterhout H, Heugens PP et al (2020) Strategic CSR: a concept building meta-analysis. J Manag Stud 57:314–350

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. Bus Soc 55:1083–1121

Zaiane S, Ellouze D (2022) Corporate social responsibility and firm financial performance: the moderating effects of size and industry sensitivity. J Manag Gov 1–41. https://doi.org/10.1007/s10997-022-09636-7

Zgrzywa-Ziemak A, Walecka-Jankowska K (2020) The relationship between organizational learning and sustainable performance: an empirical examination. J Work Learn

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Psychological and Behavior Changes of Consumer Preferences During COVID-19 Pandemic Times: An Application of GLM Regression Model

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The life we considered normal was disrupted due to measures taken to limit the spread of the novel coronavirus. Quarantine, isolation, social distancing, and community containment have influenced consumer behavior and contributed to the rapid development of e-commerce. In pandemic times, even those unfamiliar with the online environment have had to adapt and make acquisitions in this new manner. Hence, we focused our research on measuring the perception of consumers on how the restrictive measures imposed to limit the spread of the COVID-19 virus had influenced their decision to buy a product or service from the online environment, given that purchases are highly subjective and influenced by cumulative effects of economic, social, psychological and behavioral factors. Our paper comes with additional insights from the literature. It adds empirical evidence that reveals that the number of transactions and the value per transaction increased during the COVID-19 pandemic and highlights that online purchases will continue as such even after the pandemic.

Keywords: e-commerce, consumer psychology, online acquisitions, consumer behavior changes, COVID-19 pandemic

INTRODUCTION

Since 2020, the world has been affected by the emergence of SARS-CoV 2, a novel coronavirus that has unbalanced global economies with an impact unprecedented since the Great Recession (UN, 2020). On 11 March 2020, the WHO classified COVID-19 as a pandemic and imposed measures taken to limit the spread, like social distancing and quarantining or closing areas of activity where the virus cannot be controlled (WHO, 2020).

Daily activities could be carried out through online platforms, namely remote working, online courses, or online purchases. Thus, digital technologies played an important role in humanity's "new normal" in a pandemic context. The COVID-19 crisis has forced the development of digitalization which has significantly also affected the growth of e-commerce, a highly impacted segment due to repeated lockdowns and constant market fluctuations that have urged consumers to purchase more through online marketplaces (Sarfraz et al., 2019; Alessa et al., 2021; Fedushko and Ustyianovych, 2022).

However, the pandemic context has generated changes in consumers' behavior. On the one hand, at the beginning of the pandemic period, consumers shifted toward health and safety while maintaining a preference for inexpensive goods and services, given the economic crisis expected to occur alongside the health crisis (Abdullah et al., 2018; Guthrie et al., 2021). On the other hand, because most of the activities were transposed in the online environment, in the long run, given the epidemiological waves and high incidence, consumers have focused on products that bring comfort and a sense of coziness to a living space that became, almost overnight, work environment as well (Ajaz et al., 2020; Gu et al., 2021).

Our aim in this paper is to bring some insights regarding current trends in e-commerce in pandemic times like the ones generated by the emergence of the novel coronavirus disease. In this context, we focused our research on measuring consumer perception of how the restrictive measures imposed to limit the spread of the COVID-19 virus had influenced their decision to buy a product or service from the online environment, given that purchases are highly subjective and influenced by cumulative effects of economic, social, psychological, and behavioral factors. Our research investigated the main factors, difficulties, and advantages of making online acquisitions under COVID-19 pandemic restrictive measures through a questionnaire distributed online. We have used a five-point Likert scale consisting of questions that address different elements that influence the decision to make e-commerce transactions.

In this manner, we tried to get an updated picture of how e-commerce is perceived by consumers in the "new normal" of today, as traditionally, there have been claimed several systemic issues that affect the quality of online purchases, such as uncertainty for the quality of the product, the trust in the supplier, shipping problems, limited delivery or ordering time, and access to product information (Hanus, 2016; Shah et al., 2019).

Our paper comes with additional insights within the literature. It adds empirical evidence highlighting that the number of transactions and the value per transaction increased during the COVID-19 pandemic. Also, our study results reveal that online purchases will continue so even after the pandemic period.

The proposed research is structured in five sections. The first section, the present one, highlights the preliminary aspects of the scientific approach. The second section shows the background and the relevant scientific literature, and the next two sections present, respectively, the research methodologyand a discussion of the results obtained. Finally, the fifth section concludes our undertaken case study.

LITERATURE REVIEW

The pandemic caused by the emergence of the novel coronavirus disease has substantially changed the life we considered normal and brought, almost overnight, national health systems close to collapse. Humanity has been forced to adapt to face this global challenge (Baker et al., 2020). Hence, to limit the rapid spread of the virus, worldwide governments have imposed restrictive measures ranging from bans of large events, school and university closures, remote working, to a temporary shutdown of the economy, highlighting the urgent need for a strategic digital transformation (EU, 2020).

Most of the daily activities were transposed into the online environment in countries that imposed restriction measures. These measures have had a major impact on the e-commerce segment too, which registered a real breakthrough due to the closure of physical retail stores. Hence, in times of uncertainty, online shopping had become the most accessible option for consumers to satisfy their consumption needs, creating at the same time tremendous pressure on suppliers of essential goods, such as pharmacies and grocery stores, to keep up with the growing demand (Koch et al., 2020).

However, e-commerce registered a spectacular breakthrough over time, and the pandemic generated by the novel coronavirus has amplified this trend. According to the COVID-19 and e-Commerce: A Global Review Report, the global retail market share increased from 14% in 2019 to 17% in 2020. Also, according to the same research, digital marketplaces and e-commerce platforms recorded an increase in transactions from 5% to over 100% in 2020 compared to last year (Sirimanne, 2021).

Data provided by Eurostat, based on the results of a survey carried out in 2021 on ICT (Eurostat, 2021), highlights that the share of e-customers among internet users is growing. Between 2016 and 2021, the largest increase in e-commerce was recorded in the Czech Republic, Hungary, Romania, Slovenia, Croatia, and Lithuania, with most purchases being made by e-shoppers aged between 16 and 24, closely followed by the age group 25–54 (Eurostat, 2021). On the one hand, the main advantages of e-commerce contributed significantly to this growth; namely the convenience of being able to shop anytime and anywhere, access to a broader range of products, and the possibility to easily compare prices and view reviews from other consumers. On the other hand, the restrictive measures imposed to limit the spread of the virus also contributed to the growing trend.

According to Eurostat, in new shopping patterns, e-commerce purchases are influenced by gender, age, level of education, and employment situation. Hence, the share of male online shoppers among internet users is slightly higher than for women. Also, the economic volatility of present determines that consumers to pay more attention to their finances, with repercussions on purchasing power (Abdullah et al., 2021; Cosmulese et al., 2021). Still, studies reveal that customers with a higher level of education tend to purchase more (Eurostat, 2021).

Before COVID-19, most online acquisitions involved the purchase of clothes, shoes, or accessories. In the web era, tourism, fashion, luxury goods, and the organic sector focused on consumption (Zhang, 2021). But, the emergence of the novel coronavirus influenced consumer behavior and preferences (Koch et al., 2020). Hence, declaring COVID-19 as a pandemic led to panic buying of goods of strict necessity, including medication, antiseptics, and disinfectants (Loxton et al., 2020; Shehzad et al., 2020; Rai, 2021), with researchers proving that a consistent supply of goods creates a sense of security for consumers in uncertain times (Prentice et al., 2020). The fear of infection with a virus about which not much was known, and physical store closures, determined the increase in online

shopping (Mason et al., 2020). The COVID-19 pandemic appears to be a significant acceleration factor in the e-commerce segment (Pollák et al., 2021).

Hence, the ongoing uncertainty created by the pandemic context changed the consumption patterns (Kirk and Rifkin, 2020) and buying decisions (Mason et al., 2020). The restrictive measures imposed have limited social life and pushed consumers to shop online so that, during the pandemic period, socialization took place in the virtual environment, a channel used now by shoppers also as a tool to identify products, collect information, evaluate similar goods, and finally make the proper acquisitions of the products that best meet their needs (Lv et al., 2020). It seems that customers, due to the pandemic period, ordered online more often than normal, became more experienced, and their awareness has increased (Gu et al., 2021). Also, they became more selective and shifted to local brands for their acquisitions (Sumarliah et al., 2021). Studies state that the pandemic generated an increase in the sales of medical supplies, sporting items, children's products, and entertainment goods, alongside the growth of food sales (Király et al., 2020).

Due to the period of uncertainty, researchers depicted that the percentage of spontaneous purchases decreased, and the percentage of planned purchases increased (Eger et al., 2021). Is this behavior driven by hedonic or by utilitarian motives? Online acquisitions in uncertain times are motivated by their usefulness or by the entertainment and enjoyment experience the product or service provides to consumers. There are studies such as those conducted by Koch et al. (2020) who reveal that hedonic motivation is a better predictor of purchase intentions than utilitarian motives in pandemic times, consumers being able to prioritize essential products for their wellbeing, and de-prioritized products that are not necessary (Kurtisi and Alver, 2021). This result is also expected because, in times of uncertainty, the consumer is tempted to buy, mainly, what is valuable and necessary. Also, the aforementioned research highlights that women and individuals practicing social distancing show higher levels of hedonic motivation.

With these aspects under consideration, this research study proposes the following main hypotheses, depicted in **Figure 1**:

H1: *Psychosocial factors influence the decision to conduct e-commerce transactions.*
H2: *The consumer profile influences the decision to carry out e-commerce transactions.*
H3: A *good awareness of the advantages of e-commerce transactions influences such transactions.*

Some lessons were learned from this crisis, but consumer behavior cannot always be predicted in uncertain times. In this context, we consider that the way the online shopping system is perceived depends mainly on the interest given by companies in adapting their strategies to the new digital environment. Suitable applications to order online, quality products, and timely delivery represent the primary conditions necessary for the development of online commerce even after the pandemic period. Also, from our point of view, the efficiency of e-commerce depends mainly on the consumer's interests, motivation, and habits.

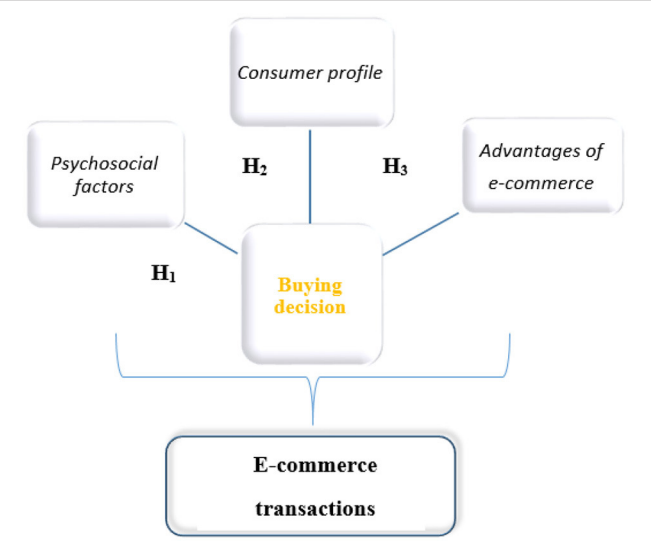

FIGURE 1 | Hypotheses development. Source: authors' own projection.

METHODOLOGY

Data Collection

The research method considered in our study is a questionnaire which allows us to gather information about consumers' perceptions of e-commerce transactions. As the decision to buy a product or service is highly subjective and influenced by cumulative effects of economic, social, psychological, and behavioral factors, the questionnaire is designed to address all those dimensions. The questionnaire consists of 78 closed questions, considering a five-point Likert scale, which addresses different elements of the decision to make e-commerce transactions, as illustrated in **Figure 2**. The questions addressing the consumers' perception of factors, difficulties, and advantages of e-commerce are also specified in detail, as they are the basis for the design and the estimation of the latent variables (constructs) we intend to estimate in the study, to reduce the data and simplify the econometric model to be estimated. Questions concern both periods analyzed, respectively, the period prior COVID-19 pandemic and the period after the COVID-19 pandemic started.

To check the relevance of public policies in supporting the transition to the home-office regime, we are checking through a set of three questions whether the subsidies granted are used to cover the expenses for e-commerce transactions value.

Additionally, we include five questions that provide us with the dependent variables in our study. We consider the value per transaction estimated on a monthly average and monthly estimated number of e-commerce transactions in each period analyzed. Both variables consist of interval type of data. Another dependent variable in our study relates to consumers' opinion on the likelihood they will perform on future e-commerce transactions, which is measured considering a five-point Likert scale.

Items selection to design our questionnaire has focused mainly on already well-known drivers for consumers' decision to

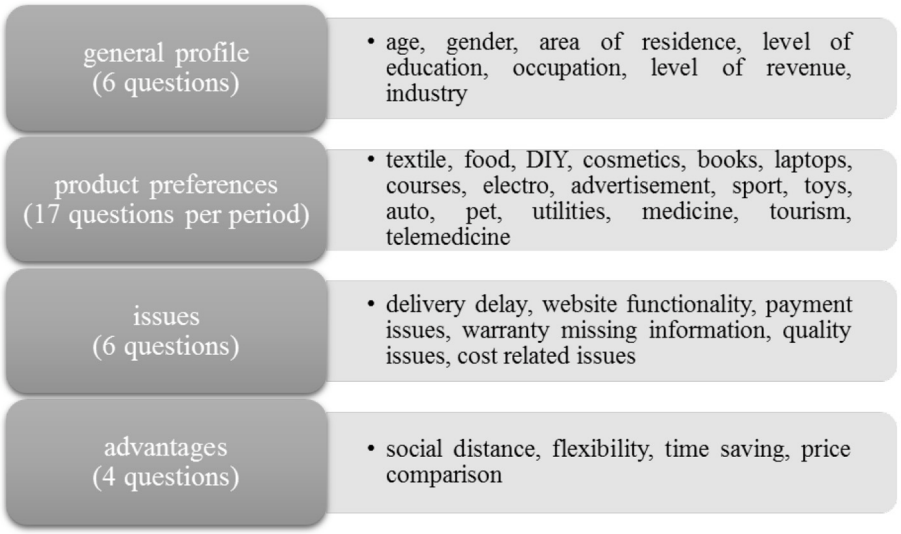

FIGURE 2 | Topics addressed within the questionnaire disseminated. Source: authors' projection.

buy, as Kalia et al. (2016) reviewed. However, the definition of consumers' profiles is similar to Zhang (2021). Further, shopping experience and consumer preferences definition have similar reasoning to Vijay et al. (2018). Nonetheless, to adjust the initial design of the questionnaire to the current context of the COVID-19 pandemic, we refer to the approach of Rao et al. (2021) and Hesham et al. (2021), especially concerning the perceived risk and uncertainty of e-commerce buying decisions.

A total number of 334 replies have been received. Dissemination of the questionnaire was available for ∼3 months, respectively, the period May–July 2021. Most of the replies are from female respondents, as about 66.35% of respondents were women. More than 68.25% of the respondents are young people between 18 and 30 years, followed by a percentage of 17.14% of respondents with ages between 30 and 40 years. A total of 69.84% of respondents live in an urban area. Related to the level of revenue, our sample is balanced between groups, as the highest weight of a group is related to the respondent having revenue per month of <1,500 lei, summing up to about 36.51%. It is followed by respondents with a level of revenue between 1,500 and 2,500 lei, gathering ∼20.32% of our sample. The respondents with a level of revenue between 2,500 and 3,500 lei cover about 19.68% of the sample. From the perspective of their occupation, the respondents are mainly students with a weight of 18.8% in our sample, while the second major group is represented by employees who count for 45.51% of the sample.

Correspondence Analysis

Evaluation of the structure of the relationship between categories of categorical variables is best reflected through a correspondence analysis. Starting from the contingency table describing the frequency of each association of categories of the variables analyzed, we reach a transformed set of data, summing up a correspondence matrix. To measure the relationship between the row profiles and the column profiles from the correspondence matrix, it is measured the distances between rows and columns using the χ^2 metric, considering the relations below (Barczak et al., 2021):

- for rows, the formula is:

$$\chi^2 = d^2\left(h, h'\right) = \sum_j \frac{\left(p_{hj}/p_h - p_{h'j}/p_{h'}\right)^2}{p_j} \quad (1)$$

where: $d^2(h,h')$ is the distance between the h-th and h'-th row, p_{hj}/p_h are the row profile elements (also called masses in correspondence analysis theoretical framework), while p_j are the average row profile elements, with h,h' = 1,2,…,H̃.

- for columns the formula is:

$$\chi^2 = d^2\left(j, j'\right) = \sum_j \frac{\left(p_{hj}/p_j - p_{hj'}/p_{j'}\right)^2}{p_h} \quad (2)$$

where: $d^2(j,j')$ is the distance between the j-th and j'-th row, p_{hj}/p_j are the column profile elements, while p_h are the average column profile elements, with $j,j' = 1,2,\ldots,J$.

Our study's central element of analysis is the total inertia, which can be defined as a measure of variance in row profiles. These column profiles show how far the row profiles (column profiles) are from their average profile. Once determined the n-dimensional space that best represents the points derived from the data is collected, the resulting configuration is rotated to maximize the variance explained by each dimension. The inertia is determined as a weighted average of the distance χ^2 between

the columns and the rows profiles (Greenacre, 2007; Barczak et al., 2021):

- for rows, the formula is:

$$\emptyset_h^2 = \sum_h r_h \cdot d_h^2 \quad (3)$$

where: d_h^2 is the distance between h-th row and the corresponding centroid, while r_h is the sum of frequencies in the row of the correspondence matrix (mass of the row);

- for columns, the formula is:

$$\varnothing_j^2 = \sum_h c_j \cdot d_j^2 \quad (4)$$

where: d_j^2 is the distance between j-th column and the corresponding centroid, while r_j is the sum of frequencies in the column of the correspondence matrix (mass of the column). Starting from the presumption that the row (column) average profile (centroid) supports the hypothesis of homogeneity, the total inertia is determined as $\frac{\chi^2}{n}$, explain the level of heterogeneity that is not explained by the sample size.

Data Reduction

As our sample consists of many questions and as many of them relate to similar core concepts, such as consumers' preferences, we want to reduce the data collected to ensure simplicity and clarity for the econometric model that is later estimated. For this purpose, we proceed to categorical principal components analysis (CatPCA), which is specially designed for categorical data collected through questionnaires (Blasius and Theessen, 2012). Categorical principal components analysis is proper to reduce ordinal data, transforming it into numerical scale by using an estimated non-linear non-monotonic function of transformation (Meulman et al., 2004). The method consists of optimal scaling of categorical data by assigning optimal scale values to each category. The overall variance accounted for the transformed variables is maximized for a specified number of dimensions.

Suppose we have n individuals for which we have collected scores for m questionnaire items. Data collected is represented in an S matrix where x_{ij} represent the score for individual i for item j. Those object scores are restricted by relation $S^T \cdot S = n \cdot I$, where I is the identity matrix. Object scores are centered values as well, as they are subject to restriction $1^T \cdot S = 0$, where 1^T is the vector of ones. Each ordinal data x_{ij} is transformed into a quantified value, based on the scale dimension established prior to the analysis, based on the theoretical framework, using a function of transformation φ. Quantified scores $q_{ij} = \varphi(x_{ij})$ are standardized, considering the restriction $q_j^T \cdot q_j = n$. Those scores are multiplied by a set of optimal weights which are called component loadings. The matrix of component loadings A consists of m rows, like the number of items on the questionnaire, and p columns representing the number of components/dimensions identified.

Maximization of variance accounted for the transformed scores consists of minimizing the loss function (5) that measures the difference between original data and principal components, expressed by the function above, using an alternative least squares algorithm (Linting and van der Kooij, 2012).

$$L(Q, A, S) = \frac{1}{n} \cdot \sum_{j=1}^{m} trace\left(q_j \cdot a_j^T - S\right)^T \cdot \left(q_j \cdot a_j^T - S\right) \quad (5)$$

The method of CatPCA is performed considering a rotated solution, obtained through the Varimax rotation procedure. After simulation of CatPCA solutions for different dimensions, we remain to the solution that maximizes the variance factors accounted for in the sample, but with a minimum number of factors, to reduce the risk of components overlapping (Hair et al., 2019). The procedure is performed separately for both periods analyzed in this study.

Ordinal Regression Analysis

Once estimated the scores for each construct, we proceed to an econometric analysis to assess their marginal effect on consumers' decisions concerning the value per e-commerce transaction and on consumers' opinions regarding the likelihood to perform future e-commerce transactions. For this purpose, we estimate a generalized ordinal regression model, as the dependent variable indicates clear order between the different possible values (Garson, 2021). The dependent variable in the case of each model estimated is an ordinal type variable that can take five different levels, depending on:

- the levels of Likert scale used to measure consumers' opinion on the likelihood they will make purchases online even after the COVID-19 pandemic ends;
- the mean of intervals considered defining the number of transactions made online per month, and the value per transaction made online on a monthly average.

In each estimated model, we consider the minimum value possible as a reference. In general, in the case of k possible values for the dependent variable, we estimate $k - 1$ binary regression models expressed by the relation below:

$$\ln \frac{P(y_i = j)}{P(y_i = r)} = \beta_j \cdot x_i \quad (6)$$

where $\beta_j$is the vector of regression coefficients, $P(y_i = j)$ is the probability that outcome j is selected, r is the "pivot" (reference) outcome, whereas x_i represents the vector of independent variables considered for each respondent included in our sample, including the constructs determined based on the CATPCA procedure and variables describing respondent's profile relevant characteristics for the analysis.

Based on this odds ratio, we determine the probability that an individual changes his preference, from the r outcome to the new

TABLE 1 | Descriptive statics purchases.

Period		Prior COVID-19 pandemic		During COVID-19 pandemic		Opinion on future e-commerce transactions
		Number transactions	Value transactions	Number transactions	Value transactions	
Mean		3.078	395.9	3.648	488.4	3.662
Median		1.50	350	4	350.0	4
Mode		1.50	350	1.50	350.0	4
Std. Dev.		2.457	388.8	2.389	420.6	1.100
Skewness		0.852	1.739	0.651	1.322	
Kurtosis		−0.650	2.513	−1.091	0.920	
Percentiles	25	1.500	100	1.500	100.0	3
	50	1.500	350	4	350.0	4
	75	4	350	4	750.0	4.250

Source: authors' calculation.

j preference, based on the relation below:

$$P\left(y_i = j\right) = \frac{e^{\beta_j \cdot x_i}}{1 + \sum_{t=1}^{k-1} e^{\beta_j \cdot x_i}} \quad (7)$$

Additionally, we can determine the odds ratio determined by the ratio $\frac{P(y_i=j)}{1-P(y_i=j)}$ that show the chance that a respondent changes his initial option.

RESULTS AND DISCUSSIONS

Descriptive Statistics

The analysis will follow the section with a comparative approach of variables analyzed to identify significant differences in consumers' purchasing behavior in the context of the COVID-19 pandemic and its short-term effects.

Table 1 provides the descriptive statistics on the number of transactions and the average value per transaction, as estimated by respondents during questionnaire dissemination. Looking at the mean of each panel, we observe no significant differences, as prior to the COVID-19 pandemic ∼3.078 transactions of about 395.9 Ron were made on average, compared with the period during the COVID-19 pandemic, characterized by a mean of 3.648 transactions of about 488.4 Ron, which is slightly higher, a result similar to the report provided by Eurostat (2021). Looking at the standard deviation of both variables analyzed, for each period considered for analysis, we observe a relatively high variation among our sample, which indicates a relatively heterogeneous sample in terms of the number of online purchasing transactions and value per transaction.

However, the polarization of options for e-commerce seems to be deepened. Despite the same median value of 4 transactions performed, at about 350 Ron for both periods, the third quartile related to the period during COVID-19 pandemic of 4 transactions translated into ∼750 Ron average, is significantly higher, compared with the period before the COVID-19 pandemic, in terms of value per transaction. Therefore, the increase in value per transaction is mainly derived from the increase of value per transaction of some respondents who expended high amounts on online purchases. Our results are similar to those obtained by Sirimanne (2021).

Respondents considered whether they would continue with online purchases, we observe that most of them believe that they will continue, as they provide a median rating of 4 ("agree"), related to a standard deviation of only 1.1. Instead, the results show they continue to be reserved on how they perceive e-commerce, looking at the 3rd quartile (4.25), because of various factors that we will further analyze in this section, such as the trust in the trader, available payment tools, price considerations or even lack of information on products' warranty. It seems that these disadvantages identified in our study are similar to those obtained by Hanus (2016).

Consumers' Purchasing Behavior in the Presence of Subsidies

The state and some companies have decided to provide either some tax incentives or even some small financial support for employees who had to transition to the home-office regime. In **Table 2**, we check if there is a statistical impact on the increase of e-commerce volumes of those financial support schemes.

The results of each statistical test performed show that respondents perceived those schemes as relevant for the increase in e-commerce, especially in the case of respondents that have declared they have worked home-office during the current COVID-19 pandemic, thus having to ensure an environment conducive to work from home, like Gu et al. (2021) depicted. However, those results do not offer insights into consumers' preferences, especially during the COVID-19 pandemic. This information is essential as the financial support schemes mainly addressed the need for IT equipment to facilitate the transition to a home-office working regime. Further in the section, we check if there are significant changes in consumers' preferences when discussing e-commerce.

TABLE 2 | Descriptive statics purchases.

Distribution		Increase in e-commerce perceived				
		Totally disagree	Disagree	Neutral	Agree	Totally agree
Home-Office acquisitions	No	51	32	28	9	3
	Yes	54	45	67	27	18

Statistics testing influence	Statistic	Value	df	Asymptotic significance (2-sided)
	Pearson chi-square	15.925	4	0.003
	Likelihood ratio	16.629	4	0.002
	Linear-by-Linear association	15.572	1	0.000

Source: authors' calculation.

TABLE 3 | Statistics on correspondence analysis related to product type choice.

Panel	Prior COVID-19 pandemic			During COVID-19 pandemic		
Dimension	Singular value	Inertia	Proportion of inertia %	Singular value	Inertia	Proportion of inertia %
1	0.365	0.133	0.818	0.359	0.129	0.817
2	0.158	0.025	0.153	0.151	0.023	0.145
Total		0.163	1.000		0.158	1.000
Chi Square	924.42		895.254			
Sig.	0.000[a]		0.000[a]			

[a] *64 degrees of freedom.*

Changes in Consumers' Preferences

We have included a dedicated section on the questionnaire disseminated, consisting of 17 items aimed to measure consumers' preferences for different types of products available on the market. Despite the insignificant changes noted in consumers' behavior in the context of the COVID-19 pandemic (Zhang, 2021), we want to get some insights into the dynamics of consumers' preferences concerning specific product types, including more specific ones such as telemedicine services. For this purpose, similar to Valaskova, 2021, we have proceeded to a correspondence analysis to draw an image of consumers' preferences, separately for the period prior to the COVID-19 pandemic and, respectively, for the period during the COVID-19 pandemic.

In **Table 3** we summarize the inertia statistics, specific for the analysis of heterogeneity in consumers' preferences (Greenacre, 2007). As inertia is a measure of the variation among the sample analyzed, which does not depend on sample size, we expect to have lower values in case of more homogenous preferences among consumers analyzed. The results show that the first dimension in our correspondence analysis describes most inertia. The results on the level of inertia per dimension extracted are explainable, as the second dimension describes better consumers' preferences only for the area of DIY (0.781), household electronics (0.744), laptops, tablets, and other similar devices (0.554). Those results suggest that consumers' preferences are more homogenous in the areas characterized by higher prices, additional technical knowledge requirements for purchasing, warranty concerns, etc.

The results show highest values of inertia on items level are identified in the case of utilities (0.059), textiles (0.022), and telemedicine (0.021), in line with the results obtained by Guthrie et al. (2021), while the lowest values relate to sports (0.001) or tourism (0.001). Therefore, it seems that on the online e-commerce platforms, a high homogeneity is found in advertisement, sports, and tourism, which are expected as those kinds of products are mainly acquired *via* online e-commerce platforms.

In **Table 4** we illustrate the product types with the TOP 3 highest and TOP 3 lowest differences in change in the inertia statistic. This way, we show which product types have suffered the highest changes in consumers' preferences to buy online in the context of the COVID-19 pandemic. First, we observe that the highest positive difference is related to the services of utilities, which suggests that heterogeneity in the sample increases, meaning that consumers' preferences to purchase this type of service vary significantly among the respondents. An essential root cause can be the lack or insufficient knowledge of recent information technologies. Second, we observe that the decrease in the measure of inertia related to online medical services suggests the current pandemic context forced consumers to have a more favorable position on purchasing such services online. Until recently, consumers have shown reluctance to acquire such services online. This change in consumer preferences has put a lot of pressure on suppliers of essential goods, such as pharmacies and grocery stores, to keep up with the growing demand, as Koch et al. (2020) depicted.

In **Figure 3**, we better illustrate the changes in preferences, this time related to the rating given by respondents as a measure

TABLE 4 | Inertia statistics on TOP 3 highest and lowest values.

Product type	Inertia		Contribution of point to inertia				Differences on inertia
			Dim. 1		Dim. 2		
Period	Prior COVID-19 pandemic	During COVID-19 pandemic	Prior COVID-19 pandemic	During COVID-19 pandemic	Prior COVID-19 pandemic	During COVID-19 pandemic	
Utilities	0.059	0.067	0.819	0.883	0.178	0.117	0.008
Textile	0.022	0.025	0.932	0.958	0.052	0.037	0.002
Sport	0.001	0.003	0.233	0.427	0.253	0.457	0.002
Food	0.003	0.001	0.852	0.803	0.046	0.052	−0.002
DIY	0.005	0.002	0.115	0.440	0.781	0.361	−0.003
Telemedicine	0.021	0.016	0.839	0.796	0.155	0.194	−0.005

Source: authors' calculation.

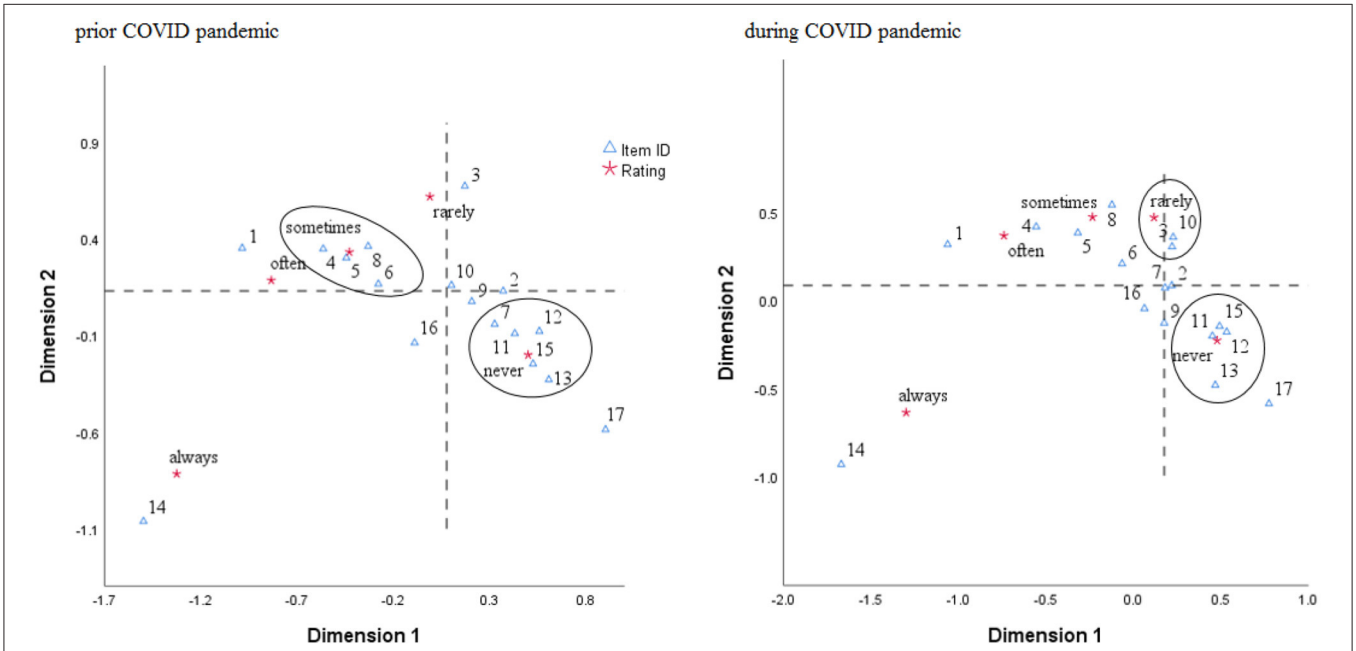

FIGURE 3 | The pattern of consumers' behavior based on correspondence analysis. Source: authors' calculation. Product types are coded as follows: 1, textile; 2, food; 3, DIY; 4, cosmetics; 5, books; 6, laptops; 7, courses; 8, electro; 9, advertisement; 10, sports; 11, toys; 12, auto; 13, pets; 14, utilities; 15, medicine; 16, tourism; 17, telemedicine.

of the likelihood they would buy the respective product type online. On the one hand, a slight difference between the two periods analyzed is observable only in the case of online courses (coded as "7"), which seem to be day by day a feasible alternative tool for traditional and continuous education. Platforms such as Coursera, or free online training available on the internet, are widely spread on consumers' preferences, providing high-quality courses, positively impacting consumers' performance. On the other hand, the sports product type seems to change slightly negatively compared to prior to the COVID-19 pandemic. Consumers prefer to purchase those products traditionally and only rarely through the online platform or dedicated websites.

In **Table 5**, we provide a summarized picture of consumers' preferences from the perspective of changes in the measure of inertia, starting from ratings provided by respondents to the questionnaire as a measure of likelihood to buy online products and services.

Overall, the results show a slight change in consumers' preferences in favor of buying products and services online, which is in line with the research conducted by Alessa et al. (2021)

TABLE 5 | Inertia statistics on consumers' ratings concerning likelihood of purchasing online.

Product type	Inertia		Contribution of point to inertia				Differences on inertia
			Dim. 1		Dim. 2		
Period	Prior COVID-19 pandemic	During COVID-19 pandemic	Prior COVID-19 pandemic	During COVID-19 pandemic	Prior COVID-19 pandemic	During COVID-19 pandemic	
Always	0.061	0.073	0.852	0.903	0.140	0.092	0.011
Often	0.027	0.024	0.911	0.816	0.020	0.086	−0.003
Rarely	0.011	0.008	0.001	0.095	0.910	0.654	−0.003
Sometimes	0.014	0.010	0.720	0.322	0.188	0.560	−0.004
Never	0.050	0.044	0.934	0.910	0.065	0.087	−0.006

Source: authors' calculation.

and Fedushko and Ustyianovych (2022). Therefore, the current context of the COVID-19 pandemic has determined consumers to reconsider their options toward e-commerce.

However, the results show a slight change toward e-commerce, their reluctance to be visibly present on their options. Further in the study, we analyze the factors that significantly affect their decision on buying products and services through e-commerce channels.

Reliability Analysis

To analyze the changes in consumers' opinions concerning the main factors influencing their decision to buy online, we first check for our scale used in the design of the questionnaire to be reliable and internally consistent. In **Table 6**, we provide Cronbach's Alpha statistical test statistics to assess if the Likert scale is reliable and the data collected is relevant for further analysis. Overall, we observe the Cronbach's Alpha statistic for each of the constructs formulated based on the questionnaire design is higher than the minimum threshold of 0.70 (Hair et al., 2019).

From a scale level perspective, we observe that the highest mean values concern respondents' opinion addressing the measure advantages related to e-commerce influence their decision to buy products and services online (3.863), which suggest a relative impact closer to the 4th Likert scale level, than the neutral scale rating (3). Instead, items addressing difficulties encountered by respondents when buying online seem inconclusive. Therefore, consumers focus instead on the advantages of e-commerce. Difficulties identified are solved either individually or with the support of the website's owners; as with the context of the COVID-19 pandemic, online traders have made visible efforts to improve their customer services.

Changes in Consumers' Opinion Concerning Factors Influencing Online Purchasing

In **Figure 4**, we represent the distribution of probabilities of respondents' ratings on the different items included in the questionnaire, addressing both the factors of the decision to buy online and the related difficulties and advantages.

On the one hand, as expected, we observe consumers' decision to buy products and services online is highly dependent on the quality of products and services and the trust in the traders. The context of the COVID-19 pandemic showed an increase in consumers' opinion on how important factors such as product quality, trust in online traders, product and service pricing, or even delivery time or ordering time are.

On the other hand, we observe that factors such as the influence of family or friends, reviews provided by other customers, consideration of sustainable consumers' preferences, or perception of product and service brand are less relevant for the decision of online buying. One reason could be that consumers can document themselves better in an online environment and with proper customer service support provided through websites that can make their decision easier.

Respondents show high attention to the advantages generated by e-commerce, more attention they pay to the difficulties encountered in deciding to buy online products or services. Developments in customer relations management solutions have provided traders with rigorous, systematic, and fast data access instruments concerning their clients. Moreover, the social platforms provide additional instruments for the traders to capture consumers' preferences using various artificial intelligence tools. Therefore, website owners receive relevant and timely information on consumers' concerns related to their products and customer services. The transition of purchasing decisions in an online environment allows them to collect those data quickly and at low costs.

