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EMA ADOPTION AND SUSTAINABILITY REPORTING:
Exploring the Impact of Industry 4.0 on Financial Performance of SMES in Eastern Indonesia's Manufacturing and Agriculture Sectors

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The aim of this dissertation is to obtain a doctoral (Ph.D.) degree in scientific field of "Management and Business"

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1. INTRODUCTION

Nowadays, due to the global pandemic and war, the shortage is started worldwide. It is common for businesses to prioritize profit maximization above all else. However, in doing so, many have actually gone against the very principles of profit maximization. These principles include economic cost, accounting cost, and opportunity cost, all of which have been violated. Unfortunately, these violations have led individuals or organizations to disregard important issues such as environmental management and conservation, which have had a significant effect on global environmental sustainability.

Environmental damage on land and sea results in an environmental imbalance and unusable further will harm human life and other creatures on earth. Business entities that consume natural resources for production have a high potential to create environmental damage. An example is the global pandemic COVID-19 due to changes in the wildlife ecosystem in Wuhan (K. E. Jones et al., 2008; O'Callaghan-Gordo & Antó, 2020; C. K. F. Rahman et al., 2020). At the beginning of 2020, the world was shaken by the problem of the Covid-19 pandemic, which was viral enough to directly impact the economic sector that hit the world as a whole (Ibn-Mohammed et al., 2021; Olivia et al., 2020). The world economy in 2020 experienced a decline that led to income problems and layoffs everywhere, resulting in difficulties for economic recovering. Governments impose a lockdown, large social scale restriction (LSSR), working from home (WFH), etc., to encounter the spread of the virus (Hidayatullah et al., 2020; Muhyiddin, M., & Nugroho, 2021; Purnama & Susanna, 2020). This government measurement hit tourism sectors and immediately led to other business and industrial sectors such as manufacturing and agriculture, especially SMEs (Pratama et al., 2021; Priyono et al., 2020). According to Abbasi et al. (2021), the decline in SMEs' performance is because of the inability of management to measure, evaluate, and manage changes due to the COVID-19 outbreak, causing waiting times or production delays.

The COVID-19 pandemic has brought sustainability issues to the forefront, as discussed by Cho et al. (2021), who examine both the positive and negative environmental impacts of the pandemic, as well as a reevaluation of accounting's role in addressing environmental challenges. During this period, businesses have been forced to prioritize survival from an economic standpoint, which may result in the neglect of the environmental and social impacts of their operations. This is in contrast to Elkington's (1998) assertion that businesses should balance the 'triple bottom line'—people, planet, and profit—ensuring that their strategies are sustainable and socially responsible while remaining economically viable. The government sees the environmental crisis and COVID-19 are seen as two different sides. The environmental crisis is seen as a slow impact, while COVID-19 is a fast impact. This perspective influence the government's point of view in the response process. According to Tregidga & Laine (2021), seeing the COVID-19 and environmental crisis in two different ways could be risky in the long run. Cho et al. argue that this COVID-19 originated from the destruction of the wild animal's environmental habitats in Wuhan, which further mutated and transmitted to humans. Therefore, government measurement of COVID-19 should not be separated between short-term and long-term policies.

Cho et al. (2021) argue that the current accounting and accountability mechanisms used in economic stimulus programs are tied to the government's policy short-term response to the COVID-19 crisis and inadequate to achieve long-term social and environmental challenges. SMEs need government assistance, both financial aid and regulatory aid. In fact, according to scholars, the lockdown policy has a positive impact on the environment. When factories, flights, and various air pollution activities are closed, expected to have a positive result to reduce air pollution (Li et al., 2020; Saadat et al., 2020; S. Sharma et al., 2020; Zambrano-Monserrate et al., 2020). However, it is just a "tiny blip" of reducing the greenhouse gases in the air. The United Nations (UN) World Meteorological Organization (WMO) report found that the heating gas chart exceeded the previous record caused by lockdown due to COVID-19. Thus, clear government policies on the environment, social issues, and business continuity are needed. This way, we can successfully balance social welfare, environmental protection, and economic gain.

This global pandemic creates profound awareness of environmental problems. Environmental concerns also arise from various impulses from outside the company, including government, consumers, stakeholders, and competitors (Bendell, 2022; Kahupi et al., 2021). To follow up on these various impulses, it is necessary to create a proactive approach to minimizing the environmental impacts. The result of the proactive environmental management action is creating a better company environmental performance (Ahmed et al., 2021; Aslam et al., 2021; Phan & Baird, 2015). For instance, foreign investors often raise concerns about sourcing raw materials and managing production processes in ways that prevent environmental issues like land degradation, ecosystem disruption, water, air, and noise pollution. They seek to ensure their investments are secure and yield returns, both in the short and long term. For long-term investments, they closely monitor the company's stability and ongoing viability, particularly regarding environmental and social impacts (Gärling & Jansson, 2021). Sharma (2019) suggest that environmental conservation efforts by companies will bring several benefits, including the interest of shareholders in company profits due to responsible environmental management to create a good company image to the community. Other results indicate that good environmental management can avoid community and government claims and improve product quality, which can increase economic benefits (Huseno, 2018; Wilson et al., 2018).