Extraction of Reduced Components

Our questionnaire has addressed multiple concerns addressing consumers' rationale, psychological factors, social factors, and economic factors (Peighambari et al., 2016; Deng et al., 2021). For data reduction, we performed a principal components analysis that helped reduce the 20 items disseminated in the questionnaire to only four main components (*constructs*). As our variables consist of categorical data, we proceed to a categorical

TABLE 6 | Reliability analysis.

Variable	Factor extracted	Panel	Period before COVID-19 pandemic					Period after COVID-19 pandemic				
		Item description	Mean	St. dev.	Cronbach's alpha	Loading component		Mean	St. dev.	Cronbach's alpha	Loading component	
On the decision of purchasing online how important is:												
Price	Psychological and behavioral factors	The price	3.544	0.29	0.857	0.571		3.601	0.264	0.889	0.405	
Quality		The product quality				0.742					0.613	
Reviews		The forums/reviews				0.433					0.423	
Trust		The trust of site/firm				0.583					0.692	
Payment		The possibility to pay online				0.445					0.670	
Delivery		The delivery time				0.717					0.674	
Ordering		The ease of ordering				0.773					0.661	
Ecological	Other items	The label for ecological product					0.522				0.318	
Brand		The brand				0.309						0.428
Family		The influence from friends/family					0.563					0.637
Which are the main difficulties encountered by the consumer in online purchasing?												
Delay	Difficulties	Delay in order delivery	2.426	0.052	0.833	0.475	–	2.426	0.052	0.833	0.475	–
Functional		Website functionality				0.623					0.623	
Payment		Payment system functional				0.610					0.610	
Warranty		Lack of warranty information				0.668					0.668	
Quality		Product quality				0.616					0.616	
Cost		Higher costs				0.557					0.557	
Which are the main benefits encountered by the consumer on online purchasing?												
Distance	Advantages	Social distancing	3.863	0.019	0.877	0.617	–	3.863	0.019	0.877	0.617	–
Flexibility		Flexibility				0.847					0.847	
Time		Time savings				0.805					0.805	
Price		Price comparison				0.741					0.741	

Source: authors' calculation.

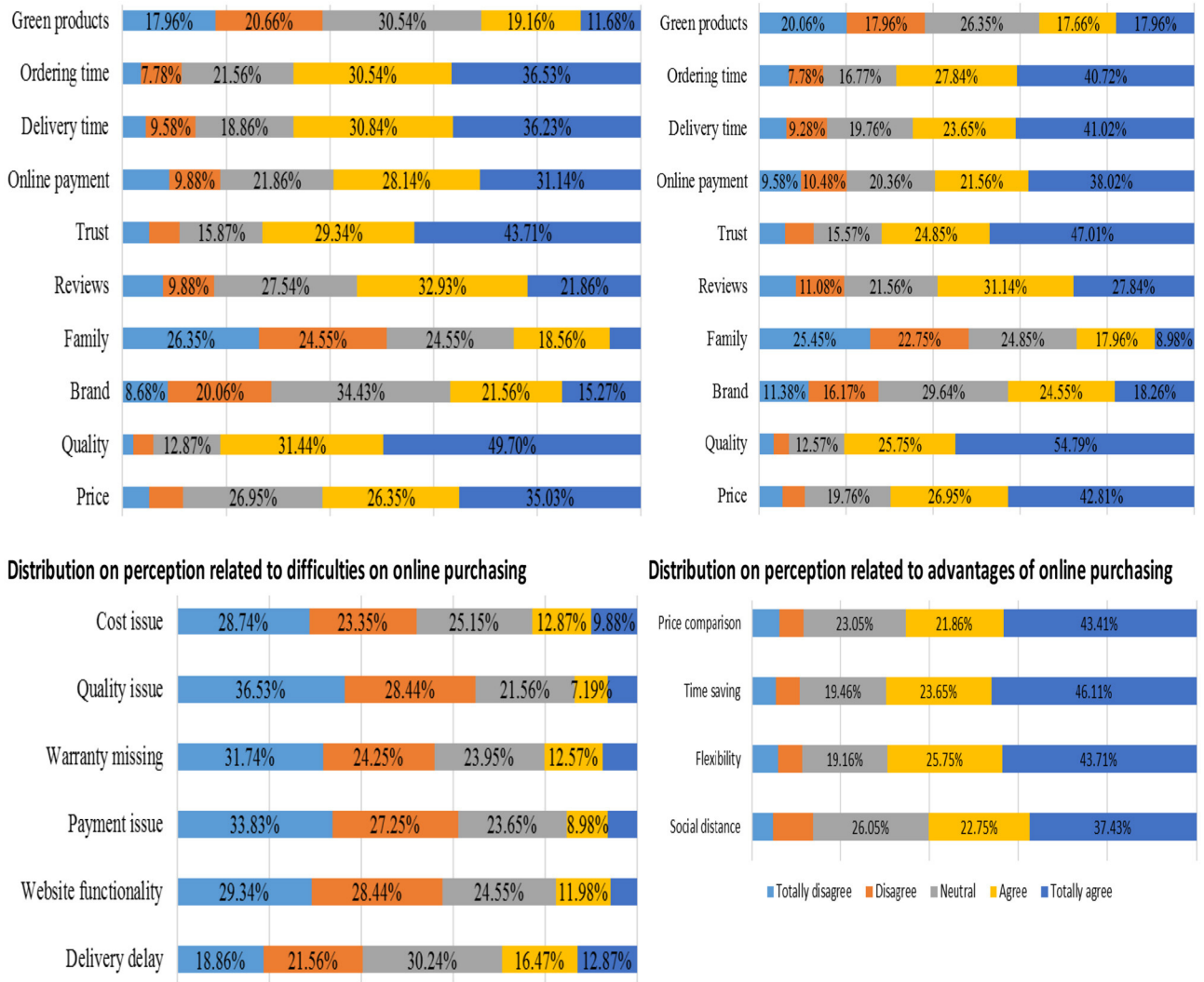

FIGURE 4 | Distributions on items reviewed on the questionnaire. Source: authors' calculation.

PCA analysis to ensure the internal consistency of the results (Meulman et al., 2004; Linting and van der Kooij, 2012).

In **Table 7**, we provide the summary statistics for the components extracted. Those latent variables measure the aggregate effects of items included, capturing the items that present the highest variation among the sample in terms of respondents' rating (Hair et al., 2019). Determined constructs represent the data collected through the questionnaire as they account for more than 66.4% of the variation in the sample for both periods analyzed. The context of the COVID-19 pandemic determined some changes in the representativeness of those constructs, as the factor related to items addressing difficulties encountered during online purchasing (*difficulties*) lose their importance, on the ground of a decrease from 16.03% account for variance in the sample to a percentage of only 11.61%. Instead, most of this decrease is transposed on the increase of variance accounted by psychological and behavioral factors from a percentage of 24.35% to the level of 30.64%.

In **Table 6**, we provide the structure of each construct identified, based on the reference of each construct to the items included on the questionnaire. Based on those results, the initial design of the constructs has not changed significantly. The only change we note is the estimation of a construct (*other items*) that incorporate mainly the item addressing respondents' perception of how they believe their decision to buy online is influenced by feedback received from friends and family members. Despite

TABLE 7 | Statistics on variation reflected by factors extracted with CATPCA.

Period	Prior COVID-19 pandemic			During COVID-19 pandemic		
Dimension	**Cronbach's alpha**	**Eigenvalue**	**% of variance**	**Cronbach's alpha**	**Eigenvalue**	**% of variance**
Psychological and behavioral factors	0.869	4.870	24.350	0.881	6.128	30.640
Other items	0.800	3.663	18.314	0.775	3.791	18.953
Difficulties	0.763	3.206	16.028	0.599	2.322	11.608
Issues	0.707	1.555	7.774	0.044	1.044	5.218
Total	0.973[a]	13.293	66.467	0.973[a]	13.284	66.419

[a] *Total Cronbach's Alpha is based on the total Eigenvalue. Source: authors' calculation.*

that these items were expected to be one of the main factors influencing the online purchasing decision, it seems that factors such as. However, the fact that this item covers only a small portion of the variation in the sample shows that feedback from friends and family members is perceived of slightly similar importance for their decision to buy products and services online.

Constructs Validation

Statistical validation of the constructs determined through CATPCA is made by performing a confirmatory factor analysis (DiStefano and Hess, 2005; Blasius and Theessen, 2012; DiStefano et al., 2019). DiStefano et al. (2019) note that the CFA should be estimated with the Asymptotic Distribution Free Estimation method. In **Figure 5**, we illustrate the design of the confirmatory factor analysis model.

However, as noted by DiStefano and Hess (2005), the use of the maximum likelihood method or the alternative method of asymptotic distribution-free estimation does not generate different results if the categorical variables have an absolute value of skewness and kurtosis lower than 2.

Based on the results provided in **Table 8**, we can validate the model as statistically significant (Hair et al., 2019). Those results ensure the internal consistency of the model of principal components analysis.

Further, we continue with the evaluation of our CFA model discriminant validity.

In **Table 9**, we summarize the measure of AVE for each factor extracted and the correlations with the other factors extracted. We observe that the average variance extracted (AVE) is higher than the correlations with the other factors extracted (Hair et al., 2019; Garson, 2021). Therefore, our model proves discriminant validity.

In **Table 10**, we provide statistics relevant to assessing the CFA model's convergent validity. The measure of composite reliability (CR) represents a better measure of constructs reliability. The results show that all constructs are reliable as the CR for each extracted factor is higher than the threshold of 0.70 (Garson, 2021).

The measure of average variance extracted (AVE) express how much variation is accounted for by each construct within the variance of items incorporated. Expect for the factor issues for which the AVE measure does not exceed the threshold of 0.50; the rest seem to be sufficiently representative for the items incorporated in the related constructs (Garson, 2021). The concern of convergent validity in case of factor issues suggests that the construct items are not well-correlated. Consequently, we will not consider this construct in further econometric analysis.

Evaluation of the Marginal Effect on Value per Transaction

Once the design of the construct was estimated, we continue with the final step, respectively, the econometric analysis that evaluates the association between the construct scores estimated before and the average level of value per each online purchasing transaction. In **Table 11**, we summarize the statistics of the model estimated. The results indicate differences in the determinant of the value per transaction if comparing the two periods of analysis, respectively the period before the COVID-19 pandemic and the period during the COVID-19 pandemic.

On the one hand, we observe that in the period prior to the COVID-19 pandemic, none of the factors determined a statistically significant effect on the odds that consumers change the value per online buying transaction.

Let us look at the next model estimated, which controls respondents' characteristics. We observe the value per transaction is still not influenced significantly by the constructs based on the questionnaire disseminated.

Instead, we observe that the decision that consumers change the value per online purchasing transaction is statistically conditioned by respondents' characteristics such as gender, activity type, or revenue level. Results show that female consumers are more reluctant to make online purchasing transactions, as they prefer to allocate the lower value of such expenses ($Coef. = -0.979$, $Sig. < 0.01$), compared with male consumers. Therefore, it seems that the value per online purchasing transaction has the odds to increase with a likelihood that decreases with about $0.376 - 1 = -0.624$.

Similar results we also observe in case of the marginal effect of the type of activity, or the level of revenue, on the odds consumers would increase the value per online purchasing transaction. Results suggest that students are less likely to increase their value per online purchasing transaction ($Coef. = -2.846$, $Sig. < 0.05$).

The level of revenue also impacts negatively the odds that consumers increase their value per online purchasing transaction, in the case of each level of revenue considered in

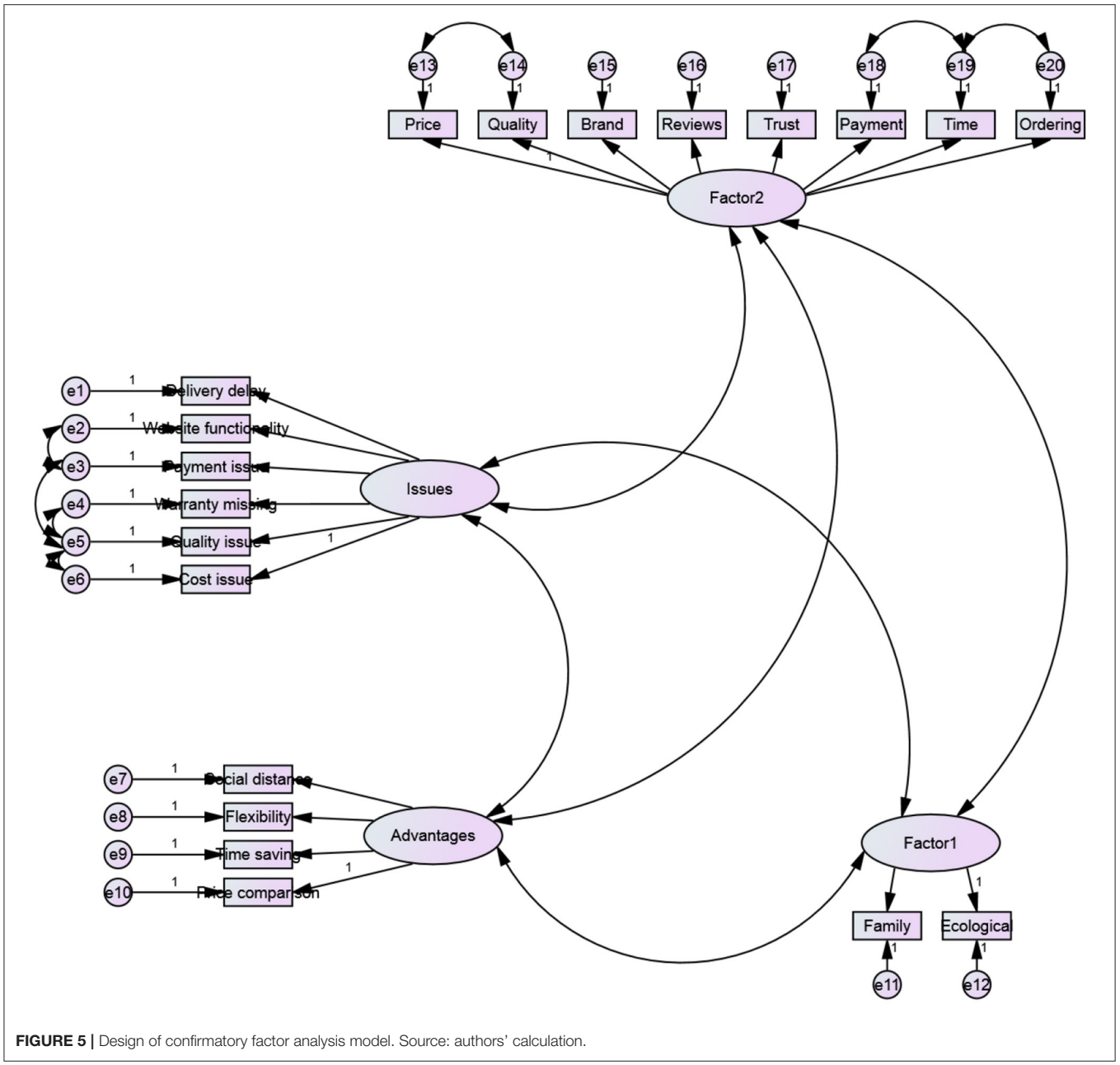

FIGURE 5 | Design of confirmatory factor analysis model. Source: authors' calculation.

the analysis, respectively, consumers with revenues <1,500 Ron ($Coef. = -1.652$, $Sig. < 0.01$), with revenue between 1,500 and 2,500 ron ($Coef. = -1.356$, $Sig. < 0.05$), or with revenue between 2,500 and 3,500 Ron ($Coef. = -1.356$, $Sig. < 0.01$). Instead, we observe that higher revenues lead to better odds of the increase in the value per online purchasing transaction, in the case of the psychological level of revenue of 1,500 Ron ($0.192 - 1 = -0.808 < 0.258 - 1 = -0.742$).

On the other hand, the results of the third model are estimated to show a significant marginal effect of the first and the last factors extracted. However, the construct *psychological and behavioral item*s have a higher impact ($Coef. = 0.257$, $Sig. < 0.05$), compared with the *other items* construct ($Coef. = 0.198$, $Sig. < 0.10$). As noted already from the categorical principal components analysis results, the factors related to feedback received from family and friends are less relevant for the consumers when deciding to increase the value per online purchasing transaction.

Based on results from **Table 6**, we see that the construct of *psychological and behavioral item*s is mostly influenced by the items addressing consumers' perception of the role of product quality (0.742), ordering time (0.773), and delivery time (0.717), with higher loading that some items which were expected to have higher relevance, such as the price factor (0.571), or the

trust on the website (0.583). However, those results do not imply direct implications on consumers' behavior. The principal components analysis better describes the components extracted from the items for which respondents have expressed opinions with higher variance in the sample. Therefore, those results show that items mentioned above are more perceived as mandatory requirements, which are already expected from the consumers to be of a satisfactory level, with the premises of competitive prices, sufficiently diverse offers on the market, and highly exigent national regulation that sanction misconduct such as e-commerce fraud.

Controlling the results for the effect of consumers' profiles, we observe the fourth model estimated that the results increase slightly but determine a similar positive effect on the odds that consumers would increase the value per online purchasing transactions in the future.

Instead, the respondents' profile seems to generate a different impact, as the gender ($Coef. = -0.572 > -0.979$, $Sig. < 0.05$) and the fact that the consumer is a student ($Coef. = -1.836 > -2.846$, $Sig. < 0.05$) have a lower impact on the odds of increasing the value per transaction. A similar negative lower impact on the odds of increasing the value per transaction concerns the different levels of revenue characterizing the consumers' profile.

Therefore, in the context of the COVID-19 pandemic, women have realized the need for e-commerce, even if they were somehow forced by the restrictions implemented to ensure social distance, despite their customs for traditional purchasing behavior, which involves including the need for social interaction during shopping sessions. Similar negative results concern as well-consumers' behavior that is conditioned by the type of activity they perform, but with a lower negative impact for both the employees ($Coef. = -0.88 > -1.836$, $Sig. < 0.10$) and the group of others ($Coef. = -1.299 > -1.836$, $Sig. < 0.10$), compared with the effect valid for the students.

TABLE 8 | Statistics on variation reflected by factors extracted with CATPCA.

	Ideal threshold (Hair et al., 2019)	Stat.	Stat.	Resolution
CFI	>0.95	0.929	0.947	Moderate
RMSEA	<0.10	0.066	0.06	Moderate
SRMR	<0.07	0.052	0.052	Moderate
Cmin/df	<3	2.44	2.217	Good

Source: authors' calculation.

Evaluation of the Marginal Effect on the Likelihood of Future e-Commerce Transactions

In **Table 12**, we present the statistics of the econometric model estimated to describe the association between the factors extracted and the option for a future increase in expenses allocated for online purchasing transactions. The period analyzed is this time related to the period during the COVID-19 pandemic.

As in the case of models estimated in **Table 12**, the models estimated in **Table 12** show a similar impact of respondents' profiles on the odds they would choose in the future to increase their interest in e-commerce. Similar to the other models is the insignificant effect of the construct advantages.

TABLE 9 | CFA model discriminant validity.

Period	Factor	Other items	Issues	Advantages	Psycho. factors
Prior COVID-19 pandemic	Other items	**0.727**			
	Issues	0.190	**0.658**		
	Advantages	0.540	0.160	**0.841**	
	Psychological factors	0.659	0.182	0.370	**0.662**
During COVID-19 pandemic	Other items	**0.845**			
	Issues	0.094	**0.669**		
	Advantages	0.553	0.100	**0.933**	
	Psychological factors	0.633	−0.005	0.328	**0.814**

Source: authors' calculation.

TABLE 10 | CFA internal consistency.

Factor	Cron. Alpha	CR	AVE	MSV	Cron. Alpha	CR	AVE	MSV
Ideal threshold		>0.7	>0.5			>0.7	>0.5	
Other items	0.707	0.898	0.528	0.434	0.044	0.952	0.714	0.401
Issues	0.800	0.820	*0.433*	0.036	0.775	0.828	*0.448*	0.010
Advantages	0.763	0.906	0.708	0.292	0.599	0.964	0.871	0.306
Psychological factors	0.869	0.599	0.438	0.434	0.881	0.792	0.663	0.401

Source: authors' calculation.

TABLE 11 | GLM regression model statistics.

Period	Prior COVID-19 pandemic				During COVID-19 pandemic			
Model	**(1)**		**(2)**		**(3)**		**(4)**	
	Coef.	**Effect**	**Coef.**	**Effect**	**Coef.**	**Effect**	**Coef.**	**Effect**
Psychological and behavioral items	0.103	1.108	0.177	1.194	0.275**	1.317	0.389*	1.475
	0.117	–	0.122	–	0.114	–	0.121	–
Advantages	−0.067	0.935	−0.098	0.907	0.039	1.039	0.052	1.053
	0.104	–	0.107	–	0.103	–	0.106	–
Other items	0.096	1.101	0.074	1.077	0.198***	1.219	0.279**	1.321
	0.103	–	0.107	–	0.108	–	0.116	–
Control variable								
Gender								
Female	–		−0.979*	0.376	–		−0.572**	0.565
		0.2369	–		0.234			
Activity								
Student	–		−2.846**	0.058	–		−1.836**	0.159
		1.0093	–		0.916	–		
Others	–		−0.665	0.514	–		−1.299**	0.273
		0.5793	–		0.589	–		
Employee	–		−0.743	0.476	–		−0.880***	0.415
			0.5207	–			0.530	–
Revenue								
<1,500		–	−1.652*	0.192		–	−0.996**	0.369
		0.482		–			0.466	–
1,500–2,500		–	−1.356**	0.258		–	−1.375*	0.253
		0.429		–			0.417	–
2,500–3,500		–	−1.356*	0.258		–	−1.273*	0.280
		0.408		–			0.378	–
Model validation								
Omnibus test								
Chi-Square	–	2.198	–	60.53	–	9.694	–	69.22
Df		3		16		3		16
Sig.		0.532		0.000		0.021		0.000
Pearson chi-square								
Value	–	1,220.4	–	1,316.6	–	1,242.4	–	1,159.9
Df		1,189		1,200		1,189		1,200
Value/df		1.026		1.097		1.045		0.967
AIC	–	856.9	–	830.9	–	835.8	–	806.7

*, **, *** *indicates significance at 1, 5, and 10%, respectively. Source: authors' calculation.*

However, the effect of gender on consumers' decision to increase their interest in e-commerce in the future is not statistically significant anymore. It has been confirmed in the case of its role in increasing the odds of an increase in value per transaction. Similar, the only statistically significant effect of the level of revenue is valid only in the case of the consumers with revenues between 2,500 and 3,500 Ron, meaning that only consumers with a higher level of revenue show interest in future e-commerce. The results indirectly suggest that respondents are still reluctant concerning e-commerce, as lower revenue levels do not translate into consumers' favorable opinions concerning future interest in e-commerce.

Overall, the results show that only psychological and behavioral factors influence consumers' decision to increase their interest in e-commerce in the future. The positive impact of constructed *psychological and behavioral items* determines an increase in the odds that future consumers would continue to buy products and services online, even increasing expenses for such purchasing transactions ($Coef. = 0.472$, $Sig. < 0.01$), even after controlling the results for consumers' profile fixed effects ($Coef. = 0.539$, $Sig. < 0.01$). Analyzing together the results in the fourth model estimated and the results in the sixth model, we appreciate that the current context of the COVID-19 pandemic has raised consumers' interest in e-commerce, which is expected

TABLE 12 | GLM regression model statistics.

Factor	Coef.	Effect	Coef.	Effect
Model	**(5)**		**(6)**	
Psychological and behavioral items	0.472*	1.604	0.539*	1.714
	0.118		0.125	
Advantages	−0.115	0.891	−0.100	0.905
	0.106		0.109	
Other items	0.151	1.163	0.174	1.191
	0.109		0.114	
Control variable				
Area				
Rural	–	−1.886***	0.152	
		0.970	–	
Activity				
Student	–	−1.886***	0.152	
		0.970	–	
Revenue				
2,500–3,500	–	−0.641***	0.527	
		0.376	–	
Model validation				
Omnibus test				
Chi-Square	–	19.63	–	44.80
df		3		16
Sig.		0.000		0.000
Pearson chi-square				
Value	–	1,207.0	–	1,286.7
df		1,189		1,200
Value/df		1.015		1.072
AIC	–	866.7	–	871.1

*, **, *** *indicates significance at 1, 5, and 10%, respectively. Source: authors' calculation.*

to lead to exponentially increasing volumes and values per online purchasing transactions.

Consequently, we can validate hypothesis **H1:** *Psychosocial factors influence the decision to conduct e-commerce transactions*. Only for some groups of respondents, did consumers significantly influence the value per transaction profile characteristics.

Additionally, we see a lower chance that consumers increase their interest in e-commerce in the future ($Coef. = -1.886$, $Sig. < 0.10$), which might be caused either by bad internet connection, reluctance, or the lack of information on the use of recent information technologies, such as the use of online payments. Nonetheless, as long as advertising campaigns do not penetrate enough the potential customers from rural areas, the future of e-commerce is not expected to increase drastically, despite the benefits of time-saving and transport cost savings.

Consequently, we can partially validate the hypothesis **H2:** *The consumer profile influences the decision to carry out e-commerce transactions*, as only for some groups of respondents does the chance in favor of e-commerce increase, based on some consumers' profile characteristics, this time only in case of consumers' area and the type of activity they perform.

The results suggest that we cannot validate the third hypothesis **H3**: *A good awareness of the advantages of e-commerce transactions influences such transactions*, as in all models estimated concerning the chance to change consumers' preferences in favor of e-commerce, regression coefficients are not statistically significant.

CONCLUSION

The pandemic period has substantially changed the life we considered normal, and people have learned that to cope with the rules of the "new normal" they must adapt and learn how to socialize, work, and purchase necessary goods in uncertain times.

Digitization played an important role during this period as most activities were transposed online due to the restrictive measures imposed to limit the spread of the novel coronavirus. Alongside digitalization, the e-commerce segment registered a spectacular development because of the fear of infection with a virus about which not much was known and physical store closures. Consumers started to do online shopping. Still, it is interesting to know what influences their buying decisions,

namely *Psychosocial factors that influence the decision to conduct e-commerce transactions? Does the consumer profile influence the decision to carry out e-commerce transactions?* A *good awareness of the advantages of e-commerce transactions influences such transactions?* Our paper reveals that consumers' decision to buy products and services online is highly dependent on the quality of products and services and the trust in the traders. The context of the COVID-19 pandemic showed an increase in consumers' opinion on how important factors such as product quality, trust in online traders, product, and service pricing, or even delivery time or ordering time are. Also, the influence of family or friends, reviews provided by other customers, consideration of sustainable consumers' preferences, or perception of product and service brands are less relevant for online buying.

Also, our research highlights that the number of transactions and the value per transaction increased during the COVID-19 pandemic and concludes that online purchases will continue so even after the pandemic.

Hence, in the context of the pandemic generated by the novel coronavirus, e-commerce has become the lifebelt for many traditional stores, which have had to implement or expand online sales quickly, click and collect shopping, or home delivery services. Also, the restrictions have highlighted that access to local services and closer collaboration with local producers are essential to continue the activity even when the traditional supply chain is stopped. Thus, when designing their marketing and product portfolio management strategies and policies, firms must consider the lessons offered by the pandemic that has highlighted that both people and businesses must adapt to the new normal of nowadays if they want to ensure continuity of performance and sustainability over time.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

REFERENCES

Abdullah, M. I., Huang, D., Sarfraz, M., Ivascu, L., and Riaz, A. (2021). Effects of internal service quality on nurses' job satisfaction, commitment and performance: mediating role of employee well-being. *Nurs. Open* 8, 607–619. doi: 10.1002/nop2.665

Abdullah, M. I., Sarfraz, M., Arif, A., and Azam, A. (2018). An extension of the theory of planned behavior towards brand equity and premium price. *Polish J. Manag. Stud.* 18, 20–32. doi: 10.17512/pjms.2018.18.1.02

Ajaz, A., Shenbei, Z., and Sarfraz, M. (2020). Delineating the influence of boardroom gender diversity on corporate social responsibility, financial performance, and reputation. *Logforum* 16, 61–74. doi: 10.17270/J.LOG.2019.376

Alessa, A. A., Alotaibie, T. M., Elmoez, Z., and Alhamad, H. E. (2021). Impact of COVID-19 on entrepreneurship and consumer behaviour: a case study in Saudi Arabia. *J. Asian Fin. Econ. Bus.* 8, 201–210. doi: 10.13106/jafeb.2021.vol8.no5.0201

Baker, S. R., Bloom, N., Davis, S. J., Kost, K., Sammon, M., and Viratyosin, T. (2020). The unprecedented stock market reaction to COVID-19. *Rev. Asset Pric. Stud.* 10, 742–758. doi: 10.1093/rapstu/raaa008

Barczak, A., Dembińska, I., Rostkowski, T., Szopik-Depczyńska, K., and Rozmus, D. (2021). Structure of remuneration as assessed by employees of the energy sector—multivariate correspondence analysis. *Energies* 14, 7472. doi: 10.3390/en14227472

Blasius, J., and Theessen, V. (2012). *Assessing the Quality of Survey Data*. London: SAGE Publications Ltd. doi: 10.4135/9781446251874

Cosmulese, C. G., Socoliuc, M., Ciubotariu, M., Kicsi, R., and Grosu, V. (2021). Optimization model for sustainable food supply based on consumer behaviour typology. The case of the chisinau urban area. *Argum. Oecon.* 1, 239–280. doi: 10.15611/aoe.2021.1.11

Deng, W., Su, T., Zhang, Y., and Tan, C. (2021). Factors affecting consumers' online choice intention: a study based on bayesian network. *Front. Psychol.* 12, 731850. doi: 10.3389/fpsyg.2021.731850

DiStefano, C., and Hess, B. (2005). Using confirmatory factor analysis for construct validation: an empirical review. *J. Psychoeduc. Assess.* 23, 225–241. doi: 10.1177/073428290502300303

DiStefano, C., McDaniel, H. L., Zhang, L., Shi, D., and Jiang, Z. (2019). Fitting large factor analysis models with ordinal data. *Educ. Psychol. Measure.* 79, 417–436. doi: 10.1177/0013164418818242

Eger, L., Komárková, L., Egerová, D., and Mičík, M. (2021). The effect of COVID-19 on consumer shopping behaviour: generational cohort perspective. *J. Retail. Consum. Serv.* 61, 102542. doi: 10.1016/j.jretconser.2021.102542

EU (2020). *European Union—COVID-19 Restriction Measures*. EU. Available Online: https://reliefwebint/map/italy/european-union-covid-19-restriction-measures-dg-echo-daily-map-20042020 (accessed December 12, 2021).

Eurostat (2021). *E-Commerce Statistics for Individuals*. Eurostat. Available online at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=E-commerce_statistics_for_individuals&oldid=551451 (accessed December 14, 2021).

Fedushko, S., and Ustyianovych, T. (2022). E-Commerce customers behavior research using cohort analysis: a case study of COVID-19. *J. Open Innov. Technol. Market Compl.* 8, 12. doi: 10.3390/joitmc8010012

Garson, D.G. (2021). *Data Analytics for the Social Sciences. Applications in R.* London: Routledge. doi: 10.4324/9781003109396

Greenacre, M. (2007). *Correspondence Analysis in Practice, 2nd edn.* New York, NY: Chapman and Hall; Taylor and Francis Group.

Gu, S., Slusarczyk, B., Hajizada, S., Kovalyova, I., and Sakhbieva, A. (2021). Impact of the covid-19 pandemic on online consumer purchasing behavior. *J. Theor. Appl. Electro. Comm. Res.* 16, 2263–2281. doi: 10.3390/jtaer16060125

Guthrie, C., Fosso-Wamba, S., and Arnaud, J. B. (2021). Online consumer resilience during a pandemic: an exploratory study of e-commerce behavior before, during and after a COVID-19 lockdown. *J. Retail. Consum. Serv.* 61, 102570. doi: 10.1016/j.jretconser.2021.102570

Hair, J.F. Jr., Black, W.C., Babin, B.J., and Anderson, R.E. (2019). *Multivariate Data Analysis, 8th edn*. Hampshire: Cencage.

Hanus, G. (2016). "Consumer behavior during online grocery shopping," *CBU International Conference on Innovations in Science and Education* (Prague: Central Bohemia University). doi: 10.12955/cbup.v4.737

Hesham, F., Riadh, H., and Sihem, N. K. (2021). What have we learned about the effects of the COVID-19 pandemic on consumer behavior? *Sustainability* 13, 4304. doi: 10.3390/su13084304

Kalia, P., Kaur, N., and Singh, T. (2016). A review of factors affecting online buying behavior. *Apeejay J. Manag. Technol.* 11, 58–73. doi: 10.29385/APEEJAY.11.2.2016.58-73

Király, O., Potenza, M. N., Stein, D. J., King, D. L., Hodgins, D. C., Saunders, J. B., et al. (2020). Preventing problematic internet use during the COVID-19 pandemic: consensus guidance. *Comprehen. Psychiatry* 100, 152180. doi: 10.1016/j.comppsych.2020.152180

Kirk, C. P., and Rifkin, L. S. (2020). I'll trade you diamonds for toilet paper: Consumer reacting, coping and adapting behaviors in the COVID-19 pandemic. *J. Bus. Res.* 117, 124–131. doi: 10.1016/j.jbusres.2020.05.028

Koch, J., Frommeyer, B., and Schewe, G. (2020). Online shopping motives during the COVID-19 pandemic—lessons from the crisis. *Sustainability* 12, 10247. doi: 10.3390/su122410247

Kurtisi, H., and Alver, M. (2021). *Online Consumer Behaviour During a Pandemic: A Study on the Effects of Covid-19 on Online Consumers in Sweden*. (Master Thesis in Business Administration) JÖNKÖPING: Sweden.

Linting, M., and van der Kooij, A. (2012). Nonlinear principal component analysis with CATPCA: a tutorial. *J. Pers. Assess.* 94, 12–25 doi: 10.1080/00223891.2011.627965

Loxton, M., Truskett, R., Scarf, B., Sindone, L., Baldry, G., and Zhao, Y. (2020). Consumer behaviour during crises: preliminary research on how coronavirus has manifested consumer panic buying, herd mentality, changing discretionary spending and the role of the media in influencing behaviour. *JRFM* 13, 166. doi: 10.3390/jrfm13080166

Lv, J., Wang, Z., Huang, Y., Wang, T., and Wang, Y. (2020). How can E-commerce businesses implement discount strategies through social media? *Sustainability* 12, 7459. doi: 10.3390/su12187459

Mason, A., Narcum, J., and Mason, K. (2020). Changes in consumer decision-making resulting from the COVID-19 pandemic. *J. Cust. Behav*. 19, 299–321. doi: 10.1362/147539220X16003502334181

Meulman, J. J., van Der Kooij, A.J., and Heiser, W.J. (2004). "Principal components analysis with nonlinear optimal scaling transformations for ordinal and nominal data," in *The SAGE Handbook of Quantitative Methodology for the Social Sciences*, ed. D. Kaplan (Thousand Oaks, CA: SAGE Publishing), 49–70.

Peighambari, K., Sattari, S., Kordestani, A., and Oghazi, P. (2016). Consumer behavior research: A synthesis of the recent literature. *Sage Open* 6, 1–9. doi: 10.1177/2158244016645638

Pollák, F., Konečný, M., and Ščeulovs, D. (2021). Innovations in the management of E-commerce: analysis of customer interactions during the COVID-19 pandemic. *Sustainability* 13, 7986. doi: 10.3390/su13147986

Prentice, C., Chen, J., and Stantic, B. (2020). Timed intervention in COVID-19 and panic buying. *J. Retail. Consum. Serv*. 57, 102203. doi: 10.1016/j.jretconser.2020.102203

Rai, P. (2021). Consumers buying behavior and challenges faced by consumers during COVID-19 pandemic regarding FMCG products (during Indian lockdown). *Turk. J. Comput. Math. Educ.* 12, 3403–3412. doi: 10.17762/turcomat.v12i10.5015

Rao, Y. H., Saleem, A., Saeed, W., and UlHaq, J. (2021). Online consumer satisfaction during COVID-19: perspective of a developing country. *Front. Psychol*. 12, 751854. doi: 10.3389/fpsyg.2021.751854

Sarfraz, M., Qun, W., Shah, S. G. M., and Fareed, Z. (2019). Do hierarchical jumps in CEO succession invigorate innovation? Evidence from Chinese economy. *Sustainability* 11, 2017. doi: 10.3390/su11072017

Shah, S. G. M., Sarfraz, M., Fareed, Z., Rehman, M. A., ur, Maqbool, A., and Qureshi, M. A. A. (2019). Whether CEO succession via hierarchical jumps is detrimental or blessing in disguise? Evidence from Chinese listed firms. *Zagreb Int. Rev. Econ. Bus*. 22, 23–41. doi: 10.2478/zireb-2019-0018

Shehzad, K., Xiaoxing, L., Sarfraz, M., and Zulfiqar, M. (2020). Signifying the imperative nexus between climate change and information and communication technology development: a case from Pakistan. *Environ. Sci. Pollut. Res.* 27, 30502–30517. doi: 10.1007/s11356-020-09128-x

Sirimanne, S.N. (2021). *COVID-19 and E-Commerce: A Global Review. UNCTAD and eTrade Global Review*. Available Online at: https://unctad.org/system/files/official-document/dtlstict2020d13_en_0.pdf (accessed December 15, 2021).

Sumarliah, E., Khan, S.U., and Khan, I.U. (2021). Online hijab purchase intention: the influence of the Coronavirus outbreak. *J. Islam. Mark*. 12, 598–621. doi: 10.1108/JIMA-09-2020-0302

UN (2020). *A UN Framework for the Immediate Socio-Economic Response to COVID-19*, Available online at: https://unsdg.un.org/resources/un-framework-immediate-socio-economic-response-covid-19 (accessed December 20, 2021).

Valaskova, K. (2021). Changes in consumers' purchase patterns as a consequence of the COVID-19 pandemic. *Mathematics* 9, 1–17. doi: 10.3390/math9151788

Vijay, V., Thoppan, J., Jeyakumar, R., and Fekete, M. (2018). Factors influencing consumer behavior and prospective purchase decisions in a dynamic pricing environment—an exploratory factor analysis approach. *Soc. Sci*. 7, 153. doi: 10.3390/socsci7090153

WHO (2020). *Virtual Press Conference on COVID-19-−11 March 2020*. Available Online at: https://www.who.int/docs/default-source/coronaviruse/transcripts/who-audioemergencies-coronavirus-press-conference-full-and-final-11mar2020.pdf?sfvrsn=cb432bb3_2 (accessed December 12, 2021).

Zhang, X. (2021). Research jungle on online consumer behaviour in the context of web 2.0: traceability, frontiers and perspectives in thepost-pandemic era: traceability, frontiers and perspectives in the post-pandemic era. *J. Theor. App. Electr. Comm. Res.* 16, 1740–1767. doi: 10.3390/jtaer16050098

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Corporate Disclosures in Pandemic Times. The Annual and Interim Reports Case

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ABSTRACT

The paper examines if COVID-19 crisis has brought changes in companies' approach on corporate reporting, with focus on annual reports. The research method is based on text mining techniques in order to build measures of readability and tone of uncertainty of annual reports, given the information published by the companies listed on four stock exchanges from Europe, namely the Bucharest Stock Exchange, ATHEX Stock Exchange, IBEX-35, and WIG-20 between 2017–2020. Findings emphasize, through text mining, multivariate analysis, and topic modeling, that the analyzed reports are less extensive in times of pandemic and tend to become more generic. Among firms' financial performance metrics considered in our models, we found that there is a significant association only between annual reports textual characteristics and respectively, firm size, price earnings ratio and accruals reported. We prove as well significant stock exchange effects and industry effects. Our results show a slight decrease in annual reports readability, while the tone of uncertainty is more prominent within firms listed on less mature stock exchanges.

KEYWORDS
COVID-19; financial reporting; economic crisis; disclosures; textual analysis

JEL
G34; H12; M41; M42

1. Introduction

The novel coronavirus caused a vast economic decline worldwide. This new context has seriously affected the daily businesses and operations of companies and highlighted the need for better communication and disclosure policies with shareholders and other stakeholders. In this sense, the annual report remains one of the main drivers of communication that companies have with their interested parties regarding the company's performance and, most important, the company's ability to continue as a going concern in an environment marked by uncertainty.

As noted by Leuz and Wysocki (2016), disclosures represent an ideal tool for reduction of information asymmetry between managers and firms' shareholders and stakeholders. However, benefits of higher financial transparency is strongly conditioned by the nature of the disclosures and the content. Instead, under the premises of integrated or sustainability reporting frameworks, managers have started using annual report as powerful marketing tools for the firms they lead, with the scope of signaling positive effects on the market and having benefits, such as lower cost of capital (Christensen, Hail, and Leuz 2019).

In times of crisis, annual reports become even more important, as they represent the main tool for managers to communicate financial results to shareholders and stakeholders as well. However, the focus is oriented toward risk management disclosure and presentation of macroeconomic context that might affect forward-looking information. Those directions lead to

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a change in the tone of annual reports, which is expected to be more negative, showing that accounting estimated reported is highly affected by external factors, and less by managers' ability (Oskouei and Sureshjani 2021).

Furthermore, managers could choose to prepare obfuscated annual reports, to hide as much as possible potential future evolutions of financial performance, to avoid transmitting any negative signal to the market, as during COVID-19 pandemic period shares liquidity has become significantly volatile (Hatmanu and Cautisanu 2021). Moreover, capital markets' systemic impact of COVID-19 becomes globally contagious, especially under uncertain conditions, when news attention negative impact on financial markets is higher than investors' rational expectation (Engelhardt et al. 2020).

Our aim in this paper is to bring some insights on the changes in the annual reports characteristics, determined by the current COVID-19 pandemic crisis. In this context, the focus of our paper is the analysis of firm-specific financial determinants on annual reports readability and tone of uncertainty of entities listed on four stock exchanges, including Bucharest Stock Exchange (BSE) and ATHEX, two stock exchanges that recorded the highest growth in the world, considering the evolution of stock markets in 87 countries with available data (Wall Street 2019). According to the ranking published by FTSE Russell in September 2020, Romania and Greece are included in the emerging markets category. In order to compare the data, we included in the study the stock exchanges from Spain and Poland, respectively the entities listed on IBEX-35 and WIG −20, classified by FTSE Russell among the developed stock markets (FTSE 2020).

Our article comes with additional insights within the literature. It adds empirical evidence on the area of analysis of readability of annual reports and sentiment analysis, for annual reports made public by firms listed on European capital markets. To our knowledge, only Lang and Stice-Lawrence (2015) analyzed another sample of European companies. It also fills in the gap on the literature by analysis annual reports, as most of the literature is limited to the 10-K disclosure analysis published by American companies. The article is the first to analyze the effect of COVID-19 on annual reports. Only Wang and Xing (2020) analyzed the effect of COVID-19 on corporate conference calls and management announcements. Nonetheless, as of our knowledge, it is the first study that addresses the problem of topic modeling on annual reports disclosed by firms listed in the four European capital markets considered in the study, to arise issues related to the risk of generic disclosures, in the context of actual COVID-19 pandemic.

This paper is structured as follows: Section 2 presents the literature review and the hypothesis development, testing the ways in which corporate disclosures are influenced by the novel coronavirus context; Section 3 presents the research methodology, Section 4 discusses the results obtained, and Section 5 summarizes the main findings, conclusions, and avenues for future research directions.

2. Literature Review

The pandemic and its effects represent a topic of great interest because many view the COVID-19 outbreak as an unprecedented event that the world has witnessed since the inception of the stock markets. COVID-19 affected the activity of companies from all business sectors, being considered an event similar to the financial crisis that began in 2008 (Wang and Xing 2020). Much has been written about the crisis, authors providing insights and perspectives, most agreeing that in uncertain times some accounting techniques used in financial reporting led to its deepening. Hence, in this novel coronavirus crisis it is interesting to study how firm's financial reports are elaborated and released into the market, to mitigate the negative impact of a pandemic on firm's performance before shareholders and stakeholders.

Overall, the literature shows that over time, the length of annual reports has increased (Dyer, Lang, and Stice-Laurence 2017; Lang and Stice-Lawrence 2015). Those premises lead to changes in the length of the annual reports, because of complexity of models used for accounting estimates (Lim, Chalmers, and Hanlon 2018).

In the current context, telling the story of COVID-19 through annual reports implies more professional judgments, that lead to lengthier annual reports, aimed to describe properly postulates, assumptions, and methods used in accounting estimation and financial reporting. Gould and Arnold (2020) stated that some companies tend to report financial effects of the pandemic through interim financial statements first, which involves a greater use of accounting estimates. Therefore, we believe that these new elements that need to be highlighted in the annual reports, given the current pandemic context, will require more robust and detailed corporate disclosures and the first hypothesis that will be tested will be ***H_1***: *in the context of COVID-19 pandemic restrictions, firms' financial characteristics determine significant changes in the length of annual reports.*

However, as noted by Dyer, Lang, and Stice-Laurence (2017), the literature underlines a trend of increasing length of annual reports, in parallel with deterioration of readability and increase of tone of ambiguity.

Researchers highlight that performing entities disclose readable reports in order to impress (Li 2008). Moreover, there are studies that show a positive correlation between managerial ability and annual reports readability, especially in case of firms reporting positive profitability (Hasan 2020). There are also studies that show readability and complexity of annual reports are significantly driven by the accounting standards (Dyer, Lang, and Stice-Laurence 2017). The increase in innate component (common complexity) of reporting complexity (readability) is mainly driven by accounting regulation (Dyer, Lang, and Stice-Laurence 2017; Efretuei 2020), while the increase of obfuscation (uncommon complexity) is more associated to management choice that depends mainly on capital markets incentives (Li 2008; Loughran and McDonald 2013; Miller 2010) and investors disclosure choices. Through more complex and less readable disclosures, managers tend to hide poor performance, by amplifying annual reports obfuscation (Li 2008; Lo, Ramos, and Rogo 2017), with impact on firms' cost of capital (Ertugrul et al. 2017).

Therefore, we believe that the readability of the annual and interim reports is influenced by the COVID-19 pandemic and the second hypothesis that will be tested will be ***H_2***: *in the context of COVID-19 pandemic restrictions, firms' financial characteristics determine significant changes in the readability of annual reports.*

Given the importance of making accurate disclosures, reporting in times of uncertainty represents a major challenge. Considering that COVID-19 pandemic negatively impacted companies around the world, the approach by which the "bad news" are disclosed into the market through annual and interim reports represents a topic of great interest. The way the information is presented and structured is essential to ensure significant impact on investors' decision, especially through the lens of impression managements techniques, as some strategies are aimed to obfuscate bad news, while most of them are designed to emphasize good news (Merkl-Davies and Brennan 2017).

The tone of the discourse used when preparing annual reports is also important, as behavioral theories show that negative words have a higher impact compared with the positive words (Tetlock, Saar-Tsechansky, and Macskassy 2008). Consequently, the positive bag-of-words are preferred by managers when preparing annual reports. However, there is little evidence on studying the tone of uncertainty of annual reports in the literature, as researchers focus more on either the use of dichotomous positive versus negative predefined lists of words (Loughran and McDonalld 2016), or the use of ambiguous words (Dyer, Lang, and Stice-Laurence 2017; Ertugrul et al. 2017).

Loughran and McDonald (2011) have shown that managers present information on a more positive tone in the annual reports, which is more likely associated with negative stock returns. Davis et al. (2015) noted as well that managers have incentives to set-up their optimistic or pessimistic tone on corporate communication of firms' results, especially when these information are more sensitive to stock prices, reflecting that the tone of disclosures became negative only after the financial crisis from 2008. However, Wang and Xing (2020) have shown, referring to annual reports related to the COVID-19 pandemic period, that low level of uncertainty tone in the earnings announcements has been made by the management.

Therefore, we believe that now, more than ever, in this uncertain times generated by the COVID-19 pandemic, managers should avoid negative or ambiguous words when reporting the consequences of the global pandemic through annual statements and the third hypothesis that will be tested will be ***H_3***: *the novel coronavirus created a context marked by uncertainty that has a significant influence on disclosure tone of the annual reports.*

Efretuei (2020) has shown that the tone of uncertainty of annual reports is negatively related to the corresponding readability, showing that managers prefer to amplify the obfuscation information, by using more words related to uncertainty and ambiguity, describing an increasing trend of this negative relation overtime. In the actual context of COVID-19 pandemic crisis, the issue of information asymmetry, through its components of moral hazard and adverse selection that arise, is highly condoned by industry-specific and domestic institutional framework as well.

Over time, economies have become increasingly interconnected and interdependent, which has exacerbated the crisis. In this context, it is vital that the information transmitted by companies into the market to be transparent and real so that the business environment could mitigate the negative impact of a pandemic on firm's performance.

3. Methodology Research

3.1. Sample Data

Our research methodology is similar to Lang and Stice-Lawrence (2015). The focus of the paper is the analysis of firm-specific determinants in annual and interim reports readability and keywords frequency, considering the period between 2017 and the first quarter of 2020, as depicted in Figure 1.

In order to emphasize local specifics of institutional and cultural framework, we used a sample that consists of firms listed on different European capital markets, respectively the Romanian capital market (BSE), Greek capital market (ATHEX), the Spanish capital market (IBEX-35), and Polish capital market (WIG-20), as depicted in Table 1.

Annual reports and interim reports were downloaded manually from firm's websites, or capital markets websites where they are listed. Overall, we included in our analysis 524 observations, controlling for industry effects and capital markets effects as well. The data are split into two main groups, namely data related to period before COVID-19 crisis, concerning period 2017 to 2018, and respectively data related to period during COVID-19 crisis, concerning period 2019–2020.

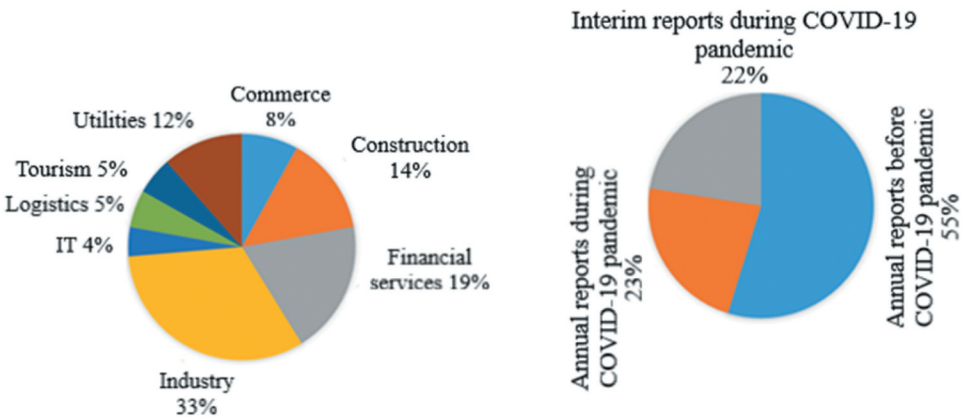

Figure 1. Sample distribution per sector and per nature of report. Source: own projection.

Table 1. Sample distribution on capital markets and years.

Capital market Firms included on sample	ATHEX	BSE	IBEX	WIG	Cluster period
2017	18	78	30	18	*Before COVID-19 pandemic*
2018	19	77	29	18	
2019	16	78	12	13	*During COVID-19 pandemic*
2020	16	77	12	13	
Invalid format of reports	23	2	41	22	
Total reports analyzed	69	310	83	62	

Source: Own projection.

3.2. Variables Definition

The data used in econometric models estimated in our study consist of some key financial performance indicators and several characteristics of the annual reports, as described in Table 2, determined based on annual reports and output generated running text mining procedures.

3.3. Construction of the Linear Regression Models

The regression model used to test the hypotheses related to annual reports characteristics has the following configuration:

$$Disclosure_{characteristics\,it} = \alpha_0 + \sum_{k=1}^{6} \alpha_k \cdot Financial_{indicator\,it} + \varepsilon_{it} \tag{1}$$

where $Financial_{indicator\,it}$ represents the financial measures of firms' characteristics, respectively *ROA, Leverage, Accruals* and *Size, Growth* and *PER* as defined in Table 2, while $Disclosure_{characteristics\,it}$ reflects each of the dependent variables defined in Table 2, respectively, *Length, Readability* and *Uncertainty*.

Estimation of the econometric models is made using the OLS method. However, in order to control for potential implications of probability distribution of independent variables, we estimate the econometric models looking for firm financial drivers using the quantile regression method as well, with focus on 1st quantile estimates, 2nd quantile estimates, and respectively 3rd quantile estimates (Wooldridge 2010).

For reliability purpose, we proceed to results triangulation, by using an alternative measure of readability of annual reports, considering the Flesch reading ease score, which is determined based on formula $FRE = 206.835 - 1.015 \cdot \frac{total\ words}{total\ sentences} - 84.6 \cdot \frac{total\ syllables}{total\ words}$. A higher *FRE* score means better readability of annual reports. Therefore, this alternative measure of document readability is the opposite of the main readability measure of our study, which consists of number of words per sentence.

To illustrate specifics of each area of activity on financial disclosures characteristics, we control our model for fixed effects as well, as described in econometric model below:

$$Disclosure_{characteristics\,it} = \beta_0 + \sum_{k=1}^{6} \alpha_k \cdot Financial_{indicator\,it} + \sum_{l=1}^{5} \alpha_{l+6} \cdot Corporate\ governance_{indicator\,it} + \sum_{m=1}^{8} \alpha_{m+12} \cdot Industry\ effects_{lt} \tag{2}$$

where $Industryeffects_{lt}$ reflects the fixed/random specific effects of each area of activity analyzed. Additionally, we look for impact of corporate governance metrics that describe better firms' institutional particularities designed to look for the quality of financial reports.

Table 2. Variables definition.

Category	Name	Description
Dependent variables	Length	Similar to Lang and Stice-Lawrence (2015) and Dyer, Lang, and Stice-Laurence (2017) papers, we consider the number of pages per each annual report included in our analysis as a measure of disclosure transparency; the measure reflects the logarithm of the number of pages of each annual report analyzed.
	Readability	As noted by Dyer, Lang, and Stice-Laurence (2017), the measure of readability, together with the measure of complexity of financial disclosures, represents a mean of analyzing annual reports understandability; the score is determined as the average number of words per sentence, per each annual report.
	Uncertainty	Similar to Wang and Xing (2020) paper, using the word list developed by Loughran and McDonald (2011), we determined weight of words related to uncertainty, on the number of total tokens (with number of characters between 4 and 25) extracted from analyzed annual reports and steamed; there are also alternative solutions to measure sentiment analysis on documents, as emerging computational text mining models and technologies give the researcher the possibility to get more detailed information, relevant for identifying the dimensions of each bag-of-words that offer currently a narrow perspective on the context the words are used in the text.
Explanatory variables	ROA	Similar to Lang and Stice-Lawrence (2015) and Wang and Xing (2020), we consider in our analysis this performance measure, determined by dividing net income to total assets, based on information disclosed by annual or interim reports.
	Leverage	In line with Ertugrul et al. (2017) we consider firms' cost of capital is significantly influenced by the effect of readability of annual reports; this measure is defined as the ratio between debts and equity reported by firms on their annual reports;
	Accruals	Francis et al. (2005) have underlined the positive relation between firms' earnings quality and disclosures quality, including indirect relation with disclosures readability; additionally, Jaafar and Hussainey (2012) underlined the substitute relation between those two elements, reason why we test if accruals amplitude can influence annual reports length and readability;
	PER	It expresses the price earnings ratio as of year-end reporting; as noted by Miller (2010), the level of financial reports readability is significantly associated with stocks return volatility and indirectly with firms' market liquidity.
	Size	Reflects the size of the firms, using natural logarithm of the total assets as an indicator; the more complex business models are, including the business strategy, the higher is the complexity of financial disclosure and the lower financial disclosures readability (Lim, Chalmers, and Hanlon 2018);
	Growth	As noted by Loughran and McDonalld (2016), managers prefer to set-up their optimistic or pessimistic tone on the annual reports, depending on the nature of the results; this measure, defined by the rate of growth in total assets, shows the effect of restructuration in firms' operations because of COVID-19 pandemic restrictions and the potential of future growth in revenue as well, seen as positive results.
	Corporate governance score	There is a unanimous position on the literature about the role of corporate governance on monitoring for the quality of financial reporting output. Through the composite corporate governance score calculated extracted from Refinitiv database, we check for implications of effective governance mechanisms implemented by firms, on corporate reporting, as a higher governance index is expected to lead to higher quality of annual reports (Leuz and Wysocki 2016). Board of directors with high experience and expertise, efficient function of internal audit, or effective internal controls are just few basic pillars for accurate, clear, and relevant corporate reports.
	Analysts coverage	The number of analysts following firms analyzed is extracted from Refinitiv database. If firms' corporate reports are analyzed by a higher number of analysts, managers are limited on their opportunities to smooth financial performance, leading to higher quality of corporate reports (Leuz and Wysocki 2016). Additionally, to avoid any misunderstanding when analysts decide on their forecasts, managers become more careful on the understandability of annual reports. Otherwise, they are subject to potential negative signals transmitted on the market.
	Fixed effects: - industry - stock market	Variables used to reduce the shock of unobserved features of the industry and institutional framework of stock markets, as those dimensions are significant on designing and preparing financial disclosures (Leuz and Wysocki 2016).

Source: Own projection.

3.4. Entropy Analysis of Annual Reports

In order to measure how uniform extracted topics are addressed in annual reports and if there is a pattern related to industry specific, or capital markets specific, we proceed to Latent Dirichlet Analysis (LDA), in order to extract distinct topics addressed in a text. After performing LDA for different number of topics extracted, we have decided on the extraction of 45 topics from the corpus analyzed, as the value of perplexity score tends to increase less (Hofmann and Klinkenberg 2014).

Each topic extracted from the corpus is characterized by a set of performance metrics. The essential metric considered in our study is the distribution of topics, based on topics coherence obtained for each annual report. The coherence of a topic is the measure whether the words in a topic tend to co-occur together. The larger the value topic coherence the lower the indication that words co-occur in different topics simultaneously. Once determined each topic coherence per each annual report, we calculate the Shannon entropy score, using the relation below:

$$Entropy_{annual\ report_{it}} = -\sum_{k=1}^{n} p_k(x) \cdot \log p_k(x) \tag{3}$$

where $p_k(x)$ is the proportion (coherence metric) from the document that topic k is addressed in annual report disclosed by firm i for year t. The interpretation of this score is that the higher the entropy of an annual report, the more uniformly are addressed in the annual report all topics extracted from the corpus running the LDA. Instead, the lower the score of entropy is, the more attention is given in the annual report to only few topics extracted from the corpus analyzed.

Different extensions of the LDA procedure are used as well to directly link the stock prices with topics addressed in the corporate communications, so that stock returns or firm profitability can be explained easily by related topics extracted from the corpus analyzed (Li et al. 2020).

Our approach is similar with Dyer, Lang, and Stice-Laurence (2017) that have explained the length of the first three topics by firms' financial characteristics and annual reports textual characteristic as well. However, in this study we do not focus on explaining length of topics extracted from annual reports, but rather on justifying annual reports readability by the diversity of topics addressed.

4. Results and Discussion

4.1. Descriptive Statistics

In Table 3 we summarize the descriptive statistics for the sample analyzed, considering two separate panels of data, respectively. **Panel A** that consists of data analyzed related to period 2017 to 2018 and **Panel B** including data analyzed related to period 2019 to 2020. We observe that there is spread in the practice of financial disclosures, as the interval of variation for either the number of pages (*length*), or the level of understanding of financial disclosures (*readability*) is high, especially in case of readability score.

Instead, the standard deviation is relatively small in case of the number of pages of financial disclosures, which means that there is only a slight spread on the practice of financial reporting along capital markets or different areas of activity. In average, the annual reports have about $e^{5.131} \approx 169$ pages, in case of annual reports related to **Panel A**. On the other side, annual reports related to **Panel B** record significant decrease to an average of 98 pages. Similar but slight changes are observed in case of reports readability, as the average number of 13.31 words per sentence corresponding to **Panel A** annual reports decrease to the number 12.77 words per sentence, in case of **Panel B** annual reports, but with higher deviation between reports analyzed.

Table 3. Descriptive statistics.

	Panel A: *before COVID-19 pandemic*					**Panel B**: *during COVID-19 pandemic*				
				Normality test					*Normality test*	
	Mean	*Std. Dev.*	*VIF*	*Stat.*	*Sig.*	*Mean*	*Std. Dev.*	*VIF*	*Stat.*	*Sig.*
Disclosures characteristics										
Length	5.131	0.746	-	0.081	.000[a]	4.581	0.815	-	0.000	.200[a,b]
Readability	13.31	5.195		0.137	.000[a]	12.77	5.162		0.132	.000[a]
Uncertainty	0.072	0.060		0.249	.000[a]	0.084	0.058		0.227	.000[a]
Firm characteristics										
Size	19.96	3.090	1.102	0.130	.000[a]	19.58	2.903	1.048	0.118	.000[a]
Leverage	2.843	20.77	1.089	0.143	.000[a]	1.859	7.288	1.112	0.199	.000[a]
ROA	1.282	3.007	1.030	0.239	.000[a]	0.020	0.082	2.116	0.145	.000[a]
Growth	0.032	0.132	1.033	0.271	.000[a]	0.057	0.214	1.106	0.189	.000[a]
PER	1.929	1.396	1.116	0.190	.000[a]	18.62	2.821	1.057	0.231	.000[a]
Accruals	−0.313	4.921	1.016	0.485	.000[a]	−0.006	0.098	1.938	0.173	.000[a]

[a]Lilliefors Significance Correction.
[b]This is a lower bound of the true significance.
Source: Authors' calculation.

The results in Table 3 show a small percentage of words reflecting the sentiment of uncertainty, as the average on **Panel A** related annual reports is about *7.2%*, while for **Panel B** annual reports is slightly higher, respectively *8.4%*, which show managers avoid, as much as possible, words that lead to unclear or uncertain messages transmitted to shareholders and stakeholders as well. However, the slight increase highlights the systemic effect of COVID-19 pandemic on business operations and financial disclosures as well.

Related to firms' characteristics summarized in Table 3, notable results for our purpose concern the changes determined by COVID-19 pandemic. The statistics show that firms suffer from negative effects of COVID-19 pandemic, through a decrease of profitability, a decrease of financial leverage and a decrease of firms' market value. On the other side, the high standard deviation of the growth variable shows that some firms are less affected than other, either because of their specific of activity that has benefit from COVID-19 pandemic, such as IT sector (Efretuei 2020), or because of business models short-term reorientation that implied also a slight increase on firms' assets, leading to changes on production capacity. Nonetheless, we observe a significant decrease of accruals once the COVID-19 pandemic crisis has started, suggesting us less earnings management.

Our results are similar with Jiang, Pittman, and Saffar (2019) who show that in times of crisis, described by high uncertainty on policy making, firms' disclosures become lengthier, less readable and with a more prominent uncertainty tone on discourse, in order to avoid compliance costs or litigation costs (Christensen, Hail, and Leuz 2019).

In Figure 2, we observe slight changes, especially related to the length of the annual reports that seem to be lower, or to the readability of the annual reports that seem to deteriorate in time, especially in case of IBEX-35 listed entities. It seems that the more mature the capital markets are, the higher the readability of annual reports is, in parallel with a lower uncertainty tone of discourse. The highest score of annual reports readability is found within entities listed on IBEX-35 capital market, considered as a developed capital market, with a high level of value and investor segmentation. The highest tone of uncertainty is observed within entities listed on BSE capital market, which is more related to cultural dimension of the corporate reporting, rather than capital markets incentives.

Additionally, in Figure 2 we observe that higher coherence of topics seems to appear in case of annual reported after COVID-19 pandemic, which show topics addressed in annual reports are equally weighted, suggesting a more general approach considered, with less focus on specific topics, similar with the concern Dyer, Lang, and Stice-Laurence (2017) have highlighted. Overall, we observe higher entropy of firms' annual reports operating in industry area, IT, commerce, and utilities.

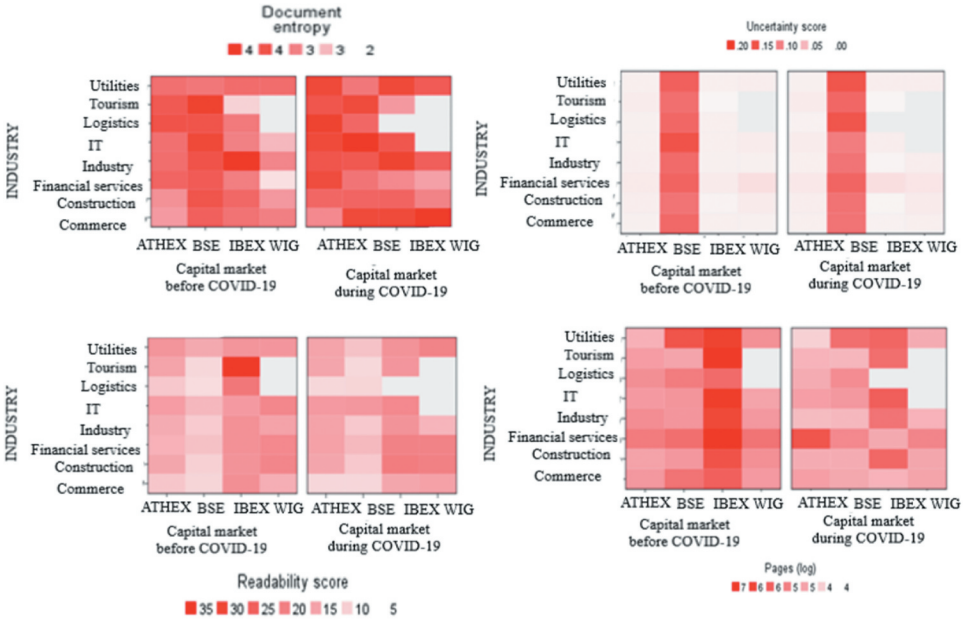

Figure 2. Marginal means conditioned by COVID-19 pandemic effects. Source: authors' projections.

4.2. Correlation Analysis

In Table 4 we provide the correlations between disclosure characteristics and firms' financial performances. The results show unanimously that firms size represents essential factor for the length and the readability of annual reports, as business strategy related to more complex business models asks for more complex annual reports (Lim, Chalmers, and Hanlon 2018). Instead, the correlation between firm size and the annual reports tone of uncertainty is significantly negative, showing that annual reports disclosed by big firms show lower tone of uncertainty.

We observe a significant positive correlation as well between readability of annual reports and firms' leverage, and a significant negative correlation between annual reports tone of uncertainty and firms' leverage, related to period during COVID-19 pandemics. Those correlations suggest to us that, in times of crisis, annual reports disclosed by firms with higher debt focus more on less uncertain information disclosed and try to transmit a more comprehensive message to the creditors.

Table 4. Pearson correlation matrix.

	Variable	Length	Readability	Uncertainty
Panel A:	*Size*	0.607**	0.576**	−0.647**
before COVID-19 pandemic	*Lev.*	−0.067	0.026	−0.106
	ROA	0.472**	0.323**	−0.411**
	Accruals	−0.086	0.065	−0.097
	Growth	−0.031	0.038	−0.030
	PER	0.097	0.181**	−0.270**
Panel B:	*Size*	0.372**	0.523**	−0.552**
during COVID-19 pandemic	*Lev.*	0.052	0.179**	−0.136*
	ROA	0.102	0.142*	0.018
	Accruals	−0.028	0.042	0.056
	Growth	0.081	0.120	−0.127
	PER	0.185**	0.086	0.029

Source: Authors' calculation.

We highlight in Table 4 a slight positive correlation between firms' profitability and the length of annual reports and their readability, for the period before COVID-19 pandemic. Firms' profitability is negatively correlated with annual reports tone of uncertainty. Like Loughran and McDonald (2011), our results suggest that managers prefer to focus their annual reports on good news, rather than bad news. However, readability of annual reports published during the COVID-19 pandemic is less influenced by firms' profitability.

Instead, we see a low statistically significant positive correlation between price earnings ratio and the length of the annual reports, only in case of period related to COVID-19 pandemic, which suggest that managers are slightly sensitive to capital markets in times of crisis.

4.3. Assessing Firm-level Determinants of Financial Disclosures

In Table 5 we provide evidence on the association between measures of annual reports and respectively firms' financial performance indicators. We addressed the existence of heteroscedasticity in our models, by performing the Modified Breusch-Pagan test. *Model 1* estimates are not heteroscedastic, as their *pvalue* is less than the threshold of *1%*, reason why we estimate the model using the White-Huber standard errors regression procedure, to ensure efficient regression coefficients estimates, concerning standard errors (Wooldridge 2010).

All models estimated in Table 5 are statistically significant, as their level of significance (*Ftestpvalue*.) is lower than the acceptable level of *1%*. Instead, we observe a relatively low R^2 *adjusted*, varying between 13.3% in case of *model 4* to 51.9% valid for *model 3*.

Table 5. Multivariate analysis on financial drivers of annual reports textual measures.

		Panel A *before COVID-19 pandemic*			Panel B *after COVID-19 pandemic*		
Dependent variable		Length	Readability	Uncertainty	Length	Readability	Uncertainty
Models		1	2	3	4	5	6
Constant		3.059*	−9.38*	0.361*	3.473*	−7.559*	0.343*
		(0.306)	(1.969)	(0.020)	(0.402)	(2.300)	(0.023)
ROA		0.028	1.570	0.001	1.160	13.12*	−0.032
		(0.117)	(1.658)	(0.017)	(0.858)	(4.914)	(0.050)
Leverage		0.039	0.050	−0.002	−0.078	0.693	−0.005
		(0.069)	(0.599)	(0.006)	(0.084)	(0.483)	(0.005)
Accruals		−0.006	0.121**	−0.002*	−0.838	−1.865	0.009
		(0.006)	(0.050)	(0.001)	(0.715)	(4.098)	(0.042)
Growth		−0.028	−0.898	0.009	0.049	−0.565	−0.025***
		(0.226)	(2.013)	(0.020)	(0.253)	(1.449)	(0.015)
PER		−0.014	0.175	−0.004***	0.042	−0.035	0.004**
		(0.033)	(0.208)	(0.002)	(0.035)	(0.198)	(0.002)
Size		0.101*	1.11*	−0.014*	0.052*	1.006*	−0.013*
		(0.015)	(0.103)	(0.001)	(0.020)	(0.116)	(0.001)
Fixed effects		Y	Y	Y	N	N	Y
Model validation							
Sample size		282	282	282	234	227	227
R^2 adjusted		0.318	0.424	0.519	0.133	0.353	0.441
F stat		9.989	15.21	21.83	3.577	10.19	14.28
P		0.000	0.000	0.000	0.000	0.000	0.000
Modified BP Test - heteroscedasticity	Stat.	11.88	2.984	1.143	2.762	0.113	0.303
	p	0.001	0.084	0.285	0.097	0.736	0.582
Hausman test - fixed effects	Stat.	13.20	23.94	38.61	10.87	5.186	58.06
	p	0.040	0.001	0.000	0.092	0.520	0.000
Breusch-Pagan test - random effects	*Stat.*	3.596	1.724	19.06	1.313	0.110	16.154
	p	0.058	0.189	0.000	0.252	0.741	0.000

* Significant for 1% significance level;
** Significant for 5% significance level;
Source: Authors calculations

Based on *Haussmann test* results, summarized in Table 5, we consider the models with industry fixed effects more relevant for our analysis in case of our models, except for *model 4* and *model 5*, as their $Sig. < 0.05$ (Lee *et al.*, Lee 2019). For *model 4* and *model 5* we have performed the *Lagrange Multiplier (LM) test* to check if random effects regression model is more relevant than the fixed effects or the pooled regression model. Based on statistics provided in Table 5, we observe that the models look for random effects ($Sig. > 5\%$), which shows that the specific of each firms' business model and management related corporate reporting policy approach is more relevant than the industry-specific effect (Lee 2019).

Firm size effect is significant for the readability, the length, and the uncertainty tone of the annual reports, no matter the panel data analyzed. The results show that the more complex is the firm's business model, the less readable the annual reports will be. Our results are similar with Dempsey et al. (2012) results, who have confirmed a positive association as well between firm size and readability of annual reports.

The results also highlight that the higher the firm size, the lower the uncertainty tone of the annual report will be, suggesting that issuers illustrate in the annual reports less information about the uncertain economic perspectives. The COVID-19 pandemic has affected annual reports, as our results show slight changes in the readability and tone of uncertainty of annual reports, reflecting an increase in readability and a less pronounced tone of uncertainty in case of larger firms.

Managers' sensitivity to capital markets is visible according to our results only on the tone of uncertainty of annual reports, described by the ***PER*** (price earnings ratio) coefficients, which differs on the panels analyzed. While during the period of COVID-19 pandemic, higher stock price earnings ratio determines more pronounced tone of uncertainty of annual reports ($Coef = 0.004, Sig. < 1\%$), during the period before the COVID-19 pandemic, higher PER determines more positive tone of annual reports ($Coef = -0.004, Sig. < 1\%$). The results show that managers would like to emphasize better the positive financial results in conditions of crisis, showing the results are obtained in terms of significant negative constraints, such as the negative economic effects of COVID-19 pandemic.

Our results show as well a negative association between the tone of uncertainty and the level of ***accruals*** reported ($Coef = -0.002, Sig. < 1\%$), for the period prior to COVID-19 pandemic. This result reveals that the lower the accruals are reported, the higher is the uncertainty tone of annual report, as there is less evidence of earnings management, because managers might explain poor financial performance referring to negative shocks on economic environment. However, the marginal effect on the tone of uncertainty on annual reports is relatively small, suggesting that managers prefer to refer less to economic environment uncertainty on annual reports, as negative information has a higher impact compared with the positive words (Tetlock, Saar-Tsechansky, and Macskassy 2008).

Our results show as well, a positive association between the level of accruals and the readability of annual reports ($Coef = 0.121, Sig. < 5\%$), valid for period before COVID-19 pandemic. In our study, higher readability score indicates less readable reports according to our readability score definition. The results we obtained suggest that, managers reporting higher level of accruals present the information through less readable reports. Those results confirm again the relation of substitution between accruals quality and disclosures quality, as lower accruals suggest higher earnings quality, positively related with higher readability of annual reports (Jaafar and Hussainey 2012).

The results describe as well a positive association between firms' ***profitability*** and the length of annual reports ($Coef = 13.21, Sig. < 1\%$), but only in case of reports published during COVID-19 pandemic. Our results highlight that higher profitability means less readable annual reports. The results suggest that managers might use less readable discourse in preparing annual reports, to hide information about earnings management that has led to higher firm's profitability, similar to Davis et al. (2015), Lang and Stice-Lawrence (2015).