Small businesses face significant challenges in keeping up with changes in the business landscape. Specifically, in this dissertation, we explore solutions to these challenges from an accounting viewpoint. This necessitates the use of a management tool that integrates an environmental information system and the related costs of managing these aspects. One effective tool for helping businesses address environmental concerns is Environmental Management Accounting, widely referred to as EMA (Burrit & Saka, 2006; Latan et al., 2018; Nguyen, 2018; Wachira & Wang'ombe, 2019). According to Lee (2011), EMA has to solve waste treatment problems by helping business entities manage environmental costs, as the main objective is to identify costs arising from environmental issues to control, transfer, and influence these costs (Jalaludin et al., 2011; Karvonen, 2000). EMA must immediately transform all conservative conceptual accounting frameworks focusing only on objects, events, and financial or financial transactions in the accounting process that caused the accounting information to be produced and presented as misleading (Jamil et al., 2015). The conceptual framework of EMA is in line with Green Accounting or Sustainability Accounting (Cairns, 2000). The Green Accounting Process is intended to integrate financial, social, and environmental objects, also transactions in an integrated and systematic manner to produce complete, relevant, reliable, and comparable accounting information for the users. SMEs need to implement EMA as a system that can help manage the environment due to pressure from stakeholders both from the community or government, who demand that SMEs care more about the environment. Lee (2011) elucidates the role of EMA in addressing waste treatment challenges, emphasizing its utility in managing the environmental costs incurred by business entities. Environmental costs, as delineated in subsection 2.5, encompass the financial ramifications associated with a company's environmental activities. This includes direct costs related to production processes and indirect costs stemming from environmental damage and the subsequent need for remediation. The primary aim of implementing EMA, as identified by Karvonen (2000), is to systematically identify costs associated with environmental issues. This identification serves three critical functions: controlling these costs, transferring the financial burden appropriately, and influencing corporate behavior towards more sustainable practices.

The future of the organization/business sustainability depends on whether or not the organization provides welfare to the community. The organization runs its operations, where the company is in running a business must pay attention to the norms that apply in society. In accounting perspective, EMA and sustainability can be analyzed from Agency Theory and Institutional Theory; Legitimacy theory and Signaling theory also from Contingency theory (Alewine & Stone, 2013; Brown & Deegan, 1998; Deegan, 2002b; DiMaggio & Powell, 1983; Efferin & Hartono, 2015; Fama & Jensen, 1983; Jensen & Meckling, 1976; Morris, 1987; Neysi et al., 2012; Stentoft et al., 2020; Tiwari & Khan, 2020).

A push is needed to apply environmental management accounting to SME business entities to be more effective, encouraging organizations to take environmental management actions (Neag & Maşca, 2012; Wachira & Wang'ombe, 2019). In addition, the implementation of industry 4.0 technology can lead to increased production levels without compromising the environment. These are factors that have been found to impact business entities based on prior research (Zandi & Lee, 2019) include: customer influence, regulatory pressure and firm's moral and social responsibility. However, there is almost no attention from related parties to the factors that encourage EMA application to SMEs, even though SMEs play an important role in the Indonesian economy (Meiryani et al., 2019; Müller, 2019). This research is adapting from previous research with different locations. Previous studies have shown different results. Zandi & Lee (2019) found that regulatory pressure factors were the dominant factor influencing EMA's adoption, especially concerning laws regulating pollution (Zandi & Lee, 2019). Dunk (2007) states that customer demand and public pressure are important factors that influence the application of environmental management to maintain product quality in terms of environmental and economic perspectives (Dunk, 2007). Jamil et al., (Jamil et al., 2015) argue that of all the factors considered to influence the application of EMA, normative pressure has a significant relationship to the application of EMA. Previous researchers argue about factors related on environmental management accounting in Indonesia are environmental management system, organizational performance, corporate environmental performance is influenced by environmental strategy, perceived environmental uncertainty, top management's commitment, green intellectual capital, energy efficiency (eco efficiency), competitive advantage (Fuzi et al., 2019; Latan et al., 2018; Sidik et al., 2019). These factor can be induce to the factors influence on environmental performance in SMEs as planning for environmental improvement; customer & supplier involvement; human resources focus; process and environmental management; and leadership (Hussey & Eagan, 2007).