Nonetheless, for the period during COVID-19 pandemic, we confirm a negative statistically significant association between the tone of annual reports and the rate of ***growth*** in sales ($Coef = -0.025, Sig. < 10\%$). This result provides us with evidence that the higher the level of growth

in sales, the lower the tone of uncertainty in annual reports. As noted by Davis et al. (2015), managers have incentives to set-up their optimistic or pessimistic tone on corporate communication of firms' results, especially when this information is more sensitive to stock prices, such as the increase in sales.

4.4. Robustness Analysis Controlling for Distribution Values Effect

In Table 6 we provide summary statistics of the quantile regression estimation models, for the period before the ongoing COVID-19 pandemic. The results confirm once again that there is a positive association between annual reports readability and firm size. The higher the firms size, the lower the annual reports readability. The result implies that firms of larger size involve more complex business models which are hardly to be reflected in sufficiently readable disclosures.

We obtain robust results as well for the association between the tone of uncertainty of annual reports and firm size. These results show that firms of larger size do not focus on emphasizing the uncertainty of economic environment when presenting annual results, probably because of their higher power of negotiation with the creditors and the other stakeholders.

We get robust results as well related to the association between readability of annual reports and the level of firms' reported accruals, which show that the higher the accruals, the less readable annual reports are. We observe that estimated regression coefficients increase from one percentile to another ($0.057 < 0.088 < 0.127$). The results show that firms of smaller size tend to be more precise on reporting, in order to explain better accounting estimates reported and avoid any future litigation cost, or capital market penalization.

Robust results are obtained also concerning the association between the uncertainty tone of annual reports and the level of accruals, showing higher level of accruals determines lower tone of uncertainty of annual reports, with the aim to transmit positive signal to investors, that should not warn investors of inaccurate earnings quality. In association with the results related to readability of annual reports, we observe that higher level of accruals determine managers to prepare obfuscated annual reports, but in a more positive tone that would likely determine less concerns for investors. Otherwise, higher investors' concerns would determine them to do further investigation and put additional pressure on firms' management team.

Table 6. Quantile analysis on financial drivers for period before COVID-19 pandemic.

	1st	*2nd*	*3rd*	*1st*	*2nd*	*3rd*
Dependent variable	Readability			Uncertainty		
Models	7	8	9	10	11	12
Constant	−10.51*	−9.177*	−3.520*	0.309*	0.347*	0.329*
	(1.440)	(1.347)	(1.850)	(0.027)	(0.016)	(0.016)
ROA	−0.320	0.836	1.975	0.020**	0.014	0.006
	(0.578)	(6.597)	(3.569)	(0.008)	(0.009)	(0.007)
Leverage	−0.155	−0.133	−0.761	0.008	0.003	0.000
	(0.285)	(0.474)	(0.584)	(0.005)	(0.005)	(0.004)
Accruals	0.057*	0.088*	0.127*	−0.002*	−0.002*	−0.001*
	(0.018)	(0.022)	(0.019)	(0.000)	(0.000)	(0.000)
Growth	−0.014	−1.282	2.080	−0.007	0.025	0.009
	(1.048)	(1.719)	(2.858)	(0.043)	(0.016)	(0.013)
PER	−0.116	0.012	0.138	−0.008*	−0.001	0.000
	(0.142)	(0.175)	(0.294)	(0.003)	(0.002)	(0.002)
Size	1.091*	1.092*	0.923*	−0.012*	−0.014*	−0.012*
	(0.074)	(0.069)	(0.090)	(0.001)	(0.001)	(0.001)
Model validation						
R^2 adjusted	0.248	0.359	0.284	0.242	0.355	0.119
Sparsity	7.468	7.350	10.45	0.118	0.090	0.106
Quasi-LR statistic	121.1	208.5	127.9	101.1	211.4	54.91
p	0.000	0.000	0.000	0.000	0.000	0.000

Source: Authors' calculations.

In Table 7 we provide summary statistics of the quantile regression estimation models, for the period before current COVID-19 pandemic started. The results look robust, compared with the estimates obtained using OLS method, but only related to firm size positive marginal effect on the readability of annual reports and firm size negative effect on the tone of uncertainty of annual reports.

The results from quantile regression show robustness for the marginal effect of firm size on readability of annual reports, no matter the percentile estimate. Instead, the negative impact of firm size on the tone of uncertainty of annual reports is statistically significant only for 1st and 2nd percentile, suggesting that only in case of annual reports with less pessimistic tone the firm size matters.

4.5. Robustness Analysis Controlling for Corporate Governance Implications

The main purpose of this analysis is to check if the entropy score of annual reports improves our regression models $R^2 adjusted$, as annual reports readability is not influenced only by managers' preferences reflected in firms' financials, but also depends on the managers ability to present a clear, concise and coherent message with focus only on the key aspects of the business model (Hasan 2020).

In Table 8 we provide the statistics for models estimation, triangulating our results by using an alternative for readability score, respectively the Flesch readability ease score, presenting in parallel results for both measures of readability of annual reports. Additionally, we control for annual reports entropy and firms' corporate governance framework as well.

We observe the negative association between annual reports readability and their entropy score is statistically significant only for models estimated for period before COVID-19 pandemic ($Coef = -2.807, Sig. < 1\%$). The results show that the higher the entropy score of annual reports, the lower is their readability, meaning that if annual reports address multiple topics, the readability is significantly affected as there is no clear orientation of the financial reporting discourse. It seems that managers prefer to follow a standard approach on corporate reporting, looking especially for compliance with generally accepted reporting standards, such the GRI standards, rather than providing relevant information which could reflect better the impact of particularities of firms' business model on financial performance.

Table 7. Quantile analysis on financial drivers for period after COVID-19 pandemic.

	1st	*2nd*	*3rd*	*1st*	*2nd*	*3rd*
Dependent variable	Readability			Uncertainty		
Models	13	14	15	16	17	18
Constant	−11.64*	−8.697*	−3.411	0.314*	0.322*	0.179*
	(2.354)	(1.867)	(2.671)	(0.017)	(0.017)	(0.063)
ROA	−3.266	−0.778	1.740	0.068	0.028	0.003
	(4.162)	(4.799)	(9.419)	(0.084)	(0.051)	(0.044)
Leverage	0.489**	0.123	−0.512	0.000	0.004	−0.001
	(0.274)	(0.331)	(0.360)	(0.006)	(0.004)	(0.004)
Accruals	6.764**	2.431	3.979	−0.046	0.025	0.010
	(3.507)	(3.695)	(6.631)	(0.065)	(0.043)	(0.039)
Growth	0.768	1.009	−0.744	−0.046*	−0.001	−0.017
	(1.879)	(1.562)	(2.014)	(0.015)	(0.018)	(0.019)
PER	0.034	−0.018	0.354	0.001	0.005**	0.006***
	(0.196)	(0.227)	(0.409)	(0.003)	(0.002)	(0.003)
Size	1.091*	1.055*	0.932*	−0.013*	−0.013*	−0.003
	(0.118)	(0.094)	(0.124)	(0.001)	(0.001)	(0.004)
Model validation						
R^2 adjusted	0.165	0.236	0.180	0.233	0.222	0.011
Sparsity	9.373	9.072	16.476	0.119	0.086	0.106
Quasi-LR statistic	62.61	101.0	51.01	95.14	111.6	12.25
P	0.000	0.000	0.000	0.000	0.000	0.057

Source: Authors' calculations.

Table 8. Control variables effect on annual reports readability score.

		Panel A:		Panel B:	
		Before COVID-19 pandemic		*During COVID-19 pandemic*	
Dependent variable		Flesch score	Readability	Flesch score	Readability
Models		(19)	(20)	(21)	(22)
Constant		40.59*	5.431	33.07*	−3.64
		(6.773)	(3.436)	(8.93)	(4.018)
Entropy		−0.921	−2.807*	1.224	0.125
		(0.986)	(0.500)	(1.346)	(0.606)
Leverage		0.474	0.242	0.169	0.278
		(1.121)	(0.569)	(1.043)	(0.469)
Accruals		0.111	0.128*	7.559	4.838
		(0.094)	(0.048)	(6.814)	(3.066)
PER		0.357	0.140	0.955**	−0.026
		(0.396)	(0.201)	(0.441)	(0.199)
Size		0.071	0.812*	−0.064	0.777*
		(0.268)	(0.136)	(0.371)	(0.167)
Corporate governance score		−0.085*	0.022	−0.164*	0.044*
		(0.030)	(0.015)	(0.045)	(0.020)
Analysts coverage		0.075	−0.042	0.446**	−0.014
		(0.119)	(0.060)	(0.191)	(0.086)
Fixed effects		Y	Y	Y	Y
Model validation					
Sample size		220	220	252	252
R^2 adjusted		0.053	0.492	0.106	0.356
F stat/Quasi-LR stat		1.980	18.08	2.823	9.486
P		0.020	0.000	0.001	0.000
Modified BP Test- heteroskedasticity	Stat.	0.44	13.127	3.158	0.316
	p	0.507	0.000	0.076	0.574
Hausman test	*Stat.*	13.13	25.99	19.01	13.19
- fixed effects	*p*	0.069	0.001	0.008	0.068
Breusch-Pagan test	*Stat.*	1.452	2.882	3.434	0.028
- random effects	*p*	0.228	0.090	0.064	0.868

Source: Authors' calculations.

Robust results are again confirmed related to the positive association between readability of annual reports and ***firm size*** as well, no matter the period analyzed and if corporate governance control variables are included in the estimated models.

Instead, the Flesch reading ease score is statistically affected only by firms' corporate governance score. This measure of readability is more sensitive to the complexity of the words used, rather than the number of words used per sentence. Our results could suggest that there isn't a pattern on how managers try to prepare obfuscated annual reports using fog words, meaning there isn't a systematic preoccupation of managers to select fog words just to reduce the readability of annual reports.

However, it seems more effective mechanisms of corporate governance lead to less readable annual reports, with a higher marginal effect on the period of COVID-19 pandemic. Higher corporate governance score shows more mature and effective governance mechanisms. The results show that annual reports are less readable because of longer sentences, but not because of the use of complex words. Corroborated, the results suggest us that management is highly accountable for financial performance, which makes them to obfuscate annual reports. As TOP management incentive plans often consist of equity compensation, they are interested to stimulate attractiveness of the stocks on the capital markets. A root-cause could be that corporate governance mechanisms are effective more in the area of management accountability, but less effective in the area of shareholders or board of director's oversight.

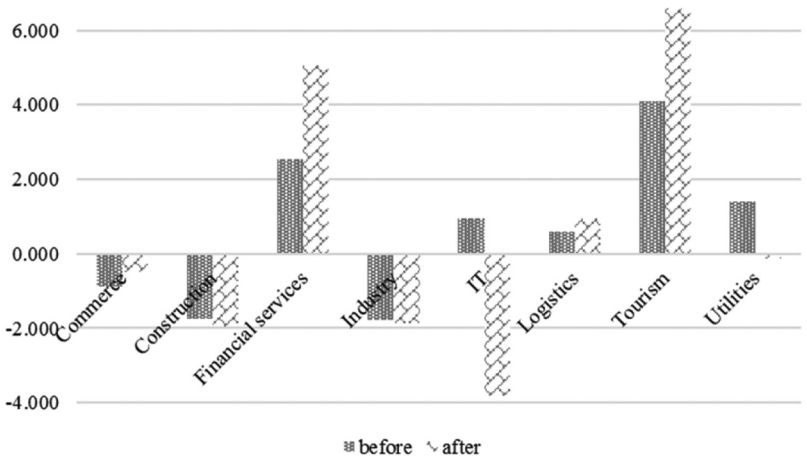

Figure 3. Fixed effects of industry on estimated models. Source: authors' calculations.

Instead, same results can suggest as well that strategic shareholders as well can put pressure on preparers inside the firm on how to prepare financial statements, as the use of fewer complex words is conditioned by higher stock market returns.

Industry effects are confirmed along all estimated models that control for effect of financial performance on annual reports readability score, based on Hausman test, for which the *p* value is less than *5%*. Our results are similar with Efretuei (2020) who have underlined the effects of the specific of several areas of activity, such as financial services, technology, tourism, or utilities. Our results show in Figure 3 significant negative fixed effects in case of firms operating in commerce, or logistics. Instead, we observe positive fixed effects in case of firms operating in financial services, logistics or tourism area. These results show that annual reports are less readable in case of firms operating in commerce or logistics area, while firms operating in financial services area seem to be more concise and clearer.

Additionally, we observe from a temporal perspective that the COVID-19 pandemic has changed drastically firms' approach on corporate reporting for firms operating in tourism, or financial services, leading to significantly less readable annual reports. Instead, in case of firms operating in IT and communications, the change in the readability of annual reports is even higher, as it goes from a positive value to a negative value, suggesting higher level of readability of annual reports. Therefore, those firms can be used for benchmark for the other firms, with the limitation of some basic constraints, such as the business model complexity, and corporate governance mechanisms.

5. Conclusions

This paper discussed the impact of firms' financial drivers on annual reports characteristics, respectively the length of the annual report, the level of readability, and the degree of negative tone reflected on analyzed annual reports. The analysis is designed to highlight how the current COVID-19 pandemic affects annual reports and how managers use them to emphasize or to hide firms' financial results.

Through multivariate analysis and text mining techniques, our paper reveals that the analyzed reports are less extensive in content and less readable. The results show increase in obfuscate information, especially in times of pandemic. However, the results are affected as well by industry fixed effects, as COVID-19 pandemic has affected distinctly the areas of economic activity. Firm size and accruals reported determine a significant positive marginal effect on annual reports readability, while firm size, accruals, and price earnings ratio determine a negative association with the tone of uncertainty of annual reports, especially during the period prior to COVID-19 pandemics.

Nonetheless, we underline that users of financial reports should be more careful on annual reports discourse, including the tone preparers use, as this could be already a sign of potential obfuscation on financial reporting.

Finally, we conclude that the lack of a common reporting framework in pandemic conditions to build a disclosure index strictly related to the size of COVID-19 presentations in the report represents one of the main limitations of our research. Future research can empirically investigate the breakdown of a composite ESG score index to understand the extent to which annual reports readability is influenced by financial information vs. non-financial information. Future research can also empirically investigate the correlation analysis of financial and non-financial indicators with the characteristics of the annual reports, for the pre and post COVID-19 period.

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References

Christensen, H. B., L. Hail, and C. Leuz 2019. Economic analysis of widespread adoption of CSR and sustainability reporting standards. *Working paper*.

Davis, A. K., W. Ge, D. Matsumoto, and J. L. Zhang. 2015. The effect of manager-specific optimism on the tone of earnings conference calls. *Review of Accounting Studies* 20 (2):639–73. doi:10.1007/s11142-014-9309-4.

Dempsey, S. J., D. M. Harrison, K. F. Luchtenberg, and M. Seiler. 2012. Financial opacity and firm performance: The readability of REIT annual reports. *The Journal of Real Estate Finance and Economics* 45 (2):450–70. doi:10.1007/s11146-010-9263-2.

Dyer, T., M. Lang, and L. Stice-Laurence. 2017. The evolution of 10-K textual disclosure: Evidence from latent dirichlet allocation. *Journal of Accounting and Economics* 64 (2–3):2–3. doi:10.1016/j.jacceco.2017.07.002.

Efretuei, E. 2020. Year and industry-level accounting narrative analysis: Readability and tone variation. *Journal of Emerging Technologies in Accounting*. doi:10.2308/JETA-18-12-21-26.

Engelhardt, N., M. Krause, D. Neukirchen, and P. Posch. 2020. What drives stocks during the Corona-Crash? News attention vs. rational expectation. *Sustainability* 12 (12):5014. doi:10.3390/su12125014.

Ertugrul, M., J. Lei, J. Qiu, and C. Wan. 2017. Annual report readability, tone ambiguity, and the cost of borrowing. *Journal of Financial and Quantitative Analysis* 52 (2):811–36. doi:10.1017/S0022109017000187.

Francis, J., R. LaFond, P. Olsson, and K. Schipper. 2005. The market pricing of accruals quality. *Journal of Accounting and Economics* 39 (2):295–327. doi:10.1016/j.jacceco.2004.06.003.

FTSE Classification of Equity Markets. September 2020.

Gould, S., and C. Arnold 2020. The financial reporting implications of COVID-19.

Hasan, M. M. 2020. Readability of narrative disclosures in 10-K reports: Does managerial ability matter? *European Accounting Review* 29 (1):147–68. doi:10.1080/09638180.2018.1528169.

Hatmanu, M., and C. Cautisanu. 2021. The impact of COVID-19 pandemic on stock market: Evidence from Romania. *International Journal of Environmental Research and Public Health* 18 (17):9315. doi:10.3390/ijerph18179315.

Hofmann, M., and R. Klinkenberg. 2014. *RapidMiner: Data mining use cases and business analytics applications*. London: CRC Press.

Jaafar, M. S., and K. Hussainey. 2012. Accruals quality visa-vis disclosure quality: Substitutes or complements? *British Accounting Review* 44 (1):36–46. doi:10.1016/j.bar.2011.12.004.
Jiang, L., J. Pittman, and W. Saffar. 2019. Policy uncertainty and textual disclosure. *SSRN Paper*.
Lang, M. H., and L. Stice-Lawrence. 2015. Textual analysis and international financial reporting: Large sample evidence. *Journal of Accounting & Economics* 60 (2):110–35. doi:10.1016/j.jacceco.2015.09.002.
Lee, F. C. 2019. *Financial econometrics, mathematics ans statistics*. New York, NY 10013, U.S.A: Springer.
Leuz, C., and P. Wysocki. 2016. The economics of disclosure and financial reporting regulation: Evidence and suggestions for future research. *Accounting Research* 54:525–622.
Li, F. 2008. Annual report readability, current earnings, and earnings persistence. *Journal of Accounting and Economics* 45 (2–3):221–47. doi:10.1016/j.jacceco.2008.02.003.
Li, J., G. Li, X. Zhu, and Y. Yao. 2020. Identifying the influential factors of commodity futures prices through a new text mining approach. *Quantitative Finance* 20 (12):1967–81. doi:10.1080/14697688.2020.1814008.
Lim, E. K. Y., K. Chalmers, and D. Hanlon. 2018. The influence of business strategy on annual report readability. *Journal of Accounting and Public Policy* 37 (1):65–81. doi:10.1016/j.jaccpubpol.2018.01.003.
Lo, K., F. Ramos, and R. Rogo. 2017. Earnings management and annual report readability. *Journal of Accounting and Economics* 63 (1):1–25. doi:10.1016/j.jacceco.2016.09.002.
Loughran, T., and B. McDonald. 2011. When is a liability not a liability? Textual analysis, dictionaries, and 10-Ks. *The Journal of Finance* LXVI (I):35–65.
Loughran, T., and B. McDonald. 2013. IPO first-day returns, offer price revisions, volatility, and form S-1 language. *Journal of Financial Economics* 109 (2):307–26. doi:10.1016/j.jfineco.2013.02.017.
Loughran, T., and B. McDonalld. 2016. Textual analysis in accounting and finance: A survey. *Journal of Accounting Research* 54:4. doi:10.1111/1475-679X.12123.
Merkl-Davies, D. M., and N. M. Brennan. 2017. A theoretical framework of external accounting communication: Research perspectives, traditions, and theories. *Accounting, Auditing & Accountability Journal* 30 (2):433–69. doi:10.1108/AAAJ-04-2015-2039.
Miller, B. P. 2010. The effects of reporting complexity on small and large investor trading. *The Accounting Review* 85 (6):2107–43. doi:10.2308/accr.00000001.
Oskouei, Z. H., and Z. H. Sureshjani. 2021. Studying the relationship between managerial ability and real earnings management in economic and financial crisis conditions. *International Journal of Finance & Economics* 26 (3):4574–89. doi:10.1002/ijfe.2031.
Tetlock, P. C., M. Saar-Tsechansky, and S. Macskassy. 2008. More than words: Quantifying language to measure firms' fundamentals. *The Journal of Finance* 63 (3):1437–67. doi:10.1111/j.1540-6261.2008.01362.x.
Wall Street. 2019. Bucharest Stock Exchange, the Highest Increase in the World in 2019.
Wang, V., and B. Xing. 2020. Battling uncertainty: Corporate disclosures of COVID-19 in earnings conference calls and annual reports. *SSRN Papers*.
Wooldridge, J. M. 2010. *Econometric analysis of cross section and panel data*. USA: The Mit Press.

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Assessment of country institutional factor on sustainable energy target achievement in European Union

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Assessment of country institutional factor on sustainable energy target achievement in European Union

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ABSTRACT

This study examines causality relation between the quality of national institutional frameworks designed to ensure higher energy efficiency and the distance to the achievement of the EU Commission targets in terms of energy consumption, using a panel of 21 EU member states. Through panel unit root tests and an estimated VAR model, our results reveal that the quality of a nation's institutional and economic energy efficiency framework does not significantly influence the gap between annual energy consumption and related EU targets, as prescribed by the energy efficiency EU Directives. However, the results show a bi-directional causality relationship suggests that the nation's institutional framework on energy efficiency should be improved. According to the impulse response function, this relationship is more related to a short-run perspective. Hence, a strong correlation exists between the level of achieving the reduction targets on energy consumption and the level of gas emissions. Our findings further reveal that the level of reported GHCs significantly influences national regulations and strategies for gas emission reductions. This research highlights the importance of each EU member state creating an appropriate legislative and institutional framework that promotes energy efficiency.

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1. Introduction

Climate change and the intensification of extreme weather events present a global challenge, with a considerable impact on both people and the environment, and on the economy itself. On the one hand, effective policies and procedures are needed to reduce greenhouse gas emissions and to improve energy security through measures intended to limit energy import dependence outside the European Union. On the other hand, strategies are needed to adapt to the effects of already visible and inevitable climate change (EEA, 2016).

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Over time, at the European Union level, measures have been adopted to ensure sustainable development, but the reality shows that more is needed to reduce the vulnerability of societies to climate change (Renna & Materi, 2021; RENA, 2019). Ensuring energy efficiency is thus one of the main objectives to be achieved by EU member states and is placed at the heart of the strategy elaborated to limit the effects of climate change. Directive 2012/27/EU established that by 2020, primary energy consumption should be reduced among member states by 20%. Over time, primary energy consumption has fluctuated, being influenced by economic conditions, the climate, or the level of implementation of energy efficiency measures by each state. In 2019, the primary energy consumption decreased, exceeding the imposed target by 3%. In 2020, the crisis generated by the novel coronavirus has triggered another global decline in energy consumption, which can be attributed to the measures taken to limit the spread of COVID-19. In this situation where the economy has not become more energy-efficient, the declines will not be sustained, as energy consumption may increase later due to the economic recovery.

However, decision-makers have proposed more ambitious targets to be achieved by 2030, namely, reducing energy consumption by 32.5% (European Commission, 2018), a decrease of 55% of greenhouse gases, and transforming Europe into the first climate-neutral continent by 2050 (European Commission, 2021). Nevertheless, the transition to a greener, more circular, and digital European economy is not easy. The challenge is how benefits can be distributed to all as equitably as possible while strengthening competitiveness, creating new jobs, and effectively addressing the costs and impact of the transition through an effective legislative framework and coherent strategies.

The main objective of our paper is to evaluate the causal relationship between the quality of national institutional frameworks designed to ensure higher energy efficiency and the distance to the achievement of the EU Commission targets. In this context, the focus of our paper is related to: (i) national institutional approaches, specifically on energy efficiency; (ii) linking the achievement of SDG 7 with energy efficiency through European directives that set targets in the field; (iii) causal analysis to identify the implications of public policies or mechanisms for stimulating and monitoring energy efficiency; and (iv) an alternative approach to the common method for analyzing the nexus between economic growth and energy consumption.

The proposed research is structured in five sections. Thus, this first section highlights the preliminary aspects of the undertaken scientific approach, while the second section finds corresponding examples in the literature analysis. The next two sections present the research methodology, including the results obtained and their discussion, respectively. Finally, the fifth section draws the final conclusions of our research.

2. Study background

The environmental problems facing the entire planet are largely the result of over exploitation of natural resources. Europe's economy is based on a continuous flow of natural resources and materials. This dependence, complemented by imports, can be a vulnerability, given that the global competition for natural resources is intensifying.

Thus, to mitigate the impact of climate change and contribute to sustainable development, creating at the same time a green economy framework, the EU imposes targets for their member states to reduce energy consumption and increase energy efficiency (Adua et al., 2021). Hence, energy efficiency is a global priority with particular interest for both decision-makers and researchers that are trying to identify efficient ways to use energy wisely. The aim is to reduce the costs related to energy production, transport, and consumption, improve government policies, and achieve the proposed EU objectives (Sineviciene et al., 2017). However, improving energy efficiency is not an easy process because to formulate effective environmental policies, it is first necessary to identify the determinants of environmental degradation (Chou & Zhang, 2020; Sarfraz et al., 2018).

Breuer et al. (2019) noted that achieving SDG targets, including SDG 7, which refers to affordable and clean energy objectives, requires a systemic approach that can be translated into a set of policies to ensure all stakeholders and decision-makers have coherent action plans. A similar approach has been underlined by Knopf et al. (2013) to discuss the need and opportunity to reform the European energy system. It emphasizes the positive impact of strategies to improve energy efficiency and, at the same time, promotes the identification and use of renewable energy sources. In this regard, member state governments have an essential role as the responsible entity for issuing and implementing national policies to lead all efforts in one direction: a significant increase in energy efficiency at the national level. This objective is even more important to achieve as the EU members are subject to clearly defined national-level targets in terms of energy efficiency for the 2030 perspective. Those targets are formally approved by the EU energy Directive 2012/27/EU, modified by EU energy Directive (UE) 2018/2002, which is already planned to be replaced by a new directive, currently under discussion, which will define the targets for 2050. So far, EU member states appear to be complying with the imposed targets, acting as global benchmarks in terms of energy efficiency (Shehzad et al., 2020; Wang et al., 2019). Other non-European countries, such as China and India, have high energy production but do not consider the negative effects of CO2 emissions; the US, by comparison, has a higher level of energy productivity and better control over carbon emissions (Sarfraz et al., 2021; Wang et al., 2017).

However, there is the little discussion related to national institutional factors when discussing the main drivers of energy efficiency, as researchers tend to focus on economic factors such as economic development, economic growth, dynamics of population, investments, financing, human capital, or energy prices (Acaravci & Ozturk, 2010; Edziah et al., 2021; Wang et al., 2019), and are mainly oriented toward analyzing manufacturing firms (Renna & Materi, 2021; Schulze et al., 2016; Solnørdal & Foss, 2018). All those studies have a common finding that discussions around the topic of energy efficiency are always related to the environmental impact of energy consumption (Uribe-Toril et al., 2019).

Therefore, the analysis of the impact of national institutional factors on energy efficiency seems to be neglected. To our knowledge, some recent papers have addressed this topic by conducting empirical analysis (Apergis & Garćı a, 2019; Lyulyov et al., 2021; Sineviciene et al., 2017; Zangheri et al., 2019). However, those

studies have not referred to national institutional factors describing the specific institutional frameworks that provide direct information on energy efficiency but instead provide national-level descriptive indicators in general. Our analysis is designed so that relevant information about national energy frameworks is analyzed, with a focus on those that impact the achievement of EU 2030 energy consumption targets, considering as reference information the RISE country indicators that assess a set of essential aspects of each national energy efficiency framework. Therefore, our study will test the following research hypothesis states that the quality of a nation's energy efficiency institutional framework significantly influences the distance between annual energy consumption and related EU targets.

3. Research methodology

3.1. Data and variables definition

For this study purpose—namely, to assess the relation of causality between the quality of national institutional frameworks designed to ensure higher energy efficiency and the distance to the achievement of the EU Commission targets in terms of energy consumption—we have considered for analysis the period 2010–2019, limited to the period for which there are available data about the RISE composite index. Therefore, the data used in our analysis is directly focused on the matter of energy efficiency and is not biased by different calculation methods. There are analyzed 21 EU members, respectively: Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Poland, Portugal, Romania, Slovak Republic, Spain, Sweden, and United Kingdom. The sample comprises 201 observations per each variable considered in the analysis.

Worldwide, numerous initiatives of public policies have been issued to promote energy efficiency, in relation to an increase of use of renewable energy and implementation of emerging energy technologies, either managed by international institutions, regional institutions, or local agency energy institutions. Our study aims to underline the role of national governments' policies in energy efficiency. To isolate the effect of international and regional effects of institutional frameworks, we have limited our sample only to EU members, which are subject to the same public energy directives that are, however, transposed differently into local regulations and which are monitored for compliance according to different enforcement systems.

The period is limited to 2010-2019 because of the limited project lifetime of the RISE (Regulatory Indicators for Sustainable Energy) project, which only commenced in 2010. The project collects data from different countries through annual surveys to measure an aggregate image of countries' readiness for implementing a sustainable energy consumption model. In Table 1, we provide a short description of the variables considered in our analysis.

3.2. Time series analysis

Our analysis uses time series data covering the period 2010-2019, structured in panels represented by 21 countries. The relationship between energy efficiency indicator and

Table 1. Description of variables considered in the model.

Variable	Name	Description	Source of data
Energy efficiency	EES	Distance measured in absolute terms (Mtoe), calculated as a difference between the observed energy consumption in a given year to the absolute primary and final energy consumption targets in 2020 or 2030 according to Directives 2012/27/EU	Eurostat (nrg_ind_eff)
Country energy efficiency score	EES	One of the four composite scores calculated to measure country sustainable development, incorporating various elements defining the national framework ensuring and monitoring for energy efficiency, shortly described by 13 pillars of energy efficiency institutional drivers, respectively: national energy efficiency planning, energy efficiency entities, information provided to consumer about electricity usage, energy efficiency incentives from electricity rate structures, incentives & mandates: industrial and commercial end users; incentives & mandates: public sector, incentives & mandates: utilities, financing mechanisms for energy efficiency, minimum energy efficiency performance standards, energy labeling systems, building energy codes, transport sector, carbon pricing and monitoring	RISE databse
Greenhouse gas emissions	GGS	Data integrating information about gasses that genrate the greenhouse effect, such as: water vapor (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) seen as primary greenhouse gases, or more human-made gases, such as sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs)	UNCTAD database
Energy dependence	ED	Extent to which an economy relies upon imports in order to meet its energy needs. It is calculated as net imports divided by gross available energy.	Eurostat (t2020_rd320)
Global competitive ness index	GCI	Annual score calculated for each country, as a weighted average of various components descrbing different essential aspects of country competitiveness, grouped into 12 pillars of competitiveness, respectively: institutions, infrastructure, macroeconomic environment, health and primary education, higher education and training, goods market efficiency, labor market efficiency, financial market development, technological readiness, market size, business sophistication and innovation	Global Competitive ness Report
Firm policy efficiency	FPE	Data that reflect the score calculated by Thomson Reuters for each firm, on an annual basis, refering to how reliable and consistent are firm policies adressing energy efficiency organsational requirements	Reifinitiv Eikon database

country institutional factor is assessed through panel data analysis methods. The analysis of time series analysis consists of several steps, respectively: (i) stationarity of panel time-series data; (ii) panel time-series causality tests; (iii) co-integration of panel time-series data.

3.2.1. Panel stationarity testing

Testing for stationarity of time series is performed by running a set of panel unit root tests: Levin-Lin-Chu t-test, Im-Pesaran-Shin test, ADF - Fisher Chi-square test, and PP - Fisher Chi-square test. All the methods have a similar principle. For instance, in the case of the Levin-Lin-Chu test is tested the assumption that all countries in the panel share the same autoregressive coefficient$\alpha_i = \rho - 1$, estimating model below:

$$\Delta y_{i,t} = \alpha \cdot y_{i,t-1} + \sum_{j=1}^{p_i} \beta_{ij} \cdot \Delta y_{i,t-j} + X_{i,t}^{'} \cdot \delta + \mu_i + \theta_t + e_{it} \quad (1)$$

where Δ is the first difference operator, p_i is the number of lags, μ_i is the unit-specific fixed effect, while θ_t denotes the time fixed effect and e_{it} The error terms follow a stationary invertible autoregressive moving-average process for each unit in the panel but are independently distributed across the panels. If $\rho < 1$, the test confirms that the time series is stationary. Otherwise, the null hypothesis $\rho = 1$ is accepted, showing that each panel has a unit root.

Once determined the integration level of the time series, based on the panel unit root tests, it can be decided if the regression model is estimated using values at level, valid for time series of $I(0)$ order of integration, or first difference values, in case of time series of $I(1)$ order of integration. Moreover, based on the time-series order of integration, we decide if further analysis is needed for the co-integration of time series, which would confirm the long-run relationship between the variables. Otherwise, the VAR model is preferred instead of the ADRL model and no longer needs short-run relations analysis.

3.2.2. Panel causality testing

Our analysis started from an extended set of time series, including energy productivity, energy consumption, World Governance regulatory quality score, World Governance rule of law score, firm ESG score, and firm target energy efficiency score, a variable which was excluded based on the results of causality tests performed. Based on Granger panel causality tests, we decided which variables are planned to be endogenous considered for the VAR model estimation.

Granger causality test consist of estimating the bivariate regressions of the form below, for each possible pair of variables considered on the analysis, testing for the hypothesis that $\beta_1 = \beta_2 = \beta_3 = \ldots = \beta_l = 0$, for each equation.

$$y_{i,t} = \alpha_0 + \alpha_0 \cdot y_{i,t-1} + \ldots + \alpha_l \cdot y_{i,t-l} + \ldots + \beta_1 \cdot x_{i,t-1} + \ldots + \beta_l \cdot x_{i,t-l} + \varepsilon_{i,t} \quad (2)$$

$$x_{i,t} = \alpha_0 + \alpha_0 \cdot x_{i,t-1} + \ldots + \alpha_l \cdot x_{i,t-l} + \ldots + \beta_1 \cdot y_{i,t-1} + \ldots + \beta_l \cdot y_{i,t-l} + \mu_{i,t} \quad (3)$$

The null hypothesis is that x does not Granger-cause$y$ in the first regression and that y does not Granger-cause x in the second regression. We can reject the null hypothesis if the F-statistic is statistically significant for a level of 5%, concluding that there is a causality relationship between the two variables, but with a clear direction of causality.

An additional VAR Granger causality test is performed to have better information limited strictly to the time series of the selected endogenous variables. The first causality granger test is performed only to select variables to be included in the VAR estimated model.

3.3. Model specification

Correlation or causality tests confirm the existence of a relationship between two variables; they do not reveal information about its strength. For this purpose, we estimate a VAR model to understand the amplitude of the relationship between our variables. By estimating the VAR model, we solve the problem of endogeneity of the variables considered in the model (Gujarati & Porter, 2009). Additionally, we can see the sign of the relation between our endogenous variables. Nonetheless, as noted by Canova and Ciccarelli (2013), panel VAR models represent useful tools for government policy analysis because: (i) they capture both static and dynamic interdependencies, (ii) treat the links across units in an unrestricted fashion, (iii) easily incorporate time variation in the coefficients and the variance of the shocks, and (iv) account for cross-sectional dynamic heterogeneities.

More frequently, the Panel VAR model and the VECM model are widely used in the literature related to energy consumption modeling and study of causality concerning country economic growth (Omri, 2014; Ozturk, 2010). The choice for the VAR model is because all endogenous variables included in the model have the same order of integration (Gujarati, Gujarati and Porter, Gujarati and Porter, 2009; Brooks, 2019). Additionally, the VAR model is preferred against the ADRL model, as there is no cointegration valid for time series with *I (0)* order of integration (Wu & Zhou, 2010). The $VAR(p)$ process used in our analysis, with a lag of p, can be expressed by the system of relations below:

$$EE_{i,t} = \alpha + \sum_{j=1}^{p} \beta_j \cdot EE_{i,t-j} + \sum_{j=1}^{p} \gamma_j \cdot EES_{i,t-j} + \sum_{j=1}^{p} \delta_j \cdot GGS_{i,t-j} + \varepsilon_{i,t} \tag{4}$$

$$EES_{i,t} = \alpha + \sum_{j=1}^{p} \beta'_j \cdot EES_{i,t-j} + \sum_{j=1}^{p} \gamma'_j \cdot EE_{i,t-j} + \sum_{j=1}^{p} \delta'_j \cdot GGS_{i,t-j} + \varepsilon'_{i,t} \tag{5}$$

$$GGS_{i,t} = \alpha + \sum_{j=1}^{p} \beta''_j \cdot GGS_{i,t-j} + \sum_{j=1}^{p} \gamma''_j \cdot EE_{i,t-j} + \sum_{j=1}^{p} \delta''_j \cdot EES_{i,t-j} + \varepsilon''_{i,t} \tag{6}$$

where $\varepsilon_{i,t}$, $\varepsilon'_{i,t}$ and $\varepsilon''_{i,t}$ denote the stochastic error terms, called innovations. Those innovations are used later for an impulse function analysis to show the effect on energy efficiency on each of the standard error shocks generated by the other endogenous variables included in the estimated VAR model.

The error terms have to follow a white noise process, known in terms of VAR models as innovations process. No autocorrelation between different panel unit residuals, ensuring: (i) no dynamic interdependencies (no lagged impact from variable l of country i to variable k of country j for lag p); (ii) no static interdependencies (no correlation between the error term of equation l of country i, with the error term of equation k of country j; (iii) no cross-sectional heterogeneities (homogeneous coefficient across the countries for lag p). Therefore, in addition to the review of the classical adjusted R^2 and the F-statistic, we check for model validation performing several additional tests,

respectively the autocorrelation LM test and the White Heteroscedasticity test to check for panel errors autocorrelation and model heteroscedasticity.

As the lag length of the model influence significantly the estimate of the VAR model, it is essential to choose the optimal one, to avoid too many lags and too many coefficients to be estimated on the not sufficiently high number of observations (Gujarati & Porter, 2009). To ensure a proper lag length of the estimated model, we will choose the one that leads to the minimization of a majority of the following information criterion: Akaike's information criterion (AIC), Hannan-Quinn criterion (HQ), Schwarz criterion (SC) (Ivanov & Kilian, 2005).

The VAR model analysis provides relevant information about the sign and the amplitude of the relation between our endogenous variables. Additionally, through VAR model estimation, we can determine the response of the energy efficiency variable to shocks on the other endogenous variables, over a longer period, by analyzing the resulted impulse response function. Additionally, the variance decomposition analysis is performed as it offers useful insights on how much each endogenous variable contributes to the changes encountered on our energy efficiency focus variable.

Further robustness analysis is performed, including on our VAR model several exogenous variables, which are confirmed with only a uni-directional causality relationship, to control our results for (i) firm operations impact on countries' change to achieve energy consumption 2030 targets; (ii) implications of country energetic security, from the perspective of the degree net imports cover a country's demand of energy; (iii) countries' competitiveness, which have implications on energy pricing and countries' power of negotiation.

4. Results and discussion

4.1. Exploratory data analysis

According to EU Commission, reported figures as of 2019, the 2020 targets on energy consumption reduction with 20% have been achieved, with more than 3%. Instead, Directive (EU) 2018/2002 has established new targets for 2030, compared to the targets decided through the Directive 2012/27/EU defining the 2020 targets on energy efficiency. In Figure 1, we represent the evolution of the energy efficiency indicator measuring the distance to the 2020 and 2030 targets, on an annual basis for the EU members, considered in our sample.

Table 2 provides descriptive statistics, and it shows smooth evolution toward the energy efficiency targets related to energy consumption, which might be the effect of the coherent macroeconomic policies directed by the EU Commission. Looking at Figure 2, we can observe significant gaps between countries regarding energy efficiency indicators, which can be justified by different country institutional frameworks, economic development, capital markets maturity, technological innovation, and human capital development (Wang et al., 2019).

Additionally, in the light of increasing awareness of governments concerning the weak results of circular economy concepts implementation, some studies show the negative effect of energy use on the environment (Halkos & Petrou, 2019). The statistics also show discrepancies countries in terms of greenhouse gas emissions (CO_2,

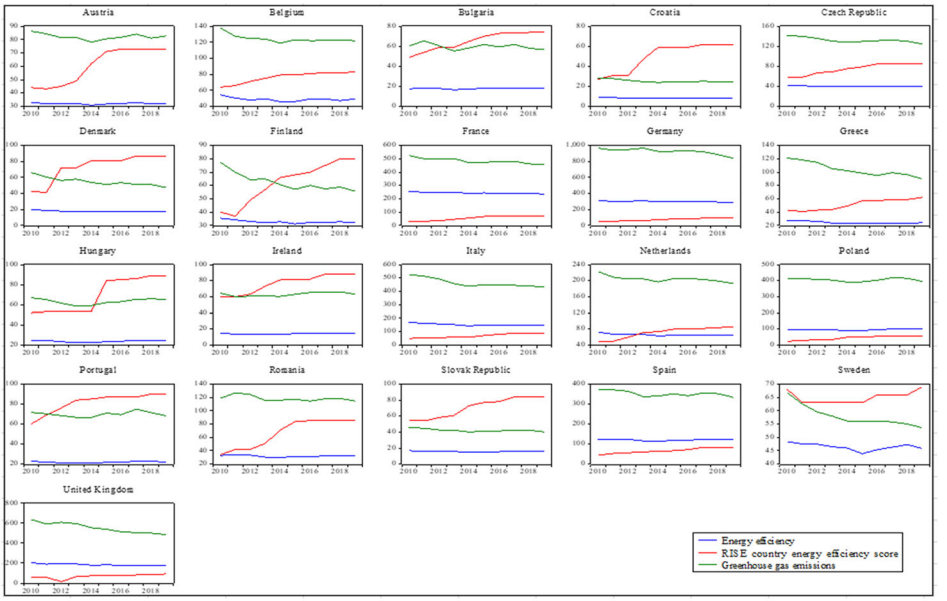

Figure 1. Evolution in time on the endogenous variables.
Source: Authors' projection

Table 2. Descriptive statistics.

	Energy dependence	Energy efficiency	Country energy efficiency score	Firm policy efficiency	Global competitiveness index	Greenhouse gas emissions
Mean	51.40	73.16	66.06	62.58	18.44	211.9
Median	48.95	32.97	67.50	86.74	5.130	100.6
Maximum	91.78	315.15	92.00	93.61	82.84	966.3
Minimum	−15.97	7.600	15.93	0.000	3.860	23.85
Std. Dev.	20.73	80.00	16.54	39.72	27.57	229.4
Jarque-Bera	3.629	104.4	10.51	41.69	85.81	136.3
Probability	0.163	0.000	0.005	0.000	0.000	0.000

Source: Authors' calculation.

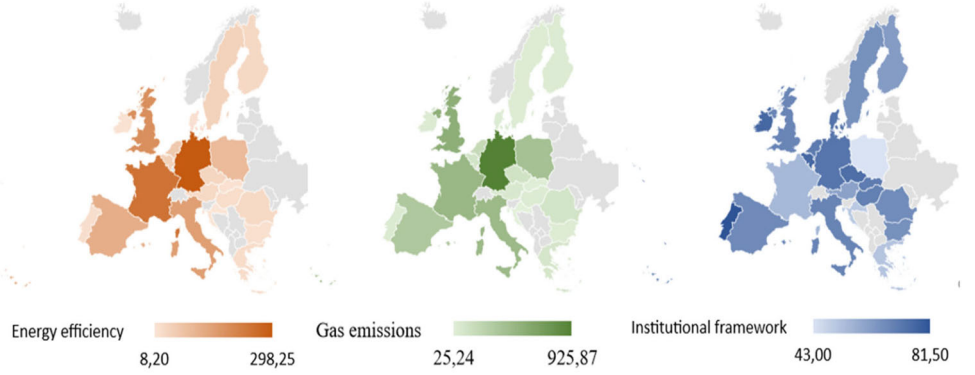

Figure 2. Country profile based on average of endogenous variables.
Source: Authors' projection

SO_x, NO*x*, etc.). The median value of greenhouse gas emissions is less than half of the mean value, while the range of values is between 23, 85 and 966,3 (Wang et al., 2017).

National decision-makers have come to the agreement that coherent strategies have to be drawn up and implemented to redesign the current energy European system, including reduction of greenhouse gas emissions through technological innovation, financing, and support of installing new renewable energy capacities that amplify as well the circular economic systems, or through the improvement of energy efficiency in other to reach an annual media 1.8% reduction of energy consumption (Knopf et al., 2013; EU Commission,2020).

Nonetheless, researchers have raised the impact of firms' impact on how energy efficiency can be achieved through firms' processes redesign or processes continuous improvements (Renna & Materi, 2021; Solnørdal & Foss, 2018). Instead, the authors underlined the gap between firms' management objectives and governments' objectives, which generally lead to poor or ineffective programs incentivizing the use of cleaner energy, such as renewable energy. This gap seems to become a systemic issue, as Solnørdal and Foss (2018) have highlighted that the national policy instruments on energy efficiency have the lowest impact on firms' energy efficiency performance. Instead, firm policies addressing the problem of energy efficiency within the organizations can create the premises for better operational performance on the use of energy if designed to the specific of firms' business model and cultural organization. This approach can explain how close the median value (86,74) is to the maximum value (93,61), showing that our sample contains mainly (more than 50%) firms with a score greater than the mean value (62,58). Firms consider relevant the need to address the problem of energy efficiency, not only from the cost and constraints perspective but also from the environmental perspective (Sineviciene et al., 2017).

4.2. Correlation analysis

In Table 3, we emphasize the correlations between our variables. One relevant correlation we can observe is between the score that reflects the quality of the country's framework supporting the initiatives on energy efficiency and the gas emissions level (0,416), showing how important is the role of the state in leading the efforts to gas

Table 3. Correlation matrix.

	Energy dependence	Energy efficiency	Country energy efficiency score	Firm policy efficiency	Global competitiveness index	Greenhouse gas emissions
ED	1					
EE	0.136*	1				
EES	0.150*	−0.058	1			
FPE	0.036	0.078	−0.031	1		
GCI	0.064	0.021	0.416*	0.025	1	
GGS	0.146*	0.963*	−0.070	0.026	0.000	1

Note: Energy efficiency (EE), RISE energy efficiency score (EES), Energy dependency (ED), Firm policy energy efficiency (FPE), Global competitiveness index (GCI), Greenhouse gas emissions (GGS).
Source: Authors' calculation.
*Significance level of correlation for 1%.

emissions reduction through reduction on energy consumption and reduction of the waste of energy because of poor energy logistic systems.

However, a strong correlation exists between the level of achieving the reduction targets on energy consumption and the level of gas emissions (0.963). The positive correlation is unexpected, but it can be explained by the fact that the measure of energy efficiency is a cumulative value over time which reduce the same time with the reduction in gas emissions because of the efforts to increase the productivity of energy consumption by producing higher value add with a lower amount of energy (Acaravci & Ozturk, 2010).

4.3. Time series stationarity analysis

The time series analysis involves the first step if there are unit roots, otherwise leading to spurious regressions (Gujarati & Porter, 2009). The commonly accepted unit root tests are the ADF (Augmented Dickey-Fuller) and PP (Phillips-Perron) (Gujarati & Porter, 2009). We perform additional more recent two panel unit root tests to these tests, respectively Levin–Lin–Chu test and Im–Pesaran–Shin test.

In Table 4, we provide the results of all unit root tests employed. The results show that all endogenous variables considered for our model are stationary at the value level, respectively I(0), at a significance level of 5%, except for the Im-Pesaran-Shin test and AD Fischer test significant for a level of 10%. These results show that one fundamental assumption required to estimate a VAR model, respectively, the endogenous variables must have the same integration order, is fulfilled (Gujarati & Porter, 2009). The I(0) order of integration allows us to use the level values of our time series, ensuring the stationarity condition required for the VAR model. After all, this order of integration shows slow progress on achieving targets on energy efficiency, reducing greenhouse emissions, and even more on structural changes of the energy efficiency country institutional framework.

Table 4. Panel unit root test results.

		Individual intercept (level)	
Variable	Method	*Statistic*	*P-value***
Energy Efficiency **(EE)**	Levin, Lin & Chu t*	−4.260	0.000
	Im, Pesaran and Shin W-stat	−1.402	0.081
	ADF - Fisher Chi-square	51.99	0.097
	PP - Fisher Chi-square	112.3	0.000
Energy Efficiency Score **(EES)**	Levin, Lin & Chu t*	−12.51	0.000
	Im, Pesaran and Shin W-stat	−2.740	0.003
	ADF - Fisher Chi-square	76.82	0.001
	PP - Fisher Chi-square	61.96	0.024
Greenhouse Gas Emissions **(GHC)**	Levin, Lin & Chu t*	−5.306	0.000
	Im, Pesaran and Shin W-stat	−1.680	0.047
	ADF - Fisher Chi-square	65.77	0.011
	PP - Fisher Chi-square	95.54	0.000

**Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.
Source: Authors' calculation.

4.4. Panel causality test results

As described in the section of methodology, the data we have started comprised more input variables, including energy production, energy consumption, World Governance regulatory quality score, World Governance rule of law score, firm ESG score, and firm target energy efficiency score, a variable which was excluded based on the results of causality tests performed.

Table 5 presents the Granger causality test results only for the variables for which significant F-statistics were obtained for different lag length scenarios, showing Granger causality with our dependent variable (energy efficiency). The optimal lag length for the VAR model estimated is 2, based on the AIC value, which is the smallest criterion value. We have performed a Granger causality test for 1 lag and 3 lags for the robustness of our results.

The results show a significant bi-directional causality between RISE country energy efficiency score (EES) and energy efficiency (EE), as both F statistics are statistically significant for a level of 1%. These results show that achievement of energy consumption reduction targets is significantly influenced by the country's institutional framework, reflected by RISE composite index dimensions, respectively: incentivization programs and tools, financing mechanisms for energy efficiency, standardization and monitoring of energy efficiency performance management, enforcement mechanisms, or strategic national efficiency planning. The results are in line with Zhang et al. (2013), who have underlined as well the importance of financing on the area of energy consumption reduction and decline on related gas emissions through government subsidies, favorable credit policies, incentivizing tax policies, or even media supervision.

Similar bi-directional results are also obtained in the case of energy efficiency (EE) and gas emissions (GHC). Energy efficiency is not reached only through better energy production, but through cleaner alternative energy solutions, such as bioenergy or wind energy which seem to be in EU Commission's attention for future financing (EU Commission, EU Commission, EU Commission, 2020).

Additionally, we observe only a uni-directional causality relation between the country's institutional framework and greenhouse gas emissions, showing that the level of reported GHCs significantly influences national regulation and strategies for gas emission reductions. Instead, the reverse causality relation is not statistically

Table 5. Granger causality analysis.

Variable type	Causality relation	No. lags	*Lag = 2*	*Lag = 3*	*Lag = 1*
Endogenous variables	EE <– EES	F statistic	4.122*	0.011	2.598
	EES <– EE	F statistic	6.052*	0.056	0.043
	EE <– GGS	F statistic	3.871*	0.019	0.183
	GGS <– EE	F statistic	3.257*	0.005	1.765
	EES <– GHC	F statistic	4.714*	0.071	0.065
	GHC<– EES	F statistic	0.091	0.477	0.089
Exogenous variables	EE <– FPE	F statistic	0.254*		
	EE <– GCI	F statistic	3.701*		
	EE <– ED	F statistic	3.247*		

EE, energy efficiency; EES, RISE energy efficiency score; GHC, greenhouse gas emissions; FPE, firm policy efficiency score; GCI, country global competitiveness index; ED, economic dependence.
*Rejection of the null hypothesis of no Granger causality at the 5% significance level.
Source: Authors' calculation.

significant, which leads us to the same conclusion as Knopf et al. (2013) and Solnørdal and Foss (2018), that country regulation and enforcement mechanisms cannot address the problem of GHC reduction properly.

4.5. VAR model estimation and analysis

If Granger causality testing has provided relevant information about how variables influence each other, the estimated VAR model reveals essential information on the amplitude of the causality between those variables. Through VAR model estimation, we solve the issue of endogeneity, but with the condition that the dynamic information on the model is limited. Instead, as noted by Gujarati and Porter (2009), VAR model estimation is sensitive to the lags considered on the model. The lag is selected based on the smallest value of the AIC value, as this criterion value (17,58) is slightly smaller than the SIC value (17,97).

In Table 6, we present the main three criteria generally sued for VAR model lag length. The lowest value of AIC is valid for the lag $k = 2$, while the value of SC indicates a lag of only $k = 1$. However, as the HQ criterion indicate the lag as well of $k = 2$, we have decided on a VAR model with two lags.

There is no lag considered on Granger causality testing, as indicated by the results of statistical testing for the optimal lag length of the model, presented in Table 6, which shows neither of the statistics determined is statistically significant. In those circumstances, we've decided on a VAR model estimation, first because of the order of integrating our variables and secondly based on the results from Table 6. Compared with the ADRL model, the VAR model does not count for the impact of short-run effects of our variables on energy efficiency. Additionally, as noted by Knopf et al. (2013), changes in energy systems optimization take time, for why public policies and firms' investment projects are expected to generate visible effects in a longer term. The medium and long-term orientation of energy projects is already acknowledged, so planning on energy efficiency became essential in the last decade. Nonetheless, institutional mechanisms are not sufficiently flexible and accountable in case of all countries, varying geographically and in time (Cattaneo, 2019), the reason why a more coherent approach has been decided by implementing globally three key policies, respectively: (i) the implementation of Energy Efficiency Standard, to encourage energy efficiency, (ii) the implementation of Feed-in-Tariff (FiT) to ensure an attractive scheme of incentives for consumers to decide in favor of renewable energy, (iii) Building Energy Performance Certification (BEPC) schemes, aimed to promote

Table 6. Lag length selection results.

Lag	LogL	AIC	SC	HQ
0	−2.019	32.100	32.167	32.127
1	−1.044	16.768	17.04*	16.877
2	−1.029	*16.66**	17.136	*16.86**
3	−1.020	16.668	17.344	16.943
4	−1.,012	16.689	17.566	17.045

AIC, Akaike information criterion; SC, Schwarz information criterion; HQ, Hannan–Quinn information criterion.
*Lag order selected by the criterion.
Source: Authors' calculation.

Table 7. VAR Model estimation.

Variable		Lag	energy efficiency	energy efficiency score	greenhouse gas emissions
Endogenous variables	Energy efficiency	1	0.570*	0.541	−0.967*
			0.164	0.588	0.515
		2	0.419*	−0.540	0.952*
			0.162	0.587	0.510
	Energy efficiency score	1	−0.026	0.746*	−0.036
			0.044	0.161	0.165
		2	0.051	0.075	0.048
			0.051	0.159	0.199
	Greenhouse gas emissions	1	0.076*	0.062	1.190*
			0.027	0.039	0.252
		2	−0.076*	−0.060	−0.202
			0.027	0.038	0.248
Exogenous variables	Constant		−1.329*	15.97*	−0.189
			0.664	2.228	2.571
Model validation	Adj. R-squared		0.999	0.814	0.999
	F-statistic		25269.4	117.5	19272.8
	AIC criterion		17.58		
	SW criterion		17.97		
Residual's diagnostic	Joint normality test	JB-Stat	1380.2*		
	Autocorrelation test	LM-Stat	10.175		
		P-value	0.3365		
	White heteroscedasticity test	Chi-sq	597.3*		
Model stability	Maximal modulus (Characteristic polynomial roots)		0.992		

Source: Authors' calculation.
*Significance level of coefficient estimated for 1%.

widening the diffusion of new technologies in conjunction with advanced energy technologies (Lu et al., 2020).

In Table 7, we summarize the estimation of the VAR model. The model is statistically significant as the $F-statistic$ is significantly higher than the critical value. Moreover, we observe a high level of R^2 *adjusted*, which explains in the case of all models at least 81,4% of the output variable. Additionally, we observe that there is no autocorrelation on the error term between different panel units, as the LM-statistic is not statistically significant ($LM-stat = 10.175,\ Sig. > 5\%$). The problem of heteroskedasticity ($Chi-square\ stat = 597.3,\ Sig. < 5\%$) is solved by estimating the model using the White standard errors method, to get consistent standard errors, as the estimated regression coefficients are not affected (Lee et al., 2019). Nonetheless, we observe our model is stable, as there is no root of the characteristic polynomial placed outside the circle with the radius of 1.

Overall, we observe energy efficiency is significantly affected by a recurrent component indicating a maximum lag of two years ($Coef. = 0,570,\ Sig. < 0.01$), indicating that achievement of targets on energy consumption reduction represents a progressive process which seems to be irreversible.

Results show no impact on energy efficiency level, generated by the level of gas emissions, as the coefficient is even statistically significant for both lags, are o opposite sign. However, this causality relation provides more conclusive information, especially on a short-run approach, that is analyzed in our study.

Instead, it seems that the country's institutional framework has played an insignificant role in achieving energy efficiency. These results show that the efforts of energy

consumption reduction are rather driven by firm-level decision, strongly influenced by cost-related constraints, such as the price of gas or electricity, the costs of penalty for gas emissions, or process-related improvements leading to environment protection, positively perceived on capital markets as well. Instead, those firm-based drivers are partly incorporated on the value of our constant ($Coef. = -1,329$, $Sig. < 0.01$), which confirms once again our previous statement. Therefore, market growth opportunities or economic constraints force managers to look for more cost-effective solutions to cover energy demand. Zangheri et al. (2019) study highlights that among the recurrent replies given by countries for achievement of the annual target, in terms of energy consumption reduction, there are also references to a price reduction of gas or electricity.

Overall, the model estimated is stable, indicated that no characteristic polynomial root identified fall outside the unit circle, showing once again variables stationary and the fact that long-run accumulated shocks are 0 and that the energy systems automatically recalibrate in time.

4.6. Impulse response function analysis

In Figure 3, we have represented the response of our endogenous variables to different shocks, such as changes in regulation or new innovative technologies that can lead to significant gas emission reduction. Thus, the graph shows how energy efficiency will be affected to one standard deviation innovations to either country RISE energy efficiency score or country reported gas emissions.

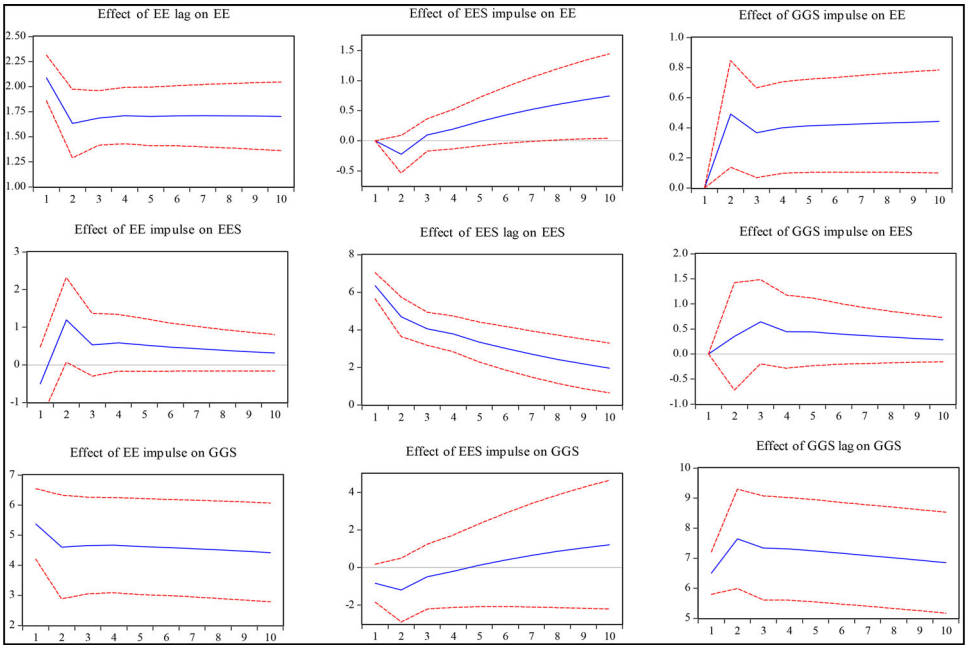

Figure 3. Representation of shock effects on model endogenous variables.
Source: Authors' projection

The graph shows that one standard error shock in historical annual energy savings determines a negative response of the current year energy savings but is limited to the first two years. In the long term, for two to four years, the historical energy savings have a slightly positive effect. Nonetheless, we observe a positive response of energy efficiency on a one standard error shock on greenhouse gas emissions in the short run for the first two years analyzed. However, for the next year, the positive effect of energy efficiency to a shock on change on GHC is reversed partially.

4.7. Variance decomposition analysis

As a final step of our analysis, we review each of the endogenous variables' role in explaining the weight of a one standard error shock determined to the response of energy efficiency. In Figure 4, we represent the distribution of contribution of each of the endogenous variables to the one standard error innovations. We have considered only ten years because of the small optimal lag length determined in the previous sections, which is two years for a long-run approach, while only one year lag is considered for a short-run perspective.

The graph and the distribution of probability show that the main driver of the response of energy efficiency to shocks is the historical short-run energy savings. In the first year, current energy efficiency is affected 100% by prior year energy efficiency shocks. In the next years, this shock affects less the current year period energy efficiency, reaching the minimum value of 86,47% in the case of the short-run analysis.

Overall, those two drivers are not significantly relevant, meaning that governments must change their perspective, from factors of regulation and enforcement, they should change to factors of facilitation and supporting factors for firms' initiatives that lead to a reduction in energy consumption. For this purpose, they must first

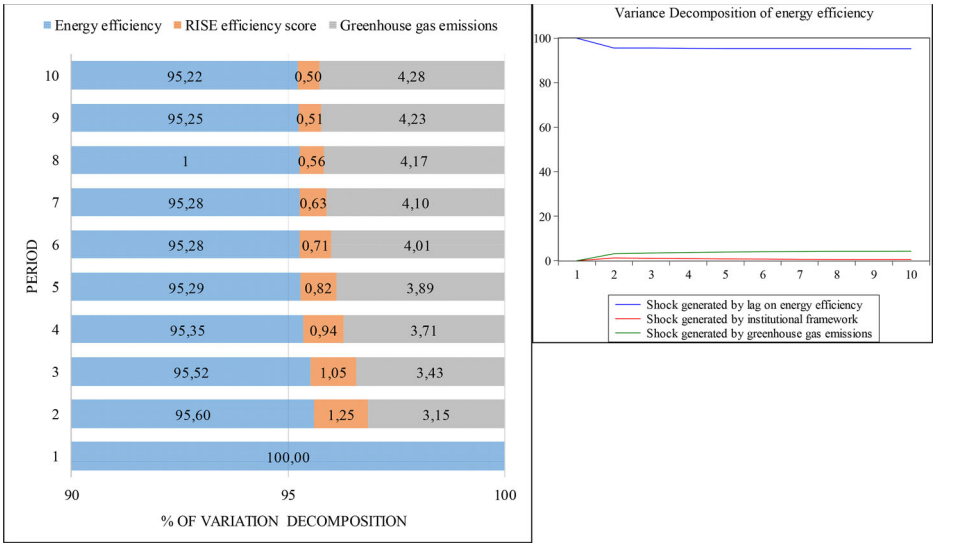

Figure 4. Representation of endogenous variables to a variation on energy efficiency.
Source: Authors' projection

ensure a more robust national regulation and sufficiently flexible, granting more standard-setting authority to organizations of profile on the energy area and specialized firms associations. Secondly, they must ensure a transparent and advantageous system of financing technological innovations in alternative energy sources. Nonetheless, as prescribed by the Directive 2012/27/EU, they must ensure effective enforcement mechanisms, such as the energy audits and regular standard reporting of energy consumption. This policy implication should prepare the countries for the currently proposed new EU Directive on energy efficiency, which will amend the initial one, with the new 2050 targets on energy consumption, energy dependency, and technological innovation related to energy production.

4.8. Robustness analysis

As the last step of our analysis, we provide the VAR model estimation results, controlling this time for the influence of firms' policy in energy efficiency, the competitiveness of the national economic environment, and countries' rate of energetic dependence. This way, we understand the impact of some of the main constraints that governments face on their efforts to keep as high as possible the distance between energy consumption and related targets of maximum energy consumption.

5. Discussion

A higher energy dependence determines higher energy productivity, meaning lower energy consumption per value add created, directly impacting our energy efficiency variable. Solnørdal and Foss (2018) and Renna and Materi (2021) stated energy consumption reduction is expected to be determined by the firms' behavior in adjusting their energy demand, through the strategic direction given by managers. The pressure is even higher for such micro-management of the energy demand. As long as energy markets prove extremely volatile, firms search for each opportunity to get an advantage on the negotiated energy price. Nonetheless, there is evidence that a nation's governance quality represents, perhaps not a central driver for energy efficiency, but rather a mediating factor (Apergis & Garćıa, 2019).

The results show no significant changes between the model provided in Table 7 and the model provided in Table 8. The control variables seem to have no significant impact on the distance between the annual energy consumption and the remaining target level. Instead, we can observe that the level of competitiveness of a national economy significantly influences the national framework for the energy efficiency of a country ($Coef = -0.037$, $Sig. < 5\%$). These results suggest a complementary relation between the maturity of the economic environment and the quality of the framework created by the government to promote energy efficiency. The economic environment can lead to energy efficiency through different channels and mechanisms, such as the efficiency of energy markets, availability of financing resources for initiatives aimed to reduce energy consumption, non-compliance costs for consumer behavior that breach legal requirements or industry standards requirements, etc. On the other side, if the economic environment is not capable of ensuring voluntary reduction of energy

Table 8. Var model estimation considering exogenous variables.

Variable		Lag	Energy efficiency	Energy efficiency score	Greenhouse gas emissions
Endogenous variables	Energy efficiency	1	0.581*	0.612	−0.828
			0.169	0.595	0.506
		2	0.408*	−0.608	0.818
			0.167	0.596	0.500
	Energy efficiency score	1	−0.025	0.746*	−0.035
			0.044	0.159	0.162
		2	0.059	0.112	0.118
			0.049	0.164	0.189
	Greenhouse gas emissions	1	0.076*	0.054	1.175*
			0.029	0.034	0.246
		2	−0.075*	−0.052	−0.187
			0.029	0.033	0.242
Exogenous variables	Constant		−1.178*	15.15*	−2.378
			0.509	2.844	2.241
	Energy dependence		−0.357	−0.422	−0.536
			0.415	0.754	1.611
	Global competitiveness index		−0.008	−0.037*	−0.072*
			0.006	0.015	0.022
	Firm policy efficiency score		0.001	−0.002	0.001
			0.004	0.015	0.009
Model validation	Adj. R-squared		0.999	0.818	0.999
	F-statistic		16727.9	79.043	13221.5
	AI criterion		31.4		
	Schwarz criterion		31.971		
Residuals diagnostic	Joint normality test	JB-Stat	1386.2*		
	Autocorrelation test	LM-Stat	7.415		
		P-value	0.594		
	White heteroscedasticity test	Chi-sq.	707.9*		
Model stability	Maximal modulus (characteristic polynomial roots)		0.992		

Source: Author's calculation.
*Significance level of coefficient estimated for 5%.

consumption, either within firms, or households, the national government should intervene and create a consolidated framework that implements adjustments in the economy by offering incentives for consumer behavior that lead to lower energy consumption and higher energy efficiency.

Apergis and Garćıa (2019) and Chou and Zhang (2020) studies have confirmed a positive impact of national governance quality on the increase of energy efficiency. However, their results referred only to indirect measures of the quality of the national framework for energy efficiency. In contrast, our study relates to a more focused energy efficiency indicator regarding the RISE energy efficiency component. Nonetheless, Chou and Zhang (2020) noted, a higher impact of national governance quality is confirmed in the case of nations with lower energy efficiency. Our study is limited to EU countries, subject to uniform energy efficiency directives, which partly leads to a higher convergence of national regulations in this area and higher energy efficiency. Evidence in the literature indicates significant progress on implementing the EU energy directives, though emphasizing the need for further concerted efforts to improve the regulation and monitoring instruments (Zangheri et al., 2019). However, we underline that the European regional initiative to coordinate the efforts toward achieving the 2030 targets in terms of energy reduction is limited, as national standard-setters must further regulate country-specific items.

The results also suggest similar complementary mechanisms, when identifying the relationship between the level of greenhouse gas emissions and the quality of a nation's institutional energy efficiency factors ($Coef = -0.072$, $Sig. < 5\%$). The higher the competitiveness of a nation, the lower the level of greenhouse gas emissions, as an effect of energy consumption reduction, which represents an opportunity for firms to optimize their cost models throughout their operational processes. However, higher competitiveness within a nation is not determined only by energy price effects on firms' cost models. Still, it can also denote that a nation has higher capabilities to foster innovation and implement advanced technologies designed to reduce energy consumption and indirectly increase energy productivity. Nonetheless, it is important to underline that the national competitiveness index also contains a component that describes the complexity of business models in an economy or the sophistication of production processes, which can have contradictory effects. First, more complex business models can be reflected by the highly horizontal and vertical integration of the operations, with potential significant scale effects determined by avoiding externalization of processes and creating value-added along the entire supply chain. On the other side, business models can also be less complex. Still, the products such firms sell can be produced through processes using technologies that require high consumption of resources, as is the case in the chemical industry.

The impact of firms' policies on macroeconomic energy consumption reduction seems to be statistically insignificant. The results are similar to Sineviciene et al. (2017), who underlined that changes to the firms' corporate governance do not lead to substantial reductions in energy consumption.

6. Conclusion

Our study aimed to assess the causality between the quality of national institutional frameworks designed to ensure higher energy efficiency and the distance to the achievement of the EU Commission targets in terms of energy consumption. Our analysis uses a time series covering the period 2010–2019, structured in panels represented by the 21 EU member states included in our sample.

Our results show a relevant correlation between the score that reflects the quality of a nation's framework supporting energy efficiency initiatives and the gas emissions level. However, the quality of a nation's institutional and economic energy efficiency framework does not significantly influence the distance between annual energy consumption and related EU targets, as prescribed by the energy efficiency EU Directives. Instead, the bi-directional Granger causality relationship is visible only for the first three years according to the impulse response function. Another strong correlation exists between the level of achieving the reduction targets on energy consumption and the level of gas emissions. Similar bi-directional results are obtained as well in the case of energy efficiency (EE) and gas emissions (GHC). Also, our findings reveal that the level of reported GHCs significantly influences national regulation and strategies for gas emission reductions. These results indicate that a nation's institutional framework can influence the achievement of energy consumption reduction targets, but only as long as the mechanisms activated work effectively and are

supported by regulations consistent with the local specificities of the economic environment. The outcomes of our research highlight the fact that institutional regulatory frameworks are important factors in achieving energy efficiency. Thus, regulations and monitoring mechanisms must correctly and concretely address this issue through coherent legislation and an effective control mechanism to reduce consumption and gas emissions to increase energy efficiency. Once this macroeconomic objective is achieved, firms can better understand how their internal processes and supporting policies and procedures should be designed to align with the direction provided by the government.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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References

Acaravci, A., & Ozturk, I. (2010). On the relationship between energy consumption, CO2 emissions and economic growth in Europe. *Energy*, *35*(12), 5412–5420. https://doi.org/10.1016/j.energy.2010.07.009

Adua, L., Clark, B., & York, R. (2021). The ineffectiveness of efficiency: The paradoxical effects of state policy on energy consumption in the United States. *Energy Research & Social Science*, *71*, 101806. https://doi.org/10.1016/j.erss.2020.101806

Apergis, N., & Garćıa, C. (2019). Environmentalism in the EU-28 context: The impact of governance quality on environmental energy efficiency. *Environmental Science and Pollution Research International*, *26*(36), 37012–37025.

Breuer, A., Janetschek, H., & Malerba, D. (2019). Translating sustainable development goal (SDG) interdependencies into policy advice. *Sustainability*, *11*(7), 2092. https://doi.org/10.3390/su11072092

Canova, F., & Ciccarelli, M. (2013). Panel Vector Autoregressive Models: A Survey (January 16, 2013). ECB Working Paper No. 1507. https://ssrn.com/abstract=2201610

Cattaneo, C. (2019). Internal and external barriers to energy efficiency: Which role for policy interventions? *Energy Efficiency*, *12*(5), 1293–1311. https://doi.org/10.1007/s12053-019-09775-1

Chou, L.-C., & Zhang, W.-H. (2020). The effect of democracy on energy efficiency in European countries. *Economic Research-Ekonomska Istraživanja*, *33*(1), 3476–3491. https://doi.org/10.1080/1331677X.2020.1774792

Edziah, B. K., Sun, H., Anyigbah, E., & Li, L. (2021). Human capital and energy efficiency: Evidence from developing countries. *American Journal of Industrial and Business Management*, *11*(06), 599–610. https://doi.org/10.4236/ajibm.2021.116038

European Environment Agency. (2016). About climate change. Retrieved from: https://www.eea.europa.eu/ro/themes/climate/about-climate-change

EU Commission. (2020). Financing a sustainable European economy. Taxonomy Report: Technical annex. https://ec.europa.eu/info/sites/default/files/business_economy_euro/banking_and_finance/documents/200309-sustainable-finance-teg-final-report-taxonomy-annexes_en.pdf

European Commission. (2021). "Fit for 55": delivering the EU's 2030 Climate Target on the way to climate neutrality. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0550&from=EN

European Commission. (2018). Directive 2018/2002/EU of the European Parliament and of the Council of 11 December 2018 amending Directive 2012/27/EU on energy efficiency. Retrieved from: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2002&from=EN

Gujarati, D., & Porter, D. (2009). *Basic Econometrics* (5th ed.). McGraw Hill Inc.

Halkos, G., & Petrou, K. N. (2019). Analysing the energy efficiency of EU Member States: The potential of energy recovery from waste in the circular economy. *Energies*, *12*(19), 3718. https://doi.org/10.3390/en12193718

Ivanov, V., & Kilian, L. (2005). A practitioner's guide to lag order selection for VAR impulse response analysis. *Studies in Nonlinear Dynamics & Econometrics*, *9*(1), 1–38. https://doi.org/10.2202/1558-3708.1219

Knopf, B., Chen, Y.-H H., De Cian, E., Förster, H., Kanudia, A., Karkatsouli, I., Keppo, I., Koljonen, T., Schumacher, K., & Van Vuuren, D. P. (2013). Beyond 2020—Strategies and costs for transforming the European energy system. *Climate Change Economics*, *04*(supp01), 1340001. https://doi.org/10.1142/S2010007813400010

Lee, C.-F., Chen, H.-Y., & Lee, J. (2019). *Financial econometrics, mathematics and statistics*. Springer.