The advancement in management accounting, particularly concerning sustainability, aligns with the progression of the industrial revolution. This revolution initiated significant changes in technological developments and production processes within economic activities.

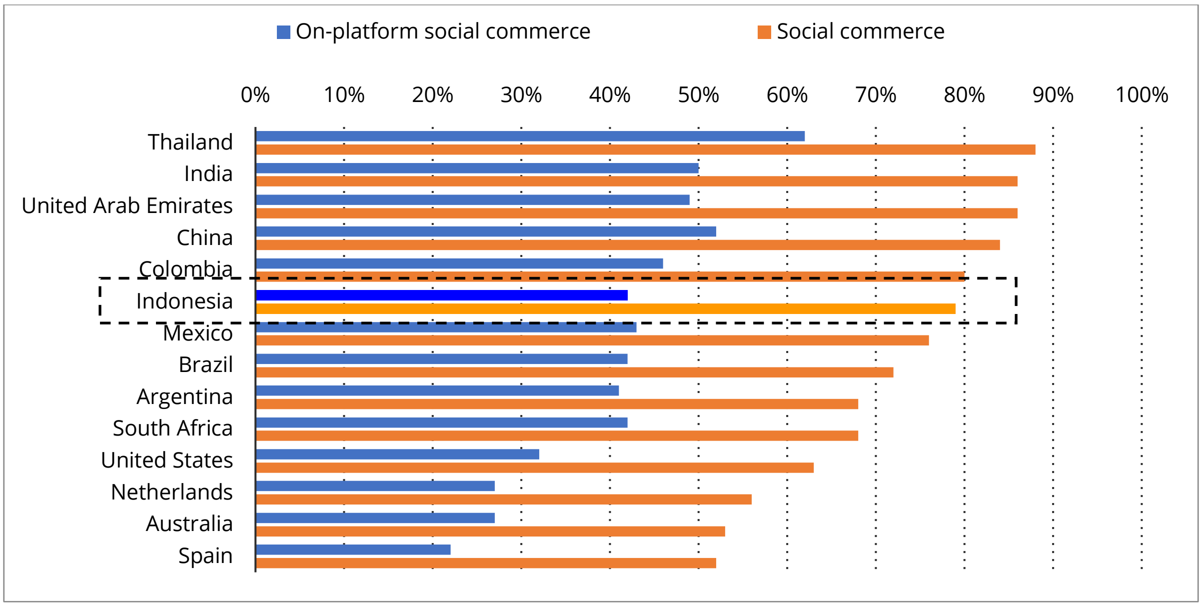
The way people interact with their work and community environments has evolved due to changes in life and work processes. The industrial era 4.0 has an impact on the mechanization and production processes, which are more controlled and monitored by an artificial intelligence (AI) application in the form of a computer algorithm as a form of Cyber-Physical Systems (Tiwari & Khan, 2020). The industrial revolution 4.0 is more perceived as a more straightforward and more effective process using AI. Furthermore, Industry 4.0 is characterized by the emergence of supercomputers, genetic engineering, nanotechnology, automobiles, auto industries, and other innovations (Romanovs, 2017). The concept of Industry 4.0 is sometimes known by various names, such as Smart Factories, Industrial Internet of Things (IIoT), Smart Industry, or Advanced Manufacturing. While differing, these terms encapsulate the core principles of the fourth industrial revolution, highlighting the integration of digital technologies, automation, and cyber-physical systems in the manufacturing process. In some prior research, Industry 4.0 has been referred to as digital transformation (Müller et al., 2020).

The Industrial Revolution has changed the paradigm shift that initially cantered on the fact that humans as vital elements of the economy are slowly shifting to be replaced by technology's digitalization as an economic driver (J. Nagy et al., 2018). For example, in Hungary, the transportation and delivery sector has led to the digitization of applications such as Volt, Netpincér, and online taxis. The trading sector is developing online buying and selling digitalization such as Árukereső and other online shops. Many online shops and online transportation companies have their payment system independent from the bank's smart payment in Indonesia, for example, GoJek. This company is an online transportation company, delivery, and other home services such as online massage, house cleaning, etc. This company has an online payment called GoPay, that can be used as electronic money for any payment and financial transaction. Many more areas are affected by the Industry 4.0 revolution, making all transactions or economic events dash, effectively, and efficiently. The rapid changes in the computerized system like this will impact the political, economic, and governmental conditions of a country.