Lu, Y., Khan, Z. A., Alvarez-Alvarado, M. S., Zhang, Y., Huang, Z., & Imran, M. (2020). A critical review of sustainable energy policies for the promotion of renewable energy sources. *Sustainability*, *12*(12), 5078. https://doi.org/10.3390/su12125078

Lyulyov, O., Pimonenko, T., Kwilinski, A., Dzwigol, H., Dzwigol-Barosz, M., Pavlyk, V., & Barosz, P. (2021). The impact of the government policy on the energy efficient gap: The evidence from Ukraine. *Energies*, *14*(2), 373. https://doi.org/10.3390/en14020373

Omri, A. (2014). An international literature survey on energy-economic growth nexus: Evidence from country-specific studies. *Renewable and Sustainable Energy Reviews*, *38*, 951–959. https://doi.org/10.1016/j.rser.2014.07.084

Ozturk, I. (2010). A literature survey on energy–growth nexus. *Energy Policy*, *38*(1), 340–349. https://doi.org/10.1016/j.enpol.2009.09.024

Renna, P., & Materi, S. (2021). A literature review of energy efficiency and sustainability in manufacturing systems. *Applied Sciences*, *11*(16), 7366. https://doi.org/10.3390/app11167366

Sarfraz, M., Mohsin, M., Naseem, S., & Kumar, A. (2021). Modeling the relationship between carbon emissions and environmental sustainability during COVID-19: a new evidence from asymmetric ARDL cointegration approach. *Environment, Development and Sustainability*, *23*, 16208–16226. https://doi.org/10.1007/s10668-021-01324-0

Sarfraz, M., Qun, W., Hui, L., & Abdullah, M. (2018). Environmental risk management strategies and the moderating role of corporate social responsibility in project financing decisions. *Sustainability*, *10*(8), 2771. https://doi.org/10.3390/su10082771

Schulze, M., Nehler, H., Ottosson, M., & Thollander, P. (2016). Energy management in industry–a systematic review of previous findings and an integrative conceptual framework. *Journal of Cleaner Production*, *112*, 3692–3708. https://doi.org/10.1016/j.jclepro.2015.06.060

Shehzad, K., Xiaoxing, L., Sarfraz, M., & Zulfiqar, M. (2020). Signifying the imperative nexus between climate change and information and communication technology development: a case from Pakistan. *Environmental Science and Pollution Research International*, *27*(24), 30502–30517.

Sineviciene, L., Sotnyk, I., & Kubatko, O. (2017). Determinants of energy efficiency and energy consumption of Eastern Europe post-communist economies. *Energy & Environment*, *28*(8), 870–884. https://doi.org/10.1177/0958305X17734386

Solnørdal, M. T., & Foss, L. (2018). Closing the energy efficiency gap—a systematic review of empirical articles on drivers to energy efficiency in manufacturing firms. *Energies*, *11*(3), 518. https://doi.org/10.3390/en11030518

Uribe-Toril, J., Ruiz-Real, J. L., Milán-García, J., & de Pablo Valenciano, J. (2019). Energy, economy, and environment: A worldwide research update. *Energies*, *12*(6), 1120. https://doi.org/10.3390/en12061120

Wang, C.-N., Ho, H.-X T., & Hsueh, M.-H. (2017). An integrated approach for estimating the energy efficiency of seventeen countries. *Energies*, *10*(10), 1597. https://doi.org/10.3390/en10101597

Wang, C.-N., Nguyen, T.-D., & Yu, M.-C. (2019). Energy use efficiency past-to-future evaluation. *An International Comparison. Energies*, *12*(19), 3804.

Wu, Y., & Zhou, X. (2010). VAR Models: Estimation, inferences, and applications. In *Handbook of Quantitative Finance and Risk Management* (pp. 1391–1398). Springer.

Zhang, Z., Jin, X., Yang, Q., & Zhang, Y. (2013). An empirical study on the institutional factors of energy conservation and emissions reduction: Evidence from listed companies in China. Energy Policy, *57*(C), 36–42.

Zangheri, P., Economidou, M., & Labanca, N. (2019). Progress in the implementation of the EU energy efficiency directive through the lens of the national annual reports. *Energies*, *12*(6), 1107. https://doi.org/10.3390/en12061107

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Non-Financial Information Disclosures and Environmental Protection—Evidence from Romania and Greece

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Abstract: Currently, sustainability and sustainable development are issues that concern society due to the high degree of pollution and the measures taken that, in many cases, do not prove their efficiency. Economic entities are aware that their involvement in the community has become necessary for the sustainable development of any business. The promotion of responsibility towards the environment is an important principle of corporate social responsibility (CSR), which is becoming an obligation that can no longer be exempted. Our intention in this paper was to study the changes generated by the European Union (EU) Directive 2014/95 regarding the manner in which oil entities listed at the Bucharest Stock Exchange (BSE) and the Athens Stock Exchange (ATHEX) between 2014 and 2018, report environment-related information. We also identified whether entities in fields that are known as polluting were more sensitive to environmental factors and if they tended to report more information compared to other business sectors. To achieve these objectives, we used qualitative and quantitative research. Namely, we analyzed the entities' non-financial reports, to identify their social responsibility actions, and we tested if they were correlated with the environment protection and also with the 2014/95 European directive stipulations. For the entities operating in this polluting area, demonstrating transparency regarding the efforts and investments made to counteract the environmental impacts is important. Non-financial corporate reporting can be an opportunity to integrate sustainability into a company's business practices and strategies to obtain benefits and to increase efficiency and, thus, to increase stakeholder confidence. The contribution of our study is to highlight the importance of non-financial information for the sustainable development of companies and the environment.

Keywords: non-financial reporting; social responsibility; sustainable development; forestry protection

1. Introduction

Climate change, the reduction in the consumption of resources used in the context in which they are globally limited, the reuse of waste materials, and the innovations made to protect the planet are objectives of major interest to organizations working to ensure sustainable development in a protected environment. One of these organizations is the Organization for Economic Co-operation and Development (OECD), which proposed three-pillar programs concerning Sustainable Development Goals regarding the environmental, economic, and social aspects.

The European Directive 2014/95/EU [1], amending the provisions of Directive 2013/34/EU [2], was created out of the need to identify among the Member States the risks related to sustainable development and to increase investor and consumer confidence [3], starting from the premise that "meeting current needs must be achieved without compromising the ability of future generations to meet their own needs" [4]. The Directive does not provide any specific disclosure framework but allows the use of national, European, or international frameworks while stating that, "details of the framework(s) relied upon should be disclosed" [1]. For international frameworks, it specifically mentions the Global Reporting Initiative G.R.I., the UN's Global Compact, the OECD's Guidelines for Multinational Enterprises, and the International Labour Organization's Tripartite Declaration of Principles concerning multinational enterprises and social policy [5]. "The EU Directive is a step ahead for the proper implementation of CSR policies, transforming it in a more regulated concept and adjusting in an appropriate manner the corporate behavior for better compliance with the sustainability needs" [6].

Directive 2014/95 lays the foundations for a new corporate reporting model that increases the level of transparency and trust by including the additional non-financial information needed to understand the impact of business activities, with sustainability being a defining element of the business strategy. Through this reporting, investors can consider both the risks and opportunities of future investments, with access to information on the environmental, social, and sustainable development issues. Non-financial reporting can help improve the entity's image in the community by publicly assuming respect for human rights, fighting corruption, and protecting the environment.

In this directive, companies must provide information on environmental, social, and personnel issues; on respecting human rights; and the fight against corruption and bribery. The statement should also include a description of the policies, results, and risks. In this context, we can state that transparency in reporting becomes an essential feature of the companies.

Globalization has also changed the volume of information needed by investors to make economic decisions. For the majority of the time, these pieces of information must be supplemented with non-financial data on performance. Non-financial reporting, also known as sustainability reporting, is the way in which companies present information related to the environmental, social, and economic aspects related to their current activities, the company values, and also their business model [7].

In our opinion, for a company to achieve sustainable and responsible development, the principles of sustainability and ethics must be part of the organizational culture, and, therefore, there must be a strong correlation between the company's declarations, their acts, and their beliefs.

Sustainability and the concept of sustainable development have begun to occupy an increasingly important place in the activity of companies, and non-financial performance is taken into account more frequently when developing investment strategies [8].

The current obligations imposed by the EU through the European Directive 2014/95/EU on the reporting of sustainability information apply to large entities of public interest and affect companies in all fields of activity [9].

In total, the targeted entities are companies listed on the stock exchange, banks, assurance companies, and other entities in the Member States exceeding the criterion of an average number of 500 employees during the financial year [10]. According to the CSR report [11], quoted by Sava [12], approximately 6000 entities are involved at the European level. In Romania, the regulation must be applied by 680 companies, out of which, 37 are listed on the Bucharest Stock Exchange, and they are required by law to publish non-financial information in 2018 for the year that ended on the 31 December 2017 [13].

Ogrean [14] posited that the introduction of the non-financial reporting obligation may increase the number of voluntarily reporting companies not exceeding the size criterion, that wish to be more competitive on the market.

The freedom offered by the European Directive 2014/95 in choosing the reporting model is a topic of great interest in the literature; in the absence of equivalent regulations, researchers are particularly

interested in comparing the non-financial information presented by entities from different countries and industries.

The previous studies on the transposition of the Directive have been carried out in countries, such as the UK, France, Italy, Poland, and Romania. In order to identify how Directive 2014/95 was transposed into national law in the UK, France, and Italy, Aureli et al. [15] made a textual analysis of the articles of the Directive regarding the regulatory choices or regulations set with reference to different aspects, the list of topics or content to be disclosed, the company scope of application, and the application of principles, such as the "company or explain" rule. Then, they searched for the regulation of the same aspects in the national laws transposing the Directive. The results of the study reflect an alignment of practices when the legal regulations were established and imposed by the EU, a spontaneous convergence of certain elements presented, and also significant differences that could prevent meeting the objectives established by the Directive, such as comparisons with previous years, accessibility of information, and changes in the entity's policies.

In the study conducted in 2017, the authors, Matuszak and Rozanska [16], stated that the analyzed Polish companies published sustainability information in accordance with the provisions of the European Directive in the Annual Report; however, the companies left out the presentation certain necessary information, such as information concerning human rights and anti-corruption.

Carini et al. [5] examined the impact of the Directive on a sample of oil entities through a disclosure scoring system based on 148 variables grouped into the following categories: environmental, employee, social, anti-corruption and bribery, and diversity and business model. The analysis considered both the complexity of the information presented and its structure. Complexity was measured by the presence of variables in the financial and sustainability reports, and overlap referred to the presence of variables in both reports. The results of the research reflected a reasonable level of compliance with the provisions of the Directive.

Dumitru et al. [8] studied the use of certain keywords in the annual reports of energy companies in Romania, before and after the transposition of the European directive 2014/95 and noticed a slight increase of these keywords after the implementation of the directive.

Imbrescu and Hategan [9] studied the impacts of adopting the requirements of the directive on agriculture and public food companies. They found that non-financial reporting was important for companies who understood that sustainability can only be achieved if they are involved in CSR activities.

By qualitative and comparative analysis, Wolny [17] investigated the changes generated by EU Directive 2014/95 in reporting environmental information given the data published by the energy sector entities listed on the Warsaw Stock Exchange during 2014–2016. The results of the study showed an improvement in reporting the activities related to environmental issues, although, during the period under review, the provisions of the directive had not yet been made mandatory for these entities.

In research conducted to determine the factors influencing the level of compliance in Romanian companies as required by the European Directive in terms of how they present non-financial information, Popescu and Bant [13] validated, by mathematical modeling, the hypothesis that there is a relationship between the presentation of non-financial information and the field of activity of the reporting entity. They identified the highest level of 100% compliance for the oil and gas branches.

To analyze the level of non-financial and diversity disclosure, Venturelli et al. [18] created an assessment model called the "Non-Financial Information score"(NFI), which records the required information as a percentage, using a manually performed content analysis. With an average NFI score of 49%, the results reflected that regulation could improve the quality of information disclosure made by large companies, which, at the time of the research, stood at unsatisfactory levels.

Persic and Halmi [19] studied the manner in which Croatian companies with at least 400 employees reported information according to the Directive. The data showed that many of the disclosed sustainability indicators are "story-tellers", meaning that they are past-oriented and qualitatively stated.

In their study on entities listed in the Spanish main market, Sierra-Garcia et al. [20] found, through mathematical modeling, that the level of compliance with European directives depended on the sector in which the entity operated. In this study, the econometric model underlined a statistically significant, positive relationship with the environmental matters index, meaning that companies in this sector revealed more information on the environmental aspects of their operations than those in other sectors. Avram et al. [21] also underlined the fact that entities in fields, such as oil, gas, and energy, obtained the best results for reporting non-financial data.

Knowing this, Directive 2014/95 provides companies with non-binding recommendations to give them the opportunity to choose different reporting frameworks, provided that they are specified, in our paper we studied the changes generated by the EU Directive 2014/95 regarding the way oil entities report information on environmental issues. We also investigated whether entities considered to be polluting were more sensitive to environmental factors and tended to report more information compared to those operating in other sectors [21–23].

Measuring environmental performance is difficult [21]. To achieve our objectives, we performed a content analysis of the Annual and Sustainability Reports published by the sampled companies between 2014 and 2018, and, for the analysis, we used the NVivo data processing program. The method used in our research brings a new perspective in the field, namely in comparing non-financial information on environmental issues between countries and sectors of activity to identify whether polluting entities reported more information than those operating in other sectors, both before (2014–2016) and after (2017–2018) the transposition of the directive.

Our paper is structured in three parts, as follows: In the first part, we present the context that determined our study and the literature on the actual knowledge in the field. In the second part, we present the hypotheses underlying the research undertaken and the study itself, highlighting and analyzing the results obtained. In the last part of the paper, we reflect discussions and conclusions, as well as the limits and future directions of the research.

2. Materials and Methods

The first objective of our research was to identify whether entities reported more non-financial information regarding environmental issues following the application of the provisions of EU Directive 2014/95. Hence, our first research question (1): *Did entities report more non-financial information after the application of the EU Directive 2014/95?* To answer to this question and achieve our objective, we introduced Directive 2014/95 / EU in the NVivo program. With the help of the word frequency criteria function, we extracted the 500 most-used words. From these, we selected the terms regarding the environmental aspects. Afterward, we introduced the Annual and Sustainability Reports published by the sampled entities between 2014–2018, and we analyzed the frequency of the key terms in each report to identify the changes generated by the directive regarding the way the studied oil entities reported information on environmental issues.

We analyzed the information presented by the entities in the Annual Reports, in the Sustainability Reports, and those published on the website as follows: for Romania, out of the six companies operating in the oil field (extraction, handling, and transportation) and listed on the Bucharest Stock Exchange (BSE), we analyzed the situation of four companies, namely Conpet, Oil Terminal, OMV Petrom, and Rompetrol Rafinărie, which belong to the category of large companies exceeding the criterion of an average number of 500 employees during the financial year, which represent 67% from the total number of listed oil companies included under the European Directive 2014/95 provisions. For Greece, out of all the companies listed on the main market, the Athens Stock Exchange (ATHEX), in the oil field (four companies), we included in our study two companies (which represent 50% of the total), Motor Oil and Hellenic Petroleum, those that published their reports on the official website of the Athens Stock Exchange and that met the size criterion established by the European Directive.

In this research, we also aimed to analyze whether oil entities tended to report more information on environmental issues compared to other entities with a low degree of pollution, resulting in

our second research question (2): Do oil entities have the tendency to report more information related to the environment compared to other entities that are not implied in polluting activities? Thereby, we included in the research banking institutions listed on two stock markets to obtain an overview in terms of the environmental protection measures. For Romania, we analyzed the Annual and Sustainability Reports prepared by BRD, Transilvania Bank, and Patria Bank; and, for Greece, we included the documents published by the following banking institutions listed on the ATHEX main market: Alpha Bank, Attica, Eurobank, and Piraeus Bank.

In total, for the analyzed period of time, namely, between 2014 and 2018, we studied 65 Annual and Sustainability Reports.

We have selected the oil entities from these countries based on the statistics that consider Romania and Greece as two countries showing little concern for environmental protection in terms of waste recycling. Therefore, we have analyzed the situation of oil entities in terms of actions and reporting of non-financial environmental information.

3. Results

Initially, the content of the European Directive 2014/95 was examined using the word frequency criteria function, which allowed for the identification of the 500 most-used words in the analyzed document. The obtained results are synthetically reflected in Figure 1, using "WordCloud" to highlight that the size of the words is directly proportional to the frequency of their occurrence in the Directive.

Figure 1. Directive 2014/95 WordCloud. Source: authors' own elaboration.

From the 500 most-used words in the directive, we manually extracted the terms regarding the environmental aspects; the results are highlighted in the following figure (Figure 2):

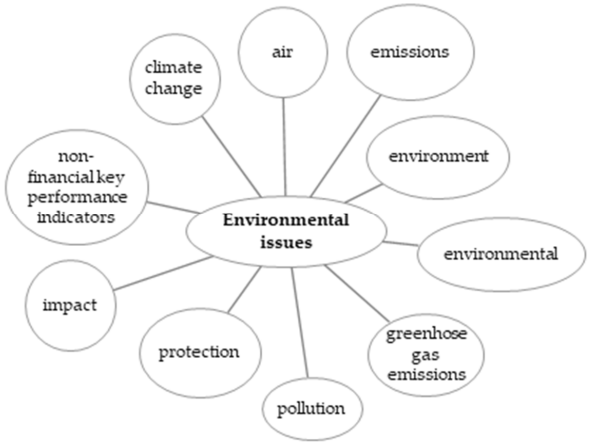

Figure 2. The keywords for environmental issues. Source: authors' own elaboration.

With reference to the keywords regarding the environmental aspects identified in the European Directive, in the search engine text search query, we also included specific environmental terms, such as spills, waste, forest, and biodiversity. We subsequently analyzed the frequency of their occurrence in the annual and sustainability reports of the sampled entities before (2014–2016) and after (2017–2018) the transposition of the Directive in the national legislative framework of each country.

The results of the research on oil entities are presented in the following table (Table 1):

Table 1. The average frequency of the environmental keywords for oil entities.

Country	**Romania**		**Greece**	
Period	**2014–2016**	**2017–2018**	**2014–2016**	**2017–2018**
No. of Reports	**12**	**8**	**6**	**4**
Environmental Key-Words Average Frequency				
air	17.33	26.00	34.67	50.00
emissions	85.67	93.00	180.33	182.00
environment	171.00	211.50	171.33	142.00
environmental	151.33	202.50	245.00	228.00
greenhouse gas emissions	320.67	390.00	316.00	324.50
pollution	24.67	31.00	37.33	40.00
protection	88.33	102.50	117.00	115.50
forest	0.33	1.50	2.33	5.00
impact	122.33	152.00	79.33	112.00
spills	18.00	21.50	10.67	24.00
waste	65.33	94.00	92.67	104.50
biodiversity	17.00	28.50	9.33	3.00
non-financial key performance indicators	193.67	277.50	88.33	72.00
climate change	68.00	101.50	71.67	110.50
TOTAL	1343.67	1732.50	1456.00	1513.00

Source: authors' own elaboration.

For Romanian entities, the results presented in the previous table reflect a slight increase in the use of all keywords selected in the reports analyzed after the date on which the provisions of EU Directive 2014/95 became mandatory. In the case of entities listed on the ATHEX main market, we found that the frequency of keywords in the reports was higher than recorded for Romanian entities. However, not all terms were used more frequently after the date on which entities had time to prepare the implementation of the directive in the period of 2017–2018. Thus, keywords (such as environment, environmental, protection, and biodiversity) and non-financial key performance indicators decreased in use. Overall, after the transposition of the directive, in the period of 2017–2018, there was a slight increase in the use of selected keywords, which is in accordance with other studies in the field, such as the ones conducted by Carini et al. [5], Dumitru et al. [8], and Venturelli et al. [18].

The frequency analysis of the keywords in the reports published by the banking entities highlighted the following results (Table 2):

Table 2. The average frequency of the environmental keywords for banking entities.

Country	**Romania**		**Greece**	
Period	**2014–2016**	**2017–2018**	**2014–2016**	**2017–2018**
No. of Reports	**9**	**6**	**12**	**8**
Environmental Key-Words Average Frequency				
air	1.00	1.00	17.00	14.50
emissions	1.00	13.50	92.00	72.50
environment	24.33	81.00	226.67	190.00
environmental	7.00	33.00	301.33	248.50

Table 2. *Cont.*

Country	Romania		Greece	
Period	**2014–2016**	**2017–2018**	**2014–2016**	**2017–2018**
No. of Reports	**9**	**6**	**12**	**8**
Environmental Key-Words Average Frequency				
greenhouse gas emissions	1.33	15.50	155.67	89.00
pollution	0.00	0.00	10.67	40.00
protection	9.33	72.00	112.00	104.00
forest	2.00	3.50	14.00	26.50
impact	24.00	189.50	97.00	129.00
spills	0.33	1.50	0.00	44.50
waste	3.00	16.00	27.00	29.50
biodiversity	0.00	0.00	25.67	62.00
non-financial key performance indicators	94.33	184.00	223.67	224.00
climate change	59.67	274.00	286.67	377.00
TOTAL	227.33	884.50	1589.33	1651.00

Source: authors' own elaboration.

For the banking entities listed on the BSE, we found that in the period of 2017–2018, the frequency of use of keywords in the reports increased significantly compared to the preparation period. There have been important changes for defining terms regarding environmental issues, such as climate change, impact, and non-financial key performance indicators. For the banking entities listed on the ATHEX main market, we found that, overall, there was a slight increase in the frequency of keywords in the reports analyzed in the period of 2017–2018 compared to the period of 2014–2016.

The analysis by activity field confirmed that oil entities tended to report more information on environmental issues compared to other entities whose activities do not register as having a high degree of pollution. These results were in accordance with the opinions expressed in the literature [21–23] and the studies conducted by Popescu and Bant [13] and Sierra-Garcia et al. [20].

In the following tables (Tables 3 and 4), we show, in detail, the results obtained before the directive became mandatory, namely the period of 2014–2016, compared to the period of 2017–2018:

Table 3. The environmental terms text search query for oil entities.

Country	Romania				Greece			
Period	**2014–2016**		**2017–2018**		**2014–2016**		**2017–2018**	
	MIN	**MAX**	**MIN**	**MAX**	**MIN**	**MAX**	**MIN**	**MAX**
Key-Words								
air	15	19	24	28	30	43	50	50
emissions	79	94	90	96	136	244	173	191
environment	150	192	194	229	150	183	139	145
environmental	118	171	149	256	211	284	221	235
greenhouse gas emissions	304	350	383	397	266	378	321	328
pollution	21	29	30	32	31	47	40	40
protection	84	92	78	127	104	141	103	128
forest	0	1	0	3	2	3	2	8
impact	116	129	134	170	65	93	80	144
spills	17	20	20	23	7	17	24	24
waste	42	86	79	109	83	99	104	105
biodiversity	12	21	23	34	6	15	2	4
non-financial key performance indicators	168	207	204	350	80	95	71	73
climate change	55	93	93	110	63	83	104	117

Source: authors' own elaboration.

Table 4. The environmental terms text search query for banking entities.

Country	Romania				Greece			
Period	**2014–2016**		**2017–2018**		**2014–2016**		**2017–2018**	
	MIN	**MAX**	**MIN**	**MAX**	**MIN**	**MAX**	**MIN**	**MAX**
Key-Words								
air	1	1	1	1	13	23	13	16
emissions	1	1	8	19	64	122	45	100
environment	16	38	81	81	176	264	169	211
environmental	7	7	28	38	238	345	152	345
greenhouse gas emissions	1	2	9	22	96	212	50	128
pollution	0	0	0	0	2	15	40	40
protection	8	10	68	76	84	142	91	117
forest	2	2	3	4	4	20	24	29
impact	11	50	181	198	63	115	123	135
spills	0	1	1	2	0	0	40	49
waste	3	3	14	18	17	32	17	42
biodiversity	0	0	0	0	20	32	43	81
non-financial key performance indicators	8	264	180	188	179	274	217	231
climate change	18	138	254	294	237	315	361	393

Source: authors' own elaboration.

Specialty literature describes relevant studies and experiments, such as the one conducted by the well-known American psychologist R. Zajonc [24], who investigated the relationship between the positive meaning associated with a word and the frequency of its exposure. In the experiment, (American) subjects were introduced to Turkish words that had no significance to them. Some words were presented only once while others were presented up to 25 times during the experiment. At the end of the study, the subjects were asked to what extent the words presented in Turkish expressed something "positive" or "negative". The results of the experiment validated the hypothesis formulated by the psychologist. The Turkish words used in the study had the quality of new stimuli. By repeatedly using these words, they became familiar to the subjects, so that they perceived them with a positive meaning. The results of the experiment emphasize the idea that, as subjects are more frequently exposed to a weak negative, neutral, or positive stimulus, a progressively positive appreciation of the stimulus is reached [25].

An example in this case is the Volkswagen scandal. According to the US Environmental Protection Agency (EPA) [26] between 2009–2015, the car manufacturer, Volkswagen sold approximately 11 million cars worldwide, equipped with illegal software meant to report lower fuel consumption and lower emissions than in reality. This scandal broke shortly after the company had been named the most sustainable entity in the automotive industry according to the Dow Jones Sustainability Index. Also, in the last Sustainability Report issued in 2014, before the scandal broke, the company mentioned the word "environment" 335 times and emphasized ethical principles and integrity in their statements: "in the long run, we can only succeed as a company if we act with integrity, respect statutory provisions worldwide and stand by our voluntary undertakings and ethical principles, even when this is the harder choice" [27].

Certainly, Volkswagen is not the only company failing to integrate sustainability into its strategies and operations, and this may influence the company's long-term development.

To avoid the impression that we are in front of an experiment demonstrating that companies frequently use terms in their reports solely to obtain a favorable perception related to environmental protection, we completed in-depth research by identifying, in the reports, the concrete measures performed by the companies for the declared purpose of environmental protection.

The identified objectives and CSR projects are presented in the following tables (Tables 5 and 6):

Table 5. Environmental management objectives.

Environmental Management Objectives	
OIL Entities	***BANKING Entities***
- adhere to all the national and European laws and regulations governing the environment and proper management of resources [28–33]. - improve performance in environmental protection activity, in particular by adopting prevention measures for pollution, technological risks, and accidents which can have negative repercussions on the environment [28–33]. - permanently assess the risks/opportunities posed in the context the organization evolves in and of the risks/opportunities related to the processes and determining the actions for their treatment [28–33]. - fully committed to acting on climate change mitigation and responsible resource management [28–33]. - improving carbon efficiency [28–33]. - continuously reinforce prevention measures along with directly and effectively responding to potential spills [28–33]. - use efficiently natural resources to minimize wastes and emissions in the air, water, and soil to prevent and reduce crude oil, oil products, and leakages [28–33]. - reduce our carbon footprint, specifically energy consumption and carbon dioxide emissions, in order to contribute to addressing the causes and impacts of climate change [28–33]. - extensive and systematic planting in areas where they operate [28–33]. - reduce noise levels [28–32]. - reduce energy consumption [28–32]. - solid waste recycling [28–33]. - marine environment protection [30].	- reduce environmental footprint by promoting the rational use of lighting, heating, and cooling installations [34–40]. - reduce water consumption [34–40]. - reduce paper consumption [34–40]. - reduce CO_2 emissions [34–40]. - recycling waste from electric and electronic equipment [34–40]. - financial support through green products and services [34–40]. - improvement in the measurement of resource consumption [34–40]. - inclusion of environmental criteria for funded projects, investments, and suppliers [34–40]. - implementation of processes for managing regulatory and natural risks deriving from climate change and development of risk assessment tools [34–40].

Source: authors' own elaboration.

Table 6. Environmental corporate social responsibility (CSR) projects.

Environmental CSR Projects	
OIL Entities	***BANKING Entities***
- planting plane trees, an extensive project aimed at contributing to the expansion of green areas in order to improve the quality of air, especially in the local communities where we have operations [28]. - 26.1 million euros investments and operating costs related to environmental protection only in 2018 [30]. - campaign encouraging customers to use electronic invoices instead of printed versions [28]. - promote environmental culture, organizing and rewarding annually, on World Environment Day, the best environmental performers across the company [31]. - company employees are involved in volunteering projects such as greening, first aid activities, education and health, renovating playgrounds and parks, or donations [31]. - programs designed to educate people for matters concerning the environment, the proper management of natural resources, energy-saving, and the protection of flora and fauna [29]. - cleaning of the Thermaic Gulf and deforestation works in the Municipality of Elefsina [29]. - support to environmental associations like the ones that play an important role in forest protection and the ones that save sea turtles [30].	- significant environmental and health actions concerning the protection of the environment [36]. - collaboration with Friends of the forests to organize environmental events like Olive picking event at the Kessarioni Aesthetic Forest [35]. - annual recycling competition [34]. - usage of energy-saving lamps in various branches and administrative buildings, placement of special containers for the collection and recycling of batteries in various branches and administrative buildings [36]. - gradually replace the cooling installations that use ozone-depleting substances as coolants [35]. - Elaboration and Implementation of Environmental Policy through related programs and Sustainable Development Reports which include environmental performance data [37].

Source: authors' own elaboration.

To highlight the actions of social responsibility with the direct and immediate impact on the environment undertaken by the entities in the oil field, we analyzed the reports published between 2015–2018. The results reflect the fact that the responsibility actions undertaken by the studied entities mainly concern the aspects presented in the next figure (Figure 3):

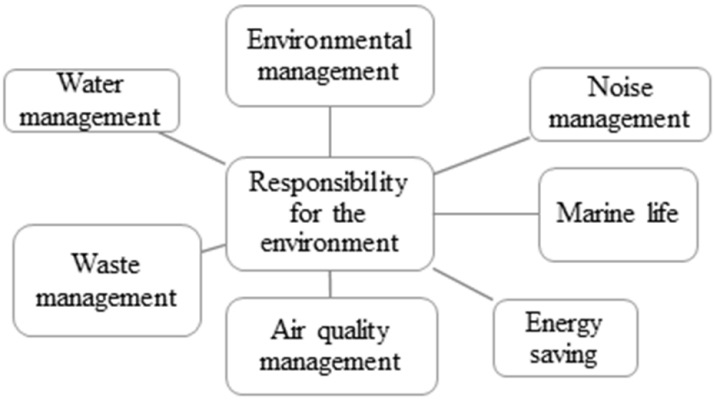

Figure 3. Environmental sustainability plans. Source: authors' own elaboration.

We found that the studied entities were aware of the impact of their activities and that they were taking measures to reduce pollution and to involve the communities where they operate in those actions. The significance of the concept of corporate social responsibility derives from this attitude of companies [41]. From the CSR projects undertaken, we can state that the frequency of use of specific environmental terms is sustained by practical actions, like the ones described in CSR projects as presented in Table 6.

The following figure (Figure 4) shows, in detail, the most-used keywords in the non-financial reports of the studied entities:

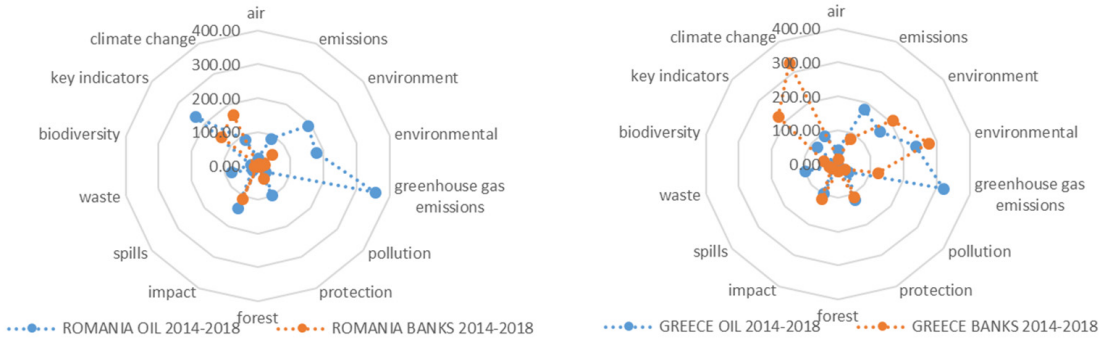

Figure 4. The most-used keywords in the oil and banking entity reports.

The analysis underlines that the words with the highest impact—those that registered the highest frequency in the reports—were *greenhouse gases*, namely GHG, (in the case of oil entities) and *climate change* (for banking entities).

4. Discussion

The consequences of the crisis that affected all economies can also be seen in the way in which entities prepare their non-financial reporting. In the Romanian banking sector, we observed a significant increase in the frequency of use of environmental keywords, amid the faster recovery of the economy. In Greece, the problem of recession lasted longer and had a greater impact, which dispelled the concerns of the banks. The results of the analysis showed that the priority of financial institutions has been to identify solutions for economic survival and not to improve reporting. In conclusion, including from

the reports of the entities listed on BSE, we proved that Romania overcame the global crisis more easily and faster compared to Greece where the banks' choices, such as bank credits granted without guarantees, proved catastrophic in terms of the economic effects.

The recession was also reflected in the oil field. When the Greek government limited daily cash withdrawals, the sale of fuel automatically decreased, as this was no longer among the subsistence priorities of the Greeks. However, the provisions of the directive had to be implemented and applied, regardless of the economic context of each country, and the deep recession in Greece placed reporting in second place for entities in this field as well. This aspect can also be observed in the results obtained, namely the insignificant increase in the number of keywords.

Thus, our results proved the existence of differences in the reporting of environmental protection issues in the two countries analyzed. Extrapolating, this indicates that the interests of the analyzed Romanian entities were primarily focused on the aspects regarding environmental protection, compared to a country severely hit by a recession. Economic conclusions, directly correlated with the financial crisis, can be drawn from such reports and we can now determine that environmental protection is a priority for countries with a functioning economy.

From the analysis undertaken, we can observe that the studied entities adopted an open attitude regarding the elaboration and disclosure of non-financial information related to the environment by making efforts to improve their reporting, even though corporate reporting is a relatively new concept [42]. The same conclusions cannot be drawn from the implementation of other European directives on environmental protection issues, such as recycling and waste management. According to data presented by the European Commission, both Romania and Greece are among the 14 countries considered to have the highest risk of not reaching the recycling target set for 2020, which is why the two countries risk infringement proceedings [43].

In 2020, the European Commission committed to reviewing Directive 2014/95 to strengthen the strategies for sustainable investment. This decision was made because the information reported does not present correct nor sufficient details of either the impact of the non-financial aspects on companies or of the impacts that companies have on society and the environment. The reporting requirements of the Directive are also not sufficiently detailed and are difficult to apply or they do not apply to companies whose beneficiaries require information on polluting activities. These action reveals the fact that the European Commission continues the fight against climate change and environmental degradation, still striving for constant improvement and active support from polluting entities.

Climate change affects the activities of oil companies, creating significant challenges and opportunities. As the main activity of companies is refining, they find themselves in a dual position of being both energy producers and consumers. Energy consumption implies significant operating costs and represents an important source of pollution, being the main source of carbon dioxide emissions. Therefore, these companies must implement projects aimed at reducing the level of energy consumption and carbon dioxide emissions as the energy consumed creates a significant impact on the environment. The purpose of energy efficiency management is to reduce the impact of the operations of these entities on the environment, to reduce financial expenses through economies, and to respect the national and international regulatory framework in the energy efficiency sector.

According to the International Energy Agency [44], energy efficiency could contribute approximately 40% through the emission reductions required to maintain global warming below 2 °C. To limit global warming, it is essential to ensure carbon neutrality by the middle of the 21st century, a goal set in the Paris Agreement signed by 195 countries [45]. Carbon neutrality means a balance between emissions and the reduction of carbon dioxide from the atmosphere through absorbents. The main absorbers are soil, forests, and oceans.

Forests are able to absorb greenhouse gas and carbon dioxide emissions. The EU wants to use this power to fight climate change and the legislation aims to prevent emissions from deforestation and obliges each EU country to offset changes in land use, which lead to CO2 emissions, through better forest management or increased forest area. According to the statistics [46] *detailed in* Figure 5, the level

of absorption of greenhouse gases by forests reveals the importance of a greater number of forested areas in the EU.

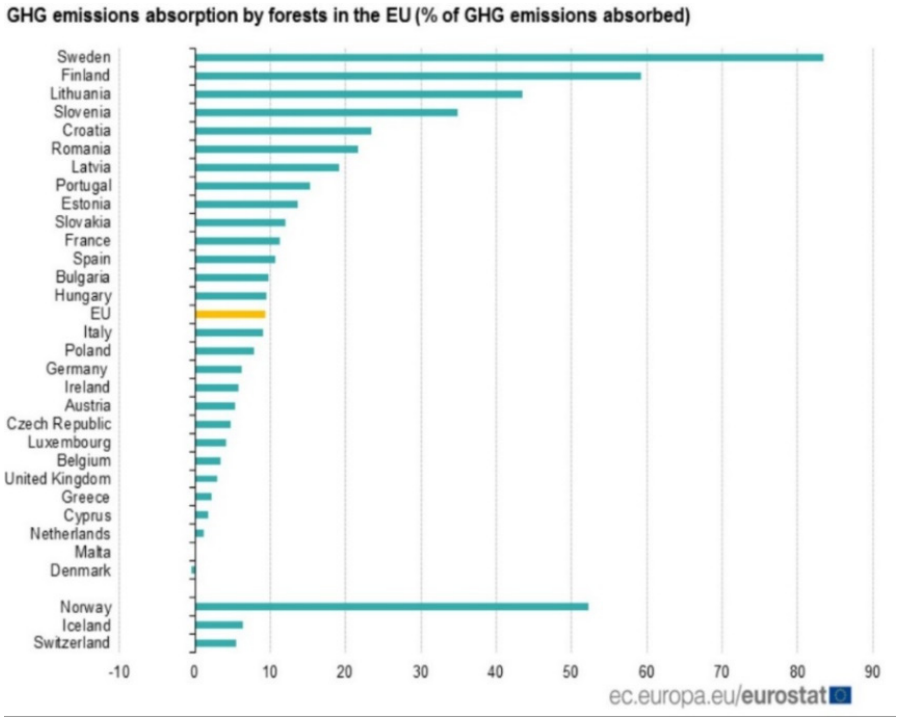

Figure 5. GHG emissions absorption. Source: Eurostat [46].

Analyzing the situation from a global perspective [47] (Figure 6), we can state that measures must be taken to increase the forested area, considering that forests are crucial in combating global climate change, as they capture carbon dioxide and greenhouse gases from the atmosphere.

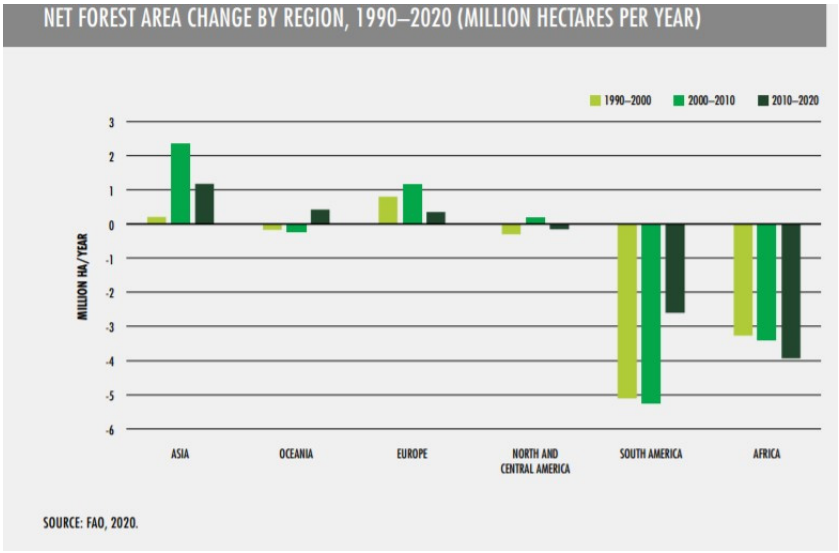

Figure 6. The net forest area. Source: FAO [47].

Unfortunately, the latest statistics show that from 2015 to 2018, Romania lost 72.1 kha of tree cover, equivalent to a 0.91% decrease in tree cover since 2000. Greece also lost 25.9 kha of tree cover, equivalent to a 0.71% decrease in tree cover since 2000 [48]. The detailed situation is presented in the next figure (Figure 7).

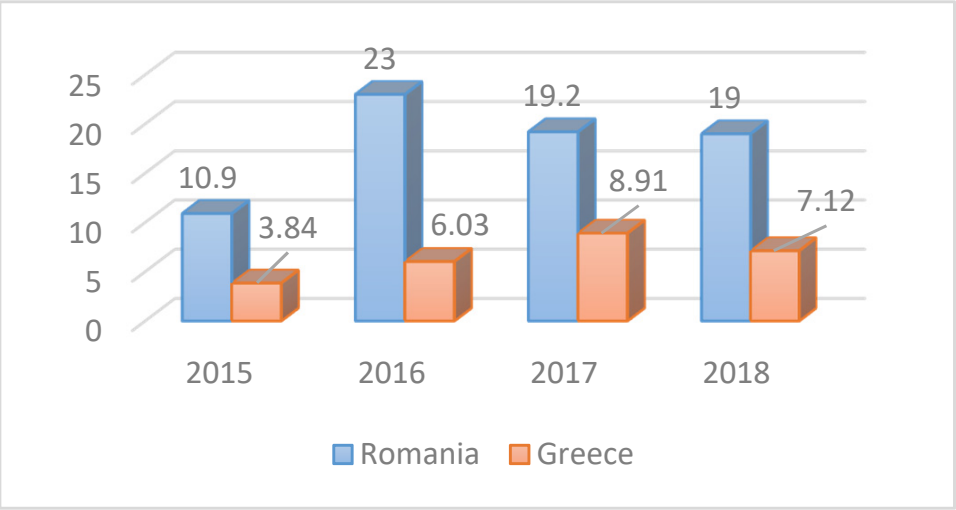

Figure 7. Tree cover loss Romania vs. Greece. Source: Global Forests Watch [48].

The respect and care for the environment should be a priority for all companies, as they operate as responsible corporate organizations in accordance with the principles of sustainable development based on environmental protection, mutual respect, and the interest for future generations to be equally able to benefit from the planet's natural reserves, maintained in good condition. In doing so, sustainability becomes part of the organizational culture promoting responsible behavior for the stakeholders, environment, and society.

5. Conclusions

The issue of global warming is one of the greatest challenges facing humanity and a major concern for both the governments and general public, as well as for the business environment and, in particular, those businesses that, through their activity, pollute the environment, such as the companies in the oil field. Respect toward people, responsibility toward the environment, and involvement in the life of the community are essential values and major concerns for all the entities under study.

However, given the fact that the tree cover area of the two countries under analysis is decreasing, we consider it appropriate to involve the entities from the oil field in more afforestation actions. Although these entities undertake measures to reduce pollution, we propose that setting up forest curtains around operating areas would make a substantial contribution to environmental protection.

From our research, we found that the European Directive 2014/95 produced changes in the non-financial reporting of the studied entities. We identified an increase in the frequency of use of environmental terms in reports published between 2014 and 2018. The research results also validated the hypothesis that entities operating in environmentally sensitive fields, such as those in the oil field, tended to report more information in non-financial reports compared to other sectors of activity.

The limitations of our research resulted from the relatively small sample of entities listed on the BSE and ATHEX main markets. Based on these limits, in future research, we aim to complete the model by adding new entities and other fields.

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References

1. Directive 2014/95/EU of the European Parliament and of the Council of 22 October 2014 Amending Directive 2013/34/EU as Regards Disclosure of Non-financial and Diversity Information by Certain Large Undertakings and Groups. Available online: http://eur-lex.europa.eu/legalcontent/EN/TXT/PDF/?uri=OJ:L:2014:330:FULL&from=EN (accessed on 29 December 2019).
2. Directive 2013/34/EU of the European Parliament and of the Council of 26 June 2013 on the Annual Financial Statements, Consolidated Financial Statements and Related Reports of Certain Types of Undertakings. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013L0034&from=EN (accessed on 29 December 2019).
3. Romania CSR Index 2017. Available online: https://www.theazores.ro/romania-csr-index-2017/ (accessed on 15 May 2020).
4. World Commission on Environment and Development. *Our Common Future*; Oxford University Press: Oxford, UK, 1987; Available online: https://idl-bnc-idrc.dspacedirect.org/bitstream/handle/10625/152/WCED_v17_doc149.pdf?sequence (accessed on 29 December 2019).
5. Carini, C.; Rocca, L.; Veneziani, M.; Teodori, C. Ex-ante impact assessment of sustainability information—The Directive 2014/95. *Sustainability* **2018**, *10*, 560. [CrossRef]
6. Frecea, G.L. Legal or Discretionary CSR: The Directive 2014/95/EU Analysis. *Ovidius Univ. Ann. Econ. Sci. Ser.* **2018**, *18*, 17–21.
7. Wszelaki, A.; Tkocz-Wolny, K. Implementation of the provisions of directive 2014/95/EU on disclosures in the field of corporate social responsibility in the enterprise's accounting practice on the example of a selected listed entity. *Sect. Environ. Legis. Multilater. Relat. Funding Oppor.* **2019**, *19*, 483–491. [CrossRef]
8. Dumitru, V.F.; Jinga, G.; Stănilă, O.G.; Dumitru, M. The impact of the European Directive 2014/95/EU on the energy companies' disclosures. In Proceedings of the 13th International Conference on Business Excellence, Sciendo, Poland, 21–22 March 2019; pp. 268–276. [CrossRef]
9. Imbrescu, C.M.; Hațegan, C.D. Ex-ante study about disclosure of b=non-financial information by romanian companies from agriculture and manufacture of food products. *J. Econ. Bus. Res.* **2017**, *23*, 45–58.
10. Manes-Rossi, F.; Tiron-Tudor, A.; Nicol, G.; Zanellato, G. Ensuring More Sustainable Reporting in Europe Using Non-Financial Disclosure—De Facto and De Jure Evidence. *Sustainability* **2018**, *10*, 1162. [CrossRef]
11. The CSR Agency. The CSR Report—Companiile care schimba Romania, no. 3, 2017. Available online: https://issuu.com/thecrrreport/docs/_revista_csr__3__pages (accessed on 15 January 2020).
12. Sava, A.; Bogdan, M.; Kocsi, K. Online disclosure of non-financial information in Romanian large companies. *Acta Tech. Napoc. Ser. Appl. Math. Mech. Eng.* **2018**, *61*, 203–208.
13. Popescu, C.R.; Bant, C. Performance Evaluation of the Implementation of the 2013/34/EU Directive in Romania on the Basis of Corporate Social Responsibility Reports. *Sustainability* **2019**, *11*, 2531. [CrossRef]
14. Ogrean, C. The Directive 2014/95/EU Is there a "new" beginning for CSR in Romania? *Stud. Bus. Econ.* **2017**, *12*, 141–147. [CrossRef]
15. Aureli, S.; Magnaghi, E.; Salvatori, F. The transposition of the non-financial reporting directive in the UK, France and Italy. *Symph. Emerg. Issues Manag.* **2018**, *1*, 48–67. [CrossRef]
16. Matuszak, Ł.; Różańska, E. CSR disclosure in Polish-listed companies in the light of Directive 2014/95/EU requirements: Empirical evidence. *Sustainability* **2017**, *9*, 2304. [CrossRef]
17. Tkocz-Wolny, K.; Wszelaki, A.; Strojek-Filus, M. Assessment of environmental reporting of energy sector companies listed on the Warsaw Stock Exchange in the light of directive 2014/95/EU. *Sect. Environ. Legis. Multilater. Relat. Funding Oppor.* **2018**, *18*, 75–85. [CrossRef]
18. Venturelli, A.; Caputo, F.; Cosma, S.; Leopizzi, R.; Pizzi, S. Directive 2014/95/EU: Are Italian Companies Already Compliant? *Sustainability* **2017**, *9*, 1385. [CrossRef]
19. Peršić, M.; Halami, L. Disclosing non-financial information in companies' reports in Croatia. *Copernic. J. Financ. Account.* **2016**, *5*, 181–200. [CrossRef]
20. Sierra-Garcia, L.; Garcia-Benau, M.A.; Bollas-Araya, H.M. Empirical Analysis of Non-Financial Reporting by Spanish Companies. *Adm. Sci.* **2018**, *8*, 29. [CrossRef]
21. Avram, V.; Calu, D.A.; Dumitru, V.F.; Dumitru, M.; Glăvan, M.E.; Jinga, G. The institutionalization of the consistency and comparability principle in the European companies. *Energies* **2018**, *11*, 3456. [CrossRef]

22. Dumitru, M.; Dyduch, J.; Guşe, R.G.; Krasodomska, J. Corporate reporting practices in Poland and Romania—An ex-ante study to the new non-financial reporting European Directive. *Account. Eur.* **2017**, *14*, 279–304. [CrossRef]
23. Barbu, E.; Dumontier, P.; Feleagă, N.; Feleagă, L. Mandatory environmental disclosures by companies complying with IASs/IFRSs: The cases of France, Germany, and the UK. *Int. J. Account.* **2014**, *49*, 231–247. [CrossRef]
24. Zajonc, R.B. Attitudinal effects of mere exposure. *J. Personal. Soc. Psychol.* **1968**, *9 Pt 2*, 1–27. [CrossRef]
25. Gavreliuc, A. Wordpress. Available online: https://alingavreliuc.wordpress.com/ (accessed on 29 December 2019).
26. US Environmental Protection Agency. Available online: https://www.epa.gov/enforcement/volkswagen-clean-air-act-civil-settlement (accessed on 15 January 2020).
27. Volkswagen Corporate Social Responsibility and Sustainability. Available online: https://annualreport2014.volkswagenag.com/group-management-report/sustainable-value-enhancement/csr-and-sustainability.html (accessed on 25 January 2020).
28. Rompetrol Rafinarie, Sustainability Report. Available online: https://rompetrol-rafinare.kmginternational.com/ (accessed on 25 January 2020).
29. Hellenic Petroleum Sustainability Report. Available online: https://www.helpe.gr/en/ (accessed on 25 January 2020).
30. Motor Oil Sustainability Report. Available online: https://www.moh.gr/Home.aspx?a_id=10515 (accessed on 25 January 2020).
31. OMV Sustainability Report. Available online: https://www.omv.ro/ro-ro (accessed on 25 January 2020).
32. Oil Terminal Sustainability Report. Available online: https://oil-terminal.com/ (accessed on 25 January 2020).
33. Conpet Sustainability Report. Available online: https://www.conpet.ro/ (accessed on 25 January 2020).
34. BRD Sustainability Report. Available online: https://www.brd.ro/ (accessed on 25 January 2020).
35. Alpha Bank Sustainability Report. Available online: https://www.alpha.gr/ (accessed on 25 January 2020).
36. Attica Bank Sustainability Report. Available online: https://www.atticabank.gr/en/ (accessed on 25 January 2020).
37. Piraeus Bank Sustainability Report. Available online: https://www.piraeusbank.gr/en/idiwtes (accessed on 25 January 2020).
38. Eurobank Sustainability Report. Available online: https://www.eurobank.gr/en/group/grafeio-tupou/159-news-page (accessed on 25 January 2020).
39. Banca Transilvania Sustainability Report. Available online: https://www.bancatransilvania.ro/ (accessed on 25 January 2020).
40. Patria Bank Sustainability Report. Available online: https://www.patriabank.ro/ (accessed on 25 January 2020).
41. Socoliuc, M.; Grosu, V.; Hlaciuc, E.; Stanciu, S. Analysis of Social Responsibility and Reporting Methods of Romanian Companies in the Countries of the European Union. *Sustainability* **2018**, *10*, 4662. [CrossRef]
42. Burcă, V.; Mateș, D.; Bunget, O. Empirical Research on Identifying main drivers leading to Integrated Reporting Framework Implementation. The case of European Region. *Rom. Econ. J.* **2018**, *70*, 52–72.
43. European Commission. Available online: https://ec.europa.eu/info/news/commission-reviews-implementation-eu-waste-rules-proposes-actions-help-14-member-states-meet-recycling-targets-2018-sep-24_en (accessed on 24 April 2020).
44. International Energy Agency. Available online: https://www.iea.org/topics/energy-efficiency (accessed on 20 January 2020).
45. European Parliament. Available online: https://www.europarl.europa.eu/ (accessed on 25 April 2020).
46. Eurostat. Eurostat Statistics. Available online: https://ec.europa.eu/ (accessed on 25 April 2020).
47. Food and Agriculture Organization of the United Nations. The State of the World's Forests. 2020. Available online: http://www.fao.org/state-of-forests/en/ (accessed on 25 April 2020).
48. Global Forests Watch. Available online: www.globalforestwatch.org (accessed on 15 May 2020).

Arch. Biol. Sci., Belgrade, 67(2), 705-714, 2015 DOI:10.2298/ABS140301042M

BIOLOGICAL ASSETS AND THE AGRICULTURAL PRODUCTS IN THE CONTEXT OF THE IMPLEMENTATION OF THE IAS 41: A CASE STUDY OF THE ROMANIAN AGRO-FOOD SYSTEM

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Abstract: Nowadays, when the contribution of agriculture and agro-food industry to the GDP is a significant, in Romania's case we appreciate that the economic aspects of this area also deserve a specific approach. The aim of this paper was to identify the incompatibility of the recognition and assessment criteria of agriculture production, biological assets and agriculture products imposed by the application of these standards in agro-food companies, and to analyze its effects concerning the financial position and performance of these entities. The paper takes into consideration the economic-financial harmonization process, which is now in full progress, both in the EU and other states, by applying the specific standards (IAS/IFRS) in the preparation of annual/interim financial reports. Finally, referring strictly to the case of Romania, after thorough research into the field in question, we suggest a presentation of the controversial assessment criteria provided by the IAS 41 standard, and also refer to the difficulties related to the implementation of this standard in the agro-food industry.

Key words: agriculture production; biological assets; IAS 41; assessment; fair value; cost.

Acronyms used: EEC – *European Economic Community;* IAS – International Accounting Standard(s); IFRS – International Financial Reporting Standard(s).

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INTRODUCTION

With the acceleration of the accounting harmonization process derived from the implementation of IAS/IFRS, it was necessary to identify the criteria required in the preparation and reporting of the financial position and economic outcome. The evolution of these criteria has always been dependent on normative decisions in force that accompanied the implementation of IAS/IFRS both for large and for medium or small firms. Regarding the agro-food companies, the International Accounting Standard Board (IASB) issued a special standard IAS 41 – *Agriculture* (Feleagă et al., 2012) that can be applied exclusively or additionally, depending on the type of activities carried out by the entity (Fig. 1). IAS 41 was approved in December 2000 and entered into force for the financial year 2003.

The reason why it was necessary to issue an *ad-hoc* standard had been determined by certain activities regarding the agricultural activity that were excluded from the scope of other international accounting standards (e.g. IAS 2 – Inventories); events associated with agricultural activities were and still are difficult to be represented by an accounting model based on the measurement criteria of the historical cost and achievement concept, but it should be noted that IAS 41 is not the only one to be applied to financial statements of agro-food companies.

IAS 41 – *Agriculture* intervenes in the regulation of some important aspects for the accounting record of economic and financial operations of the agricultural entity (Adamo, 2004; Azzali et al., 2007). This standard establishes the classification and measurement rules of stocks of agricultural produce and biologic assets, expressing a clear preference for the *fair value* measurement criteria against historical cost.

In the agro-forestry sector, where firms have a specific accounting procedure, most of the time the financial statements are prepared based on existing supporting documents provided by the entity, showing a structure of financial statements with additional posts, taking into consideration the sensitive operations that require forestry, technical and agriculture related knowledge, in addition to economic and managerial knowledge. This knowledge proves to be very important given the accounting documents deficiency and reduced volume of information provided by the management of agro-food companies.

Taking into account that the balance sheet should be a summary accounting document, i.e. to take into consideration the systematic and chronological record of the economic and financial operations of the entity, for agro-food companies, this component of the financial statement structure fails to allow the development of a credible informational system regarding its financial position and economic outcome.

Table 1. Examples of biological assets and agricultural produce resulting from the processing that occurs after harvest, offered by IAS 41.

Biological assets	Agricultural produce	Product resulting after harvest
Sheep	Fleece	Staple, carpets
Trees from a plantation	Lump	Timber
Plants	Cotton	Clothes, clothing
	Cane	Sugar
Dairy cattle	Milk	Cheese
Pigs	Housing	Sausages, processed bacon
Shrubs	Leaves	Tea, treated tobacco
Vine	Grapes	Wine
Fruit Trees	Fruit picked	Processed fruit

Periodically, the agro-food companies establish and develop financial statements presenting the situation of the assets, liabilities and capital, and the situation of the income and expenses. These statements are called annual (or interim, if reported quarterly or half-yearly) because they are reported at the end of a calendar or agriculture year.

In addition to the annual financial statements, the agricultural companies also prepare a set of financial statements, which are called estimated statements presenting the economic events that can be checked in a real or hypothetical situation, in this type of financial statements being also included the adequate or convenient investment analysis.

A major contribution to the uniformization of the records from the agricultural firms with those of other companies in other economic sectors, in order to develop common economic and financial indicators, was brought by Piccinini (1988), Bartola and Arzeni (1995), Lounay (1967), Delfould (1971), Todea et al. (2005) and Budean (2008).

The estimated financial statements are designed to determine the probable profit that, under normal technical and economic conditions, can be obtained by an agro-food entity. Such financial statements do not necessarily have to use data from the company accounting, but primarily data on production, prices that can be obtained and costs incurred in a certain production context, in addition to a rigorous estimated calculation method.

In preparing the estimated financial statements, computational techniques derived from the following equation are used: PBV = [(CHD+Tx)+(Chs+D+BF)] = +/- R (1), where PBV = gross value of production for sale; Chd = sundry charges; Tx = taxes and contributions; Chs = salary costs; D = amount of payable interest; BF = value of financial benefits; R = return on investment performed by the entity.

Thus, the analysis of the financial statements is oriented to accept various aspects of the economic management, in terms of financial, economic or patrimonial outcome, a distinction to be emphasized primarily due to the accuracy or

Table 2. Measurement of biological assets at the entry in an agricultural entity patrimony and in the subsequent financial years.

Initial registration	**Financial year N**	**Financial year N +1**	**Financial year N +2**
Fair value less estimated costs at the point of sale	Costs less accumulated depreciation and impairment losses	Costs less accumulated depreciation and impairment losses	Costs less accumulated depreciation and impairment losses
Initial registration	**Financial year N**	**Financial year N +1**	**Financial year N +2**
Fair value less estimated costs at the point of sale	Fair value less estimated costs at the point of sale	Fair value less estimated costs at the point of sale	Fair value less estimated costs at the point of sale

Table 3. Measurement of biological assets at the entry in an agricultural entity patrimony and in the subsequent financial years.

Initial registration	**Financial year N**	**Financial year N +1**	**Financial year N +2**
Costs less accumulated depreciation and impairment losses	Costs less accumulated depreciation and impairment losses	Costs less accumulated depreciation and impairment losses	Costs less accumulated depreciation and impairment losses
Initial registration	**Financial year N**	**Financial year N +1**	**Financial year N +2**
Costs less accumulated depreciation and impairment losses	Fair value less estimated costs at the point of sale	Fair value less estimated costs at the point of sale	Fair value less estimated costs at the point of sale

precision of data or information to be provided; these are closely interrelated and interconnected.

It is known that in the entity's economic environment the financial liquidity from internal or external sources, funding sources are invested in property assets consisting of fixed and circulating capital necessary to boost the production activity of goods and services by obtaining profit, enabling coverage of all production factors involved (Pacciani, 2005).

MATERIALS AND METHODS

International Financial Reporting Standard IAS 41 - Agriculture: measurement and accounting of biological assets and agricultural produce

IAS 41 defines the accounting treatment, the presentation of financial statements and information related to agricultural activities. According to this international standard, the agricultural production means the product obtained from an entity's biological asset during harvest; and the agricultural activity means the management by the entity of the biological transformation process of living animals or plants (biological assets) through their sale as agricultural produce or subsequent biological assets. In addition, IAS 41 defines the accounting treatment for biological produce during their growth, degeneration, production and procreation, and initial exhaust of agricultural product at harvest.

The measurement criterion required by IAS 41 is the *fair value,* less costs to sale, a *fair value* actually representing the initial value of the biological produce until harvest, unless the *fair value* cannot be reliably estimated, in which case there is recourse to the cost criterion less accumulated depreciation and impairment losses.

The effects of the implementation of the IAS 41 and accounting issues in the agriculture sector has been studied and analyzed by many authors, such as Herbohn and Herbohn (2006), Elad (2004, 2007), Jansson and Fagerström (2011).

IAS 41 intervenes in the regulation of aspects that are significant for the recording into the accounting of the financial and economic operations of agricultural firms, specifying in advance how to proceed in order to identify the agricultural assets and define the biological assets. Regarding the identification of agricultural activities, IAS 41 defines them as the management of an entity that deals with the biological transformation of biological assets and whose object is their sale as agricultural produce or subsequent biological assets.

An agricultural activity may include various types of activities, such as growing livestock, forest exploitation, and annual or continual agricultural production activities, growing trees, floriculture and fish farming. IAS 41 specifies at the same time that, given the great diversity of these activities, there may be some common aspects, such as:

1) *Tendency to evolve:* living animals and plants may undergo biological transformations, which are actually connected to their status as living beings, animals or plants using natural resources, such as light, water, air and land, in order to alter biological characteristics both in quantitative and qualitative terms;

2) *Management of the transformation process:* this aspect facilitates the biological transformation, improving or at least stabilizing the conditions

Table 4. Duration of the working day depending on production place (*adapted after ISIA, 2012*).

Culture	Place of production	
	No. of days/ Ha - plane	No. of days/ha hills and mountains
Crops	15	20
Pasture	10	15
Cattle food	20	30
Cattle food from green corn	15	20
Sugar beet	20	-
Potatoes	30	45
Minimally processed climbing beans	365	420
Tomatoes for canning	50	50
Tobacco	100	100
Protected crops	400	400
Fixed conditioned greenhouses	800	800
Animal breeding		
Dairy cattle	15	20
Beef Cattle	2	5
Horses	12	12
Pigs for reproduction	10	12
Porkers	0.5	0.6
Dairy sheep	5	6
Sheep for meat	3	4
Rabbits for reproduction	2.5	3
Rabbits for Meat	30 days/50 pieces	30 days/50 pieces
Birds bred for eggs	1 day/40 pieces	1 day/40 pieces
Birds bred for meat	1 day/160 pieces	1 day/160 pieces ati
Bees	12 days/10 beehouses	12 days/10 beehouses
Intensive fishculture	730	730
Extensive fishculture	4	4
Nursery gardens and protected crops	Hours/Year, plain	Hours/Year, hills and mountains
Conditioned greenhouses	2250	2475
Unheated greenhouses and potted plants	720	792
Nursery gardens for fruit plants for seeds and roses	2250	247
Nursery gardens for shrubs and ornamental plants	600	660
Manufacturing industry	Working days have X products to be processed	Working days have X products to be processed
Vine in wine	0.3	0.3
Milk in butter	0.1	0.1
Milk in cheese	0.1	0.1

necessary for the process to take place, serving to distinguish agricultural activities from other activities;

3) *Transformations exhaust:* the quantitative and qualitative changes determined by biological transformations can be measured and monitored as a routine activity.

Regarding the definition of biological assets, this term refers to a living animal or plant, and a group of biological assets represents grouping similar living animals or plants. A biological asset can be sold, transformed into agricultural produce (trees turned into wood) or biological assets (e.g. sheep giving birth to a lamb). In addition to biological assets IAS 41 applies to agricultural produce representing the harvest of biological assets by the entity, but only until the harvest. From that moment another standard IAS 2 – *Inventories* intervenes, or any other international accounting standard considered appropriate for the situation.

The conditions imposed by IAS 41 on the recognition of a biological asset or agricultural produce (Examples – Table 1), consist in the fact that the entity must: control the asset as a result of some previous events; it is possible for that asset to produce future economic benefits to the entity; *fair value* or cost of the asset to be measured reliably.

The situation in which an agro-food entity is forced to implement the standards IAS/IFRS in drafting the financial statements is primarily determined by: the intention to orient towards a financial market in order to benefit from future economic development; openness of the entity capital to an institutional partner (mutual fund investment, *private equity, venture capital);* favoring acquisition projects of a foreign company; wish to sell their business in a short period of time to an international investor, etc.

Returning to IAS 41, it was approved by the European Commission for homologation of international accounting rules applicable to European companies, but also to facilitate the convergence of criteria for drafting the financial statements related to resident companies with international ones.

The implementation of IAS 41 into the accounting of agricultural entities will certainly help to: use a common language on financial markets; confront the firms competing on the global market; improve relationships with banks and financial institutions.

Expanded results and discussions: controversies of measurement criteria provided in IAS 41 and difficulties in implementing them in Romanian agro-food companies

Regarding the accounting and measurement criteria according to the *conceptual framework* of IASB, an entity must record a biological asset or agricultural produce, only if it has control over that asset resulting from a past event, if it is likely to generate future economic benefits and if the asset *fair value* or cost can be measured reliably.

According to IAS 41, the value of a biological asset must be measured based on its initial value when entering into the company patrimony in accordance with the *fair value* of a similar biological asset, which corresponds to the cost of sale, unless the *fair value* cannot be reliably estimated. Costs of sale incurred by those biological assets, excluding commissions paid to distributors or agents, the contributions owed to the monitoring

authorities and commodities exchange, taxes for transfer operations, etc. The costs of sale include transportation costs and other costs necessary to physically bring the asset at the point of sale.

The calculation of the *fair value* for a biological asset or agricultural produce may be facilitated by regrouping the biological assets or agricultural produce depending on certain characteristics, such as age or quality. The entity to which they belong, decides on these characteristics depending on those used and promoted on the market as a calculation basis for price.

An agricultural produce derived from the entity's biological assets should be measured at *fair value,* based on the evaluation of the estimated cost of sale, at harvest; this measurement is represented by the cost recorded at the date when IAS 2 or another accounting international standard will be applied. The reliance on cost criteria should be considered as an alternative, namely: in some cases the cost value can approximate the *fair value;* when little biological transformations have taken place, the initial cost criterion must be maintained; in this case the impact of biological transformation on price is not significant.

The recognition and measurement criteria promoted by IAS 41 can be summarized as follows (Fig. 2). As can be seen, the existing controversies between the measurement criteria either at *fair value* or at initial cost arise from subjective arguments required by IAS 41. The Issues to be highlighted concern the relationship between the living stock and their measurement criterion; reasons leading to abandoning the caution principle when the fair value is applied in measuring stocks (IAS 2), as well as the other difficulties arising from measurement at *fair value.*

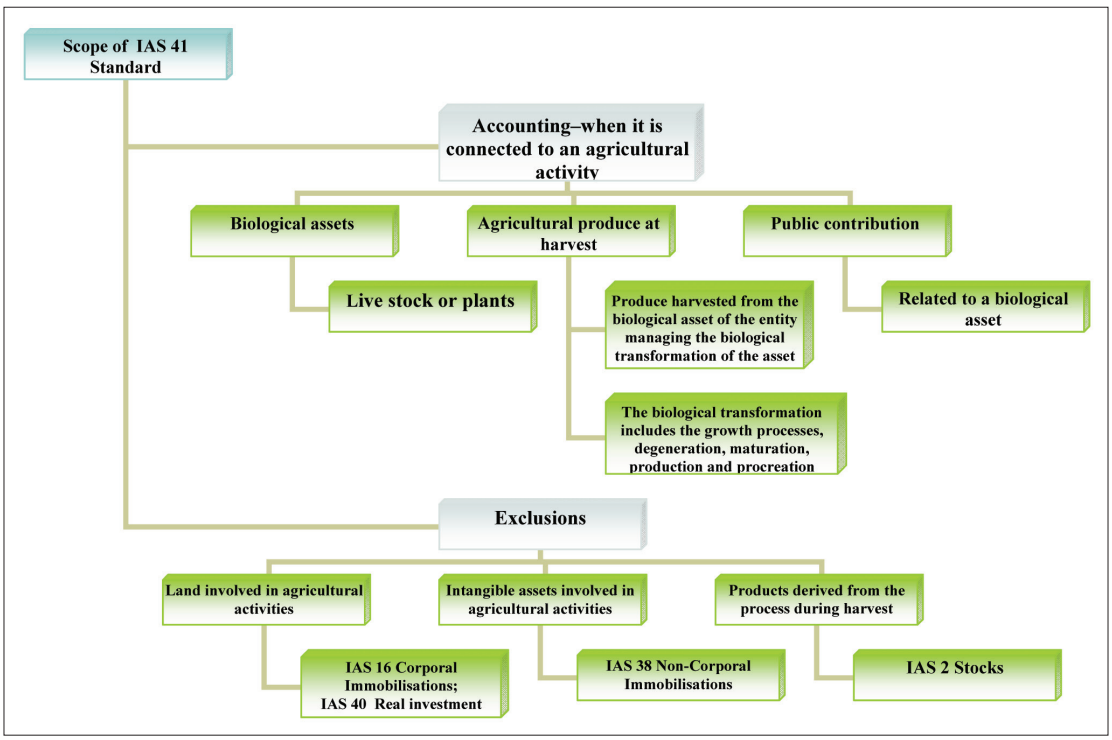

Fig. 1. Scope of the IAS 41 standard

Most of the time, in order to complete the *fair value,* estimation models and techniques are used, such as:

a) Market Approach: which consists in determining the values on current market transactions;

b) Income Approach: which consists in determining the values related to future benefits generated;

c) Cost Approach: which applies when both aforementioned methods cannot be applied.

The reasons for renouncing the principle of caution, for measuring the stocks and leading to predominantly choose the *fair value* measurement criteria can be found (Alexander and Arcer, 2006) - with some remarks - during the multi-annual period of agricultural production, in the sensitivity of the *fair value* to the market dynamic of animals and plant stocks.

The measurement of biological assets at the entry in an agricultural entity patrimony can be represented as follows (Table 2); for agricultural produce, the alternatives of the accounting registration at the entry into the entity patrimony and financial years will be as follows (Table 3).

In essence, the measurement criterion of agricultural produce is the same as the one indicated for the biological assets, but if for the last ones, IAS 41 allows the measurement at the cost criterion, if the *fair value* cannot be reliably estimated, for the agricultural produces, the *fair value* will be applied in all circumstances.

Actually, IAS 41 assumes that it is possible to permanently measure at the *fair value* the agricultural produces at harvest.

Difficulties in implementing the Standards IAS / IFRS in the Romanian Agro-food companies

With reference to the Romanian system, keep in mind that "the financial accounting is oriented in two different directions. A number of groups and companies apply the International Financial Reporting Standards (IFRS), including IAS 41. Most companies still apply the provisions of the Decision no. 3055/2009 of the Ministry of Public Finance. These regulations are consistent with the Directive 478/660/EEC of the Council of Europe on the annual accounts of certain types of commercial companies and with Directive 783/349/EEC of the Council of Europe on consolidated accounts. However, accounting rules in Romania are converging to a number of issues with IFRS referential. The general criteria for recognizing the assets in national regulations are taken from the international conceptual framework regarding the preparation and presentation of financial statements. The provisions of IAS 41 are not directly reflected into the Romanian regulations" (Feleagă et al., 2012).

IAS 41 requires quite important restrictions on the registration of property in the balance sheet, but also on the information provided about the biological assets and agricultural produce that can be obtained.

Regarding the registration of elements into the financial statements, it has been established that an entity shall disclose separately the accounting value of their own biological assets, this can be an type of record, carried out on groups of homogeneous assets, such as living animals, plants, etc.

The variations of the biological assets fair value are recorded into the profit-and-loss account as separate components or explained in

the balance sheet. In the explanatory note, it is necessary to present the information regarding the nature and level of growth of biological assets.

IAS 41 encourages entities to distinguish assets as: consumable supplies, such as animal meat, cereals, etc.; fruit, such as dairy cattle, fruit trees, etc.; mature, presenting the needed characteristics to be collected; immature, not having the needed characteristics to be collected.

Little importance is given by the IAS 41 standard to issues with which the agricultural entities must deal, namely: maximum annual working periods by activities and successive transformations (crops, livestock and processed agricultural products).

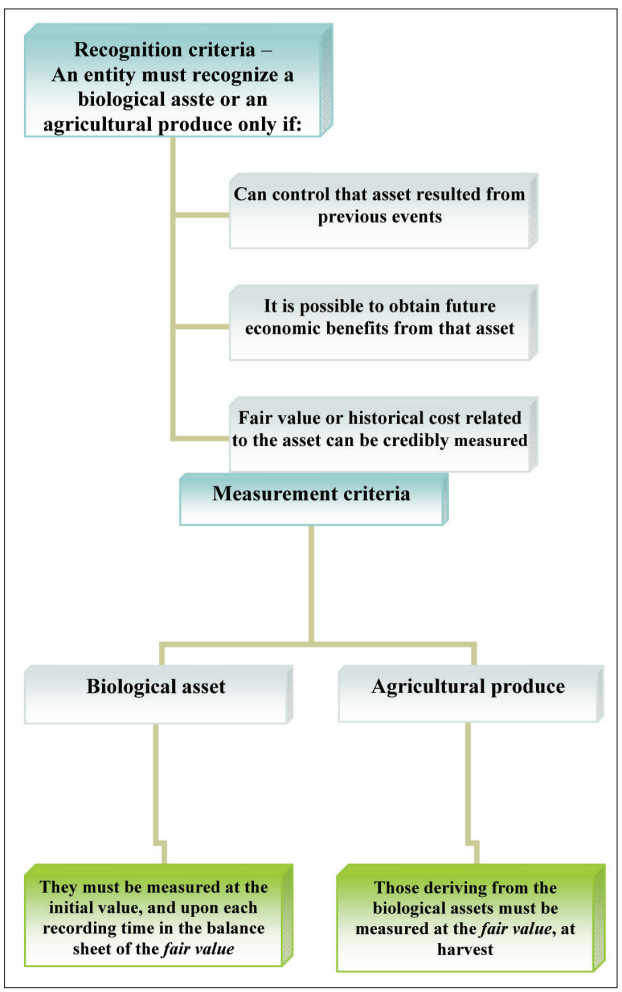

Fig. 2. Recognition and evaluation criteria of biological assets and agricultural produces in accordance with IAS 41

The working days are the ability to work on machinery and equipment used, on ancillary work, on manual work, on administration work (including sales), management, supervision and monitoring activities. Usually, one working day matches a number of 6.5 hours. For example, the duration of a working day depends on the place of production, as it can be seen in the table below (Table 4). Once the working time is calculated, the amount of compensations awarded for the work performed by the employees can be determined, depending on their role in the entity.

Returning to IAS 41, in determining the fair value and the effects resulting from the measurement, the entity shall: indicate the criteria taken into consideration in determining the *fair value* of biological assets and agricultural produce; present the *fair value* less the estimated cost of sale of agricultural produce harvested during the accounting year and determined at harvest; *fair value* change due to occurring physical or price changes.

The multiannual period of agricultural production determining a continuous recording in the entity's accounting determines a distribution of the economic and financial result between the financial years that were completed by the agricultural production.

A reconciliation between the changes occurring in the accounting value of biological assets between the time of entry into patrimony and end of the current accounting year, should include: profits or expenses derived from the change of *fair value*; increases due to purchases; decreases due to sales; reductions due to harvest; increases due to consolidation of enterprises;

differences derived from the translation of financial statements by a foreign entity.

Choosing the *fair value* evaluation criterion means a uniform distribution in time of the outcome, whether livestock breeding is gradually increasing and if estimated prices are not decreasing (Epsetin and Jermakowicz, 2007).

CONCLUSIONS

As can be noticed from our paper, IAS - *Agriculture* applies retrospectively so as to be able to capture the registration effects into the agro-food entities accounting of agricultural produce and biological assets, as if this accounting standard has always been used in the preparation and reporting of financial statements. Our investigations have allowed us to establish that the conflicts between the national Romanian accounting norms and IAS 41 are because agro-food companies reduce the importance of measurement under the historical cost in favor of the *fair value.* However, the concrete practice of *fair value* estimation is often impossible, the market price being the one reflecting the value of the agricultural produce concerned or biological asset, depending on certain conditions or criteria of differentiation, especially as some types of agricultural produce are frequently found in quotations from local exchanges.

REFERENCES

Adamo, S. (2004). Il modello di bilancio IAS/IFRS, In: *Informazione contabile e bilancio di esercizio* (Ed. Cagno Nicola), 433. Cacucci Publishing House, Bari, Italy.

Alexander, D. and *Arcer, S.* (2006). International Accounting/ Financial Reporting Standards Guide. CCH, Chicago.

Azzali, S., Fornaciari, L. and *Pesci, C.* (2007). Bilancio consolidato, esercizi svolti e commentati secondo i principi contabili nazionali e internazionali. Giappichelli Publishing House, Torino, Italy.

Bartola, A. and *Arzeni, A.* (1995). Analizi di gestione mediante indici di bilancio. Inea Publishing House, Millan, Italy.

Budean, V. (2008). Analiza patrimoniului unităţilor agroalimentare, 14-79. Princeps Edit Publishing House, Iasi, Romania.

Delfoud, P. (1971). Problemes methodologiques de compatibilite economique agricole. Editions Cujas, Paris.

Elad, C. (2004). Fair value accounting in the agricultural sector: some Implications for International accounting harmonization. *European Accounting Review*, **13**(4): 621-641.

Elad, C. (2007). Fair value accounting and fair trade: an analysis of the role of International Accounting Standard no. 41 in social conflict. *Socio-Economic Review* **5**(4): 755-777.

Epsetin, B.J. and *Jermakowicz, E.K.* (2007). International Financial Reporting Standards, 937. Wiley Editions.

Feleagă, L., Feleagă, N. and *Răileanu, V.* (2012). Theoretical considerations about implementation of IAS 41 in Romania. *Theoretical and Applied Economics,* **2**(567): 31-38.

Herbohn, K.F. and *Herbohn, J.* (2006). International Accounting Standard (IAS) 41: What are the implications for reporting forest assets? Small-scale Forest Economics. *Management and Policy*, **5**(2): 175–189.

IAS 41 - Agriculture, Paragraph no. 10, www.iasb.com

ISIA - Istituto Superiore di Istruzione Agraria, Duca degli Abruzzi – Padova (2012). Il bilancio estimativo del dell'azienda agricola,
www.ducabruzzi.it/materialididattici/Polato/bilancio%20estimativo.doc

Jansson, A.M. and *Fagerström, A.* (2011). Accounting for Forest Assets: the case of IAS 41 and fair value. Proceedings of Business and Information, Bangkok.

Lounay, R. (1967). L'enterprise agricole. Analyse, diagnostic, prevision. Librarie Armand Colin, Paris.

Pacciani, A. (1979). Contabilita e analizi di gestione nelle cooperative agricole. Il Mulino Publishing House, Bologna, Italy.

Pacciani, A., Belletti, G. and *Milani, F.* (2005). L'Evoluzione Della Cooperazione farm in Tuscany, Relazione Finale, 11. Firenze Publishing House, Italy.

Piccinini, A. (1988). Analizi di bilanci e cooperative agricole. *Rivista di Politica Agraria*, no. 2.

www.ducabruzzi.it/materialididattici/Polato/bilancio%20estimativo.doc

Todea, N., *Burja, Camelia, Burja V.* and *Deaconu, S.C.* (2005). Gestiunea şi contabilitatea exploataţiilor agricole, 19-131. Risoprint Publishing House, Cluj-Napoca, Romania.

Chapter 2

The role of accounting and auditing in the digital age. From digitization to digital transformation

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Abstract. The digital age is at the center of business attention as a major challenge for the accounting profession. A solid financial accounting system, developed in real time through centralization, standardization, comprehensibility, and automation, helps management understand how their organization works - and how they can improve productivity by removing key constraints.

Using technology to increase the talent needed in the accounting profession, in a world surrounded by data by actively exploiting the opportunities arising from digital tools and new data sources and by combining these opportunities with their deep knowledge of business processes, accounting professionals can focus on areas that require judgment, inspiring the confidence and trust of stakeholders and shareholders to build a better working environment in the digital era.

Accounting digital innovation involves conversion of analog information to digital information, incorporating technology as a part of daily financial activity and using it smartly, in operational processes, demonstrating the quality and value that technology-related solutions can generate when exploited in business. This growth in technology is causing changes in accounting business models.

Using in-depth financial accounting analysis and business intelligence canvas digital transformation can contribute to the optimization of the corporate world with competence and relevance ensured to meet the expectations of shareholders and stakeholders.

Keywords: Digital accounting, Cloud Accounting, accounting software and services, Mobile Accounting, accounting culture.

2.1 Introduction

The fourth industrial revolution is transforming industries and revolutionizing the applicability of accounting in the rapidly evolving business environment.

Even if the traditional accounting principles have passed the test of time, the Venetian merchants defined and shaped the modern financial world in which we all live, accounting has undergone significant changes with the advent of digital technologies. This shift from conventional to digitized and then to digital has opened new opportunities, allowing private and public organizations alike to streamline processes, improve accuracy and increase overall efficiency(Cristina et al., 2021).

Digital accounting offers numerous benefits for companies and organizations, providing a comprehensive solution for managing financial processes, providing efficiency, accuracy, and strategic insights for businesses of all sizes(Kliukin, 2023).

By implementing accounting software, we can automate routine repetitive tasks such as data entry, electronic invoice processing, reduce the risk of errors and free up time for more strategic activities, generate real-time financial reports or reduce human errors associated with manual entry of data and calculations.

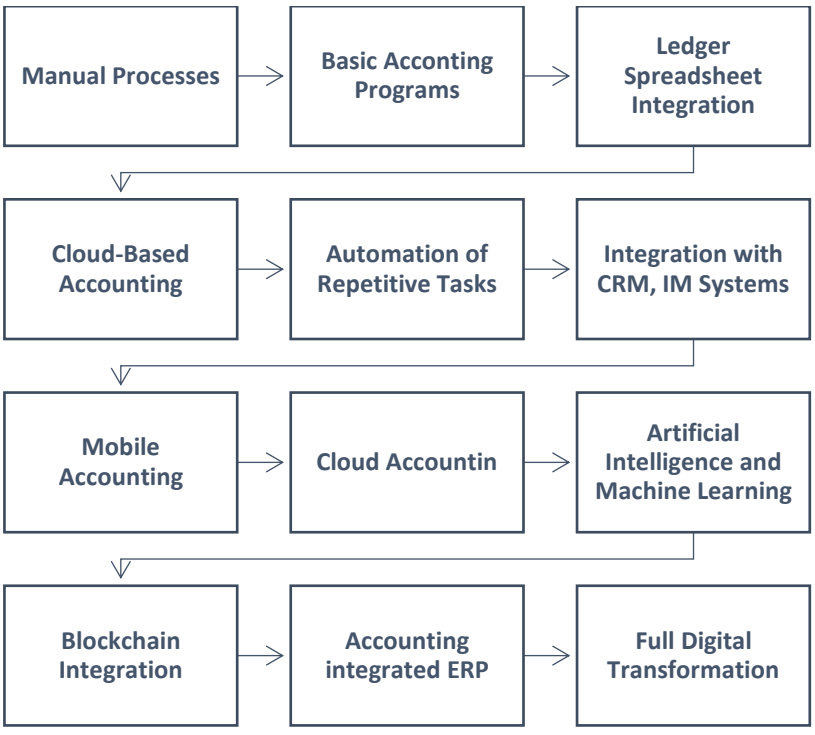

Figure 1. *Transition from digitalization to digital integration in the accounting process*

Accounting digitization usually occurs in stages, with public or private economic entities gradually adopting and integrating digital technologies into their accounting processes.

The phases may vary depending on the size of the organization, industry and specific business needs. Initially, accounting digitization included the formation, representation and transmission of financial data in electronic format.

Computing systems and accounting programs have transformed the financial industry and implicitly the global economy. Technological advances and the rapid evolution of Industry 4.0 have improved the ability of accounting professionals to interpret and report data faster and more efficiently(Fartushniak & Chasovnikova, 2023).

Ever since the beginnings of bookkeeping, Venetian merchants played a pivotal role in shaping modern financial and business environments.

Double-entry bookkeeping introduced a systematic way to record financial transactions and this method enhanced transparency by requiring businesses to record both the debit and credit aspects of each transaction just as cloud accounting is trying to achieve today This transparency was and will continue to remain crucial for stakeholders, including owners, investors, and creditors, to understand the financial health of a business.

Later with the widespread use of computing systems and computers, basic accounting software was introduced to automate key tasks and financial reporting.

In the last decade, the shift to cloud-based accounting solutions that provide accessibility from anywhere allowing collaboration in real time, data synchronization and remote access.

In the transition from digitization to accounting digitization, accounting systems were integrated with other business systems, such as improving data consistency.

The adoption of AI and machine learning technologies for tasks such as predictive analysis, fraud detection and data categorization adds intelligence and efficiency to accounting processes and the exploration and integration of blockchain technology for greater security, transparency and traceability of financial transactions contributes to the digitization of audit and internal control(Begkos et al., 2023).

All these stages shown in figure 1 formed the digital accounting canvas perfectly integrating accounting and financial management.

Accounting digitization involves the integration of digital technologies into various accounting processes to streamline operations, improve efficiency and provide more accurate and timely financial information through a step-by-step approach.

In the first stage, economic entities switch from manual accounting, on paper, to computerized systems. Digitization helps to automate tasks such as entries in the journal, calculations, drawing up the balance sheet and drawing up the basic financial statements. This first stage allows for greater accuracy, efficiency and ease of data acquisition compared to traditional analog methods.

In the second stage, accounting systems and data migrate to cloud-based platforms. This second stage provides real-time access to financial information from anywhere in a global economic context, facilitating collaboration between multiple users. Accounting systems based on cloud services often offer features such as automatic updates,

scalability and data security, allowing economic entities to focus on their core activities while benefiting from improved accessibility.

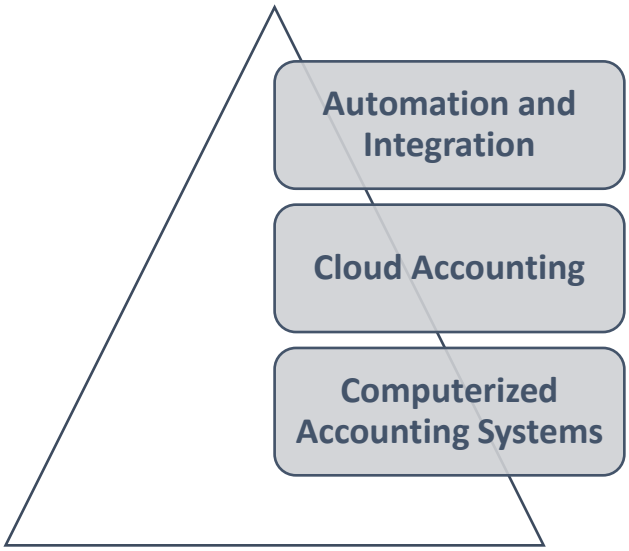

Figure 2. *Three key stages in the digitalization of accounting*

The third stage involves the integration of advanced technologies for automating routine tasks and improving overall efficiency such as Robotic Process Automation (RPA). This is used for tasks such as processing invoices, reconciling data and generating consolidated financial reports. Integration with other business systems, such as Customer Relationship Management (CRM) and inventory management, simplifies the flow of data between different departments. This phase aims to reduce manual efforts, minimize errors and improve the speed of financial accounting processes.

2.2 |A Comprehensive Digital Transformation Strategy for Modern Accounting and Audit

The concern related to digital transformation is constantly spread in the corporate world and represents a constant of sustainable development and their integration in the circular models of economic exchanges(Hung et al., 2023).

Digital transformation in accounting often begins with a reassessment and integration of basic accounting principles. The foundation of accounting, which includes principles like accuracy, reliability, and relevance, remains crucial in the digital age.

Digital transformation in accounting builds upon and enhances basic accounting principles by leveraging technology to improve accuracy, reliability, relevance,

completeness, consistency, cost-effectiveness, and security in financial processes. The integration of digital tools aligns with the foundational principles of accounting to provide a more efficient and robust financial management framework.

Accounting Principle	Digitalization influence	Digitalization applicability
Accrual Principle	Digitalization enables real-time tracking of financial transactions, making it easier to apply the accrual principle by recognizing revenues and expenses when they are incurred, not when cash is received or paid	Companies leverage digital payment systems to receive and make payments in real time and use ERP systems that integrate various business processes, including finance. These systems facilitate real-time tracking by automatically updating financial information across different departments
Conservatism Principle	Digital accounting systems can provide instant access to historical data, facilitating a conservative approach by recognizing losses and liabilities as soon as they are foreseeable, while gains and assets are recognized only when realized	Digital accounting systems facilitate the matching principle, which involves matching expenses to the revenues they help generate. This ensures a conservative approach by recognizing costs associated with generating revenue in the same accounting period and include provisions for bad debts, potential legal liabilities, or anticipated losses on investments.
Consistency Principle	Digital systems ensure consistency in accounting practices by automating repetitive tasks, reducing the likelihood of errors due to manual inconsistencies	Digital accounting systems automate the process of data entry, reducing the likelihood of human errors associated with manual input. Digital systems use algorithms and rules to automatically code and categorize transactions. This ensures that similar transactions are consistently recorded under the appropriate accounts, promoting standardization and accuracy in financial reporting

Reliability Principle	Digital systems enhance the reliability of financial information by reducing the risk of errors and providing audit trails for every transaction	Automated systems can be configured to generate alerts and notifications when anomalies or errors are detected. Digital systems often integrate with other business systems, such as inventory management or sales platforms. This integration helps ensure that data is consistently and accurately transferred reducing the risk of discrepancies.
Full Disclosure Principle	Advanced reporting capabilities in digital systems allow for comprehensive disclosure of financial information, ensuring transparency and compliance with the full disclosure principle	Advanced reporting capabilities often involve integrating data from various sources within the organization. This includes financial data, operational data, and other relevant information. Integrated data sources contribute to a more holistic and comprehensive view of the company's financial position and this consistency makes it easier for stakeholders to compare information across different periods and facilitates a clearer understanding of the company's financial performance
Materiality Principle	Digital systems make it easier to assess materiality by providing tools for analyzing and presenting financial data, helping businesses determine the significance of transactions and events	Visualization tools, such as charts and graphs, enable companies to present financial data in a visually appealing and understandable format and offer dynamic reporting capabilities that allow users to drill down into financial data at various levels of detail. This aids in the identification of material trends or outliers, making it easier for stakeholders to assess the significance of specific items.

Tabel 1. Digital tools that support accounting principles.

Digitalization streamlines cost tracking and recording, making it easier to adhere to the cost principle by valuing assets at historical cost rather than market value. and ensures consistency with the monetary unit principle by recording and reporting financial transactions in a standardized currency, eliminating the challenges associated with manual currency conversions(Anton, 2023).

Regarding time period principle, digitalization facilitates timely and accurate financial reporting, aligning with the time period principle by providing insights into the company's performance over specific accounting periods.

Advancements in digital transformation have a profound impact on how accounting information is captured, processed, and utilized. The transition from traditional accounting information flow to digital accounting is a multifaceted process that requires careful planning, effective communication, and ongoing monitoring(Ruggeri et al., 2023).

It involves not only the adoption of new technologies but also the transformation of workflows and the cultivation of a digital mindset within the economic entity.

The integration of digital technologies enhances the overall quality and utility of accounting information for informed decision-making.

Accounting information	Traditional Aspect	Digital Transformation Aspect
Accuracy	In traditional accounting, there is a risk of errors during data entry and calculations	Automation tools and integrated systems reduce the likelihood of errors, providing more accurate financial information. Computerized accounting systems and algorithms in digital tools help maintain precision in calculations
Reliability	Reliability is dependent on the consistency and accuracy of manual processes	With the adoption of digital tools, reliability is enhanced through real-time data access, secure cloud storage, and automated processes. Digital systems contribute to a more dependable financial reporting system
Relevance	Accounting processes may result in delays in generating relevant financial information.	Digital tools, including cloud accounting and analytics, provide timely and relevant data. Real-time reporting and analysis enable stakeholders to make informed decisions based

		on current financial insights
Completeness	Manual processes may lead to delays and omissions in completing financial records	Automated systems help ensure completeness in financial records, with features like automatic data entry, transaction tracking, and real-time updates.
Consistency	Maintaining consistency in manual processes can be challenging due to human errors and variations.	Digital systems promote consistency through standardized processes and automated workflows. This reduces the likelihood of inconsistencies in financial reporting.
Cost-Effectiveness	Manual processes may be time-consuming and labor-intensive, potentially leading to higher costs	Automation and digital tools contribute to cost-effectiveness by reducing the time and resources required for routine tasks. Cloud-based solutions also eliminate the need for physical storage and manual backups
Security	Physical records and manual processes pose security risks, including the loss or damage of documents	Digital systems offer enhanced security through features like encryption, access controls, and secure cloud storage. Blockchain technology provides a tamper-resistant and secure audit trail

Tabel 2 The transition from accounting information processing

New technologies have a profound impact on how accounting information flows within an organization. These advancements significantly transform the way financial data is processed, communicated, and utilized.

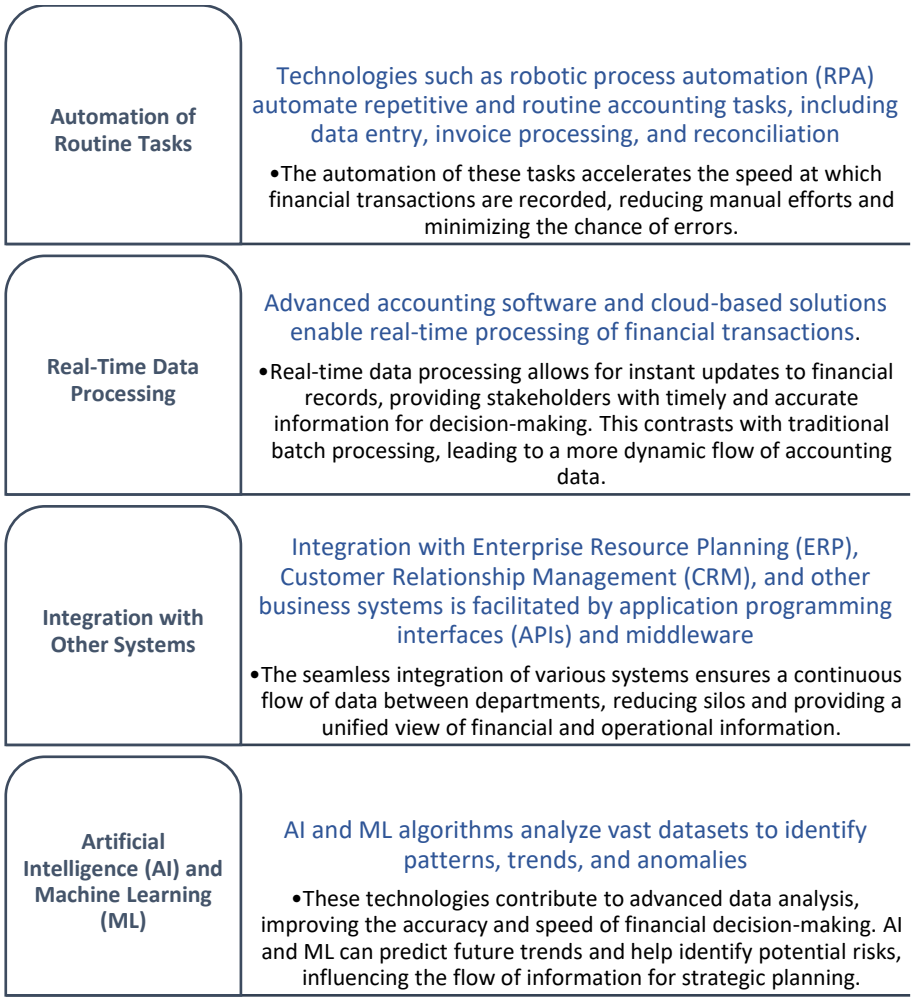

Figure 3. Flow of financial information in the digital transformation age

While the digitalization of accounting offers numerous benefits, it also introduces certain risks that will require the full attention of CPA.

The increased reliance on digital systems exposes organizations to cybersecurity risks. Hackers may attempt to gain unauthorized access to financial data, leading to data breaches, identity theft, or financial fraud. Employees with access to digital accounting systems can pose insider threats if they misuse or mishandle sensitive financial data. This could be intentional (malicious) or unintentional (due to negligence or lack of awareness)

Another risk that organizations need to be mindful of will be the errors in data entry, software glitches, or system malfunctions that can compromise the integrity of

financial data. Inaccurate information may lead to flawed financial reporting and decision-making.

Like all industrial revolutions that proceeded 4.0, implementing new technologies requires a skilled workforce. A lack of proper training for employees in the accounting field and CPA can result in mistakes, inefficiencies, and a failure to fully utilize the capabilities of digital accounting systems. Employees may resist the adoption of new technologies, leading to resistance and a slower transition. Change management strategies are crucial to overcome resistance and ensure a smooth digital transformation.

The rapid changes in technology may outpace regulatory frameworks, leading to compliance challenges. Failure to keep up with evolving regulations and standards could result in legal consequences and financial penalties for economic entities.

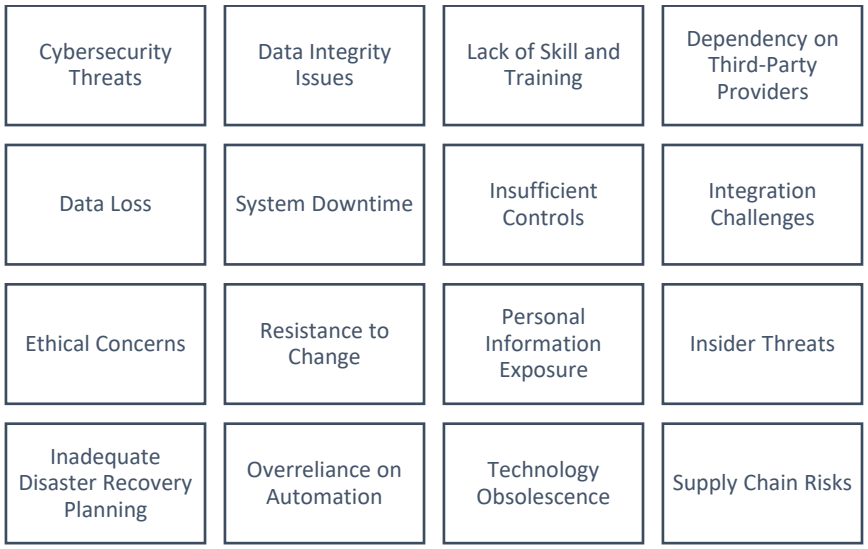

Figure 4. *Risks that may occur in the digitalization of accounting practices*.

Another risk associated with data loss may include accidental deletion, hardware failures, or other technical issues that can result in the loss of critical financial data. Without proper backup and recovery mechanisms, organizations risk significant data loss and operational disruptions. On the same line of risk associated with data analysis we need to also mention technical issues, maintenance, or cyber-attacks that can lead to system downtime. Extended periods of unavailability can disrupt financial processes, impact decision-making, and cause financial losses in the current or future financial exercise.

If we analyze the control and audit process, inadequate internal controls in digital accounting systems may lead to fraudulent activities, unauthorized access, or unauthorized changes to financial records. Proper segregation of duties and access controls are essential to mitigate these risks. In the exercise of the financial activities, the use of advanced technologies, such as artificial intelligence and machine learning, may raise ethical concerns related to bias in algorithms, lack of transparency, and the potential misuse of sensitive financial data.

The collection and storage of sensitive financial data in digital systems raises privacy concerns. Inadequate privacy measures can result in unauthorized access to personal information, leading to reputational damage and legal consequences. Thes systems are prime targets for cybercriminals due to the valuable financial information they store. A data breach can result in unauthorized access to sensitive financial data, leading to identity theft, financial fraud, and reputational damage. Financial data often includes personally identifiable information (PII) such as names, addresses, social security numbers, and bank account details. Inadequate protection of this information can expose individuals to privacy risks and potential harm.

Assessing the pross and cons of the transition process from digitization to digitalization in the field of accounting and audit, Certified Public Accountants (CPAs) need to adapt to emerging trends and acquire new skills to stay relevant and effectively navigate the evolving landscape. These new skills will have to include:

a) Data Analytics because accountants should develop proficiency in data analytics and business intelligence tools.
b) Automation and Technology Integration due to the increased usage of robotic process automation (RPA) and accounting software in companies.
c) Cybersecurity Awareness because CPAs should have a solid understanding of cybersecurity principles.
d) Blockchain and Cryptocurrency Competence blockchain technology and its applications especially if they verify financial transactions.
e) Soft Skills and Communication because accountants evolve and need strong communication and interpersonal skills.
f) Environmental, Social, and Governance (ESG) Reporting because accountants should be familiar with ESG reporting standards and be able to integrate non-financial metrics into their assessments.

The integration of digital processes in accounting and incorporation of AI into the field of accounting and audit is indeed a transformative and inevitable process(Zlati et al., 2022).

The application of AI technologies has the potential to revolutionize various aspects of accounting and audit, offering efficiency, accuracy, and new opportunities for CP accountants(Cristina et al., 2021).

It is important to recognize the need for ethical considerations, oversight, and collaboration between AI systems and accounting professionals. As AI becomes more prevalent in accounting and audit, CPA will likely need to develop a blend of all skills mentioned above to effectively collaborate with digital tools and AI and harness their full potential.

2.3 Conclusions

By leveraging digital tools and technologies, companies can ensure that their financial transactions are tracked in real time, leading to improved decision-making, increased efficiency, and better overall financial management. Incorporating privacy considerations into the design and development of digital accounting systems is crucial. This involves ensuring that privacy features are built into the system from the outset rather than being added as an afterthought.

Digital systems incorporated in accounting practices in companies streamline the assessment of materiality by providing tools for automated analysis, data visualization, real-time monitoring, and collaborative decision-making. These capabilities enhance the efficiency and accuracy of materiality assessments, ultimately contributing to more informed financial reporting and decision-making processes.

Digital accounting systems enable companies to implement a conservative approach by promptly recognizing losses and liabilities when foreseeable and adopting a cautious stance in recognizing gains and assets. These systems provide the tools and functionality needed to adhere to accounting principles and standards, resulting in accurate and transparent financial reporting.

Transition from digitization to digitalization contributes to consistency in accounting practices by automating repetitive tasks, reducing the likelihood of errors, and ensuring compliance with standards and regulations. This not only improves the accuracy of financial reporting but also enhances efficiency within the accounting function. The application of advanced reporting capabilities in digital systems enables companies to fulfill the full disclosure principle by providing comprehensive, standardized, and transparent financial information. These capabilities contribute to a more informed and confident decision-making process for stakeholders.

The future digital framework will enhance the reliability of financial information in companies by automating processes, implementing validation checks, providing error alerts, maintaining audit trails, and enforcing consistent procedures. These measures collectively contribute to the accuracy and integrity of financial data, reducing the risk of errors in accounting practices.

To mitigate these risks, organizations should invest in robust cybersecurity measures, provide continuous training for employees, stay informed about regulatory changes, implement strong internal controls, and conduct regular risk assessments. A proactive and comprehensive approach to risk management is essential to maximize the benefits of digitalization while minimizing potential drawbacks.

Addressing the risks of digitalization in accounting requires a proactive and strategic approach to digital transformation, including thorough risk assessments, ongoing monitoring, and continuous improvement of cybersecurity and data management practices.

As digitalization continues to transform the business environment, audit practices will continue to evolve to meet the demands of a rapidly changing landscape. Adapting to new technologies and methodologies is essential for auditors to maintain the effectiveness and relevance of their assurance services.

Governments play a crucial role in addressing and facilitating the digitalization of accounting by developing and updating regulatory frameworks to accommodate

and govern the use of digital technologies in accounting. We recommend that this include addressing issues related to data protection, privacy, cybersecurity, and compliance with accounting standards. National bodies will need to allocate resources for research and development initiatives focused on advancing digital accounting technologies. This support can lead to innovations that improve the efficiency, security, and functionality of accounting systems both national and international like IFRS and US GAAP. The digital economy often involves cross-border transactions, and IFRS may need to provide clarity on how to account for transactions in this context. As digital assets and cryptocurrencies become more prevalent, IFRS may need to provide specific guidance on their accounting treatment. This includes considerations for recognition, measurement, and disclosure of digital assets on financial statements.

References

1. AbuAkel, S. A., & Ibrahim, M. (2023). The Effect of Relative Ad-vantage, Top Management Support and IT Infrastructure on E-Filing Adoption. Journal of Risk and Financial Management, 16(6). https://doi.org/10.3390/jrfm16060295
2. Anton, C. E. (2023). Opinions of Accounting Companies Managers Regarding the Digitalization Process of Accounting. Bulletin of the Transilvania University of Brasov. Series V: Economic Sciences. https://doi.org/10.31926/but.es.2023.16.65.1.11
3. Awang, Y., Taib, A., Shuhidan, S. M., Zakaria, Z. N. Z., Ifada, L. M., & Sulistyowati, S. (2023). Mapping between Digital Competencies and Digitalization of the Accounting Profession among Postgraduate Ac-counting Students. Asian Journal of University Education, 19(1). https://doi.org/10.24191/ajue.v19i1.21226
4. Batsakis, G., Theoharakis, V., Li, C., & Konara, P. (2023). Internationalization and digitalization: Their differing role on grocer and non-grocer retailer performance. Journal of Retailing, 99(3). https://doi.org/10.1016/j.jretai.2023.07.005
5. Begkos, C., Antonopoulou, K., & Ronzani, M. (2023). To datafication and beyond: Digital transformation and accounting technologies in the healthcare sector. British Accounting Review. https://doi.org/10.1016/j.bar.2023.101259
6. Cristina, T., Marian, S., Veronica, G., & Dan-Andrei, C. (2021). Fiscal and accounting fraud risk detection using beneish model. A romanian case study. International Journal of Business and Society, 22(1). https://doi.org/10.33736/IJBS.3176.2021
7. Diófási-Kovács, O., & Nagy, J. (2023). Beyond CO2 emissions – The role of digitalization in multi-dimensional environmental performance

measurement. Environmental and Sustainability Indicators, 18. https://doi.org/10.1016/j.indic.2023.100252

8. Fartushniak, O., & Chasovnikova, J. (2023). Accounting identification of money at business entities in the conditions of digitalization. Eco-nomic Analysis, 33(1). https://doi.org/10.35774/econa2023.01.164
9. Ghobakhloo, M., Asadi, S., Iranmanesh, M., Foroughi, B., Mubarak, M. F., & Yadegaridehkordi, E. (2023). Intelligent automation imple-mentation and corporate sustainability performance: The enabling role of corporate social responsibility strategy. Technology in Society, 74. https://doi.org/10.1016/j.techsoc.2023.102301
10. 1Gnatiuk, T., Shkromyda, V., & Shkromyda, N. (2023). Digitalization of Accounting: Implementation Features and Efficiency Assessment. Journal of Vasyl Stefanyk Precarpathian National University, 10(2). https://doi.org/10.15330/jpnu.10.2.45-58
11. Grosu, V., Cosmulese, C. G., Socoliuc, M., Ciubotariu, M. S., & Mihaila, S. (2023). Testing accountants' perceptions of the digitization of the pro-fession and profiling the future professional. Technological Forecasting and Social Change, 193. https://doi.org/10.1016/j.techfore.2023.122630
12. Hrytsenko, O. (2023). MAIN DIRECTIONS OF THE DIGITALIZATION OF ACCOUNTING AND THEIR APPLICATION IN THE EDUCATIONAL PROCESS. Sj-Economics Scientific Journal, 49(2). https://doi.org/10.58246/sj-economics.v49i2.627
13. Hung, B. Q., Hoa, T. A., Hoai, T. T., & Nguyen, N. P. (2023). Ad-vance-ment of cloud-based accounting effectiveness, decision-making quality, and firm performance through digital transformation and digi-tal leader-ship: Empirical evidence from Vietnam. Heliyon, 9(6). https://doi.org/10.1016/j.heliyon.2023.e16929
14. Ivascu, A. Domil, M. Sarfraz, O. Bogdan, V. Burca, and C. Pavel, "New insights into corporate sustainability, environmental manage-ment and cor-porate financial performance in European Union: an ap-plication of VAR and Granger causality approach," Environmental Science and Pollution Re-search, vol. 29, no. 55, 2022, doi: 10.1007/s11356-022-21642-8.
15. Izmalkova, I. V., Polennikova, G. I., & Tatarenko, L. Yu. (2023). Digi-talization of accounting processes in the context of economic development in modern conditions: problems and impact on business processes. Вестник Алтайской Академии Экономики и Права, 1(№6 2023). https://doi.org/10.17513/vaael.2857
16. Kliukin, A. D. (2023). Modern development of digitalization of the agroin-dustrial complex: domestic and foreign experience. Agrarian Economics, 12. https://doi.org/10.29235/1818-9806-2022-12-72-86
17. Kolisnyk, O., Hurina, N., Druzhynska, N., Holovchak, H., & Fomina, T. (2023). INNOVATIVE TECHNOLOGIES IN ACCOUNTING AND AUDITING: THE USE OF BLOCKCHAIN TECHNOLOGY. Finan-cial and Credit Activity: Problems of Theory and Practice, 3(50). https://doi.org/10.55643/fcaptp.3.50.2023.4082

18. Krisdiyawati, K., & Maulidah, H. (2023). ANALISIS IMPLEMENTASI AKUNTANSI DIGITAL GUNA PENCATATAN KEUANGAN PADA UMKM. Jurnal Riset Akuntansi Politala, 6(1). https://doi.org/10.34128/jra.v6i1.174
19. L.K., F., & O.R., L. (2023). Accounting Practices in A Digitalized World: Nigerian Perspective. African Journal of Accounting and Financial Research, 6(1). https://doi.org/10.52589/ajafr-dwn2co6g
20. Oleiwi, R. (2023). THE EXTENT TO WHICH TEXTBOOKS FULFILL THE REQUIREMENTS OF DIGITAL TRANSFORMATION IN ACCOUNTING AND AUDITING. In-ternational Journal of Professional Business Review, 8(5). https://doi.org/10.26668/businessreview/2023.v8i5.1509
21. Petchenko, M., Fomina, T., Balaziuk, O., Smirnova, N., & Luhova, O. (2023). ANALYSIS OF TRENDS IN THE IMPLEMENTATION OF DIGITALIZATION IN ACCOUNTING (UKRAINIAN CASE). Financial and Credit Activity: Problems of Theory and Practice, 1(48). https://doi.org/10.55643/fcaptp.1.48.2023.3951
22. Rozhkova, N. K., & Blinova, U. Yu. (2023). Conceptual problems of financial accounting in a digital economy. UPRAVLENIE / MANAGEMENT (Rus-sia), 10(4). https://doi.org/10.26425/2309-3633-2022-10-4-78-83
23. Ruggeri, D., Leotta, A., & Rizza, C. (2023a). Correction to: Digitalisation and accounting language games in organisational contexts. Journal of Manage-ment and Governance, 27(3). https://doi.org/10.1007/s10997-022-09656-3
24. Ruggeri, D., Leotta, A., & Rizza, C. (2023b). Digitalisation and accounting language games in organisational contexts. Journal of Management and Governance, 27(3). https://doi.org/10.1007/s10997-022-09626-9
25. Schiffmann, O., Hicks, B., Nassehi, A., Gopsill, J., & Valero, M. (2023). A Cost–Benefit Analysis Simulation for the Digitalisation of Cold Supply Chains. Sensors, 23(8). https://doi.org/10.3390/s23084147
26. Tran, N. H. (2023). Factors Impacting Digital Accounting Systems Trend: Empirical Evidence from An Emerging Market. International Journal of Membrane Science and Technology, 10(2). https://doi.org/10.15379/ijmst.v10i2.1167
27. Zlati, M. L., Ionescu, R. V., Antohi, V. M., & Grosu, V. (2022). Growth and integration's impact under a new dynamic approach. Environment, Devel-opment and Sustainability, 24(5). https://doi.org/10.1007/s10668-021-01739-9