The model of adoption challenge and benefits of industry 4.0 on SMEs by using TAM model are company size, manufacturing complexity, and attitude towards industry 4.0 (Masood & Sonntag, 2020). The increasing number of online-based business applications and financial transactions that require no meeting between sellers and buyers has resulted in the financial industry has to transform into a financial technology-based business or better known as Fintech (Financial Technology) (Batunanggar, 2019; Hsueh & Kuo, 2017; Suryono et al., 2019). Fintech forces the disruption of innovation in the financial sector that provides technology to provide financial facilities independently outside of conventional financial institutions. Financial services such as financing and fundraising can be provided by an application service created by anyone due to financial innovation in the industrial 4.0 (Gupta & Xia, 2018).

The 4.0 industrial revolution in the financial sector, especially the Fintech industry, has brought about job adjustments and financial transactions (Hsueh & Kuo, 2017; Kharisma, 2020; Koesworo et al., 2019). The emergence of the online industry in the current era causes financial transactions to no longer to require cash (Albert et al., 2020; C. C. Chang & Lai, 2003; Fan et al., 2013; Zhang et al., 2017). It can still be replaced with digital money such as PayPal, SmartPay, and other virtual accounts (González, 2004; Irwin et al., 2012). Accounting as a scientific field concerning the process of financial recording to financial reporting must follow scientific developments in the current 4.0 industrial revolution. Information technology and Big Data analysis are scientific studies that must be mastered and adjusted by the accounting profession (Akhter & Sultana, 2018). Therefore, Industry 4.0 technologies, such as predictive analytics and cloud manufacturing, can enhance sustainability accounting and reporting. However, while there is potential for enhanced sustainability reporting, it also advises caution due to such technologies' complexities and adoption challenges (Tiwari & Khan, 2020). This insight signals a shift towards integrating advanced technologies in accounting.

Figure 1. **Percentage of Online Consumers Buying**
Data from social networks in selected countries worldwide in 2022



Source: Statista, 2023

In the digital landscape of 2022, a notable trend emerges concerning online consumer behavior and the growth of digital advertising markets. Focusing on Indonesia's digital and economic landscape reveals significant strides in both areas. Figure 1 above indicating the percentage of online consumers making purchases via social networks positions Indonesia at an impressive 6th rank globally. This highlights the country's strong digital consumer base, reflecting a considerable penchant for online shopping. In terms of economic performance, Indonesia stands out in the G20, ranking fourth in GDP growth for the second quarter of 2023, and advancing to third place, trailing only behind India and China. This remarkable growth can be attributed in part to strategic policy shifts by the Indonesian government. A key example is the prohibition on exporting raw materials like nickel ore, with a focus on exporting value-added goods instead. This approach has yielded substantial results, particularly in the nickel-based product sector, where exports surged from 1 billion USD in 2013 to a staggering $20.9 billion in 2021. President Jokowi's optimistic projections see these policies driving Indonesia's GDP to $3 trillion by 2030. Indonesia is poised to achieve a balanced growth trajectory by aligning its burgeoning production and manufacturing sectors with the principles of environmental and social responsibility. This approach is encapsulated in the '3Ps' concept, which emphasizes a harmonious balance among people, planet, and profit. Such a holistic strategy is crucial for Indonesia to sustain its growth momentum while ensuring long-term sustainability and social well-being.

The data from Statista and IQAir paints a contrasting picture of Indonesia's air quality and environmental challenges. In Western Indonesia, particularly in urban areas like Jakarta, air quality is significantly compromised due to pollution. Conversely, Eastern Indonesia is known for its clean, fresh air. This contrast is underscored by forest coverage data: as of 2020, Indonesia had 92 million hectares of forest, ranking it 8th worldwide. However, a concerning aspect is the loss of 230 hectares of forest in 2022, which places Indonesia as the fourth highest in terms of net forest area lost globally that year. Geopolitical factors further complicate the environmental challenges in Indonesia. Many of the polluting companies in Western Indonesia are owned by foreign entities. Tightening environmental regulations could lead the Indonesian Government into international legal disputes, risking substantial compensation claims. In response to these challenges, one strategic move under consideration is the relocation of the capital from its current location in Western Indonesia to the Eastern region. This shift emphasizes the urgency for strong environmental policies. As Indonesia contemplates this significant move, the implementation of stringent and effective environmental regulations becomes increasingly critical. This strategy aims not only to address the immediate air quality issues but also to ensure long-term environmental sustainability in both regions of the country.

The integration of long-term environmental sustainability with Industry 4.0 presents both significant challenges and unique opportunities for conventional business processes, especially for small and medium-sized enterprises (SMEs). While these advancements may threaten traditional business models, they also offer substantial opportunities for job creation and innovation within SMEs (Tuegeh et al., 2021; Vasin et al., 2018). The emergence of the 4.0 revolution era will change the work pattern of the business world. Innovations in Industry 4.0 will increase the production process's complexity at the micro and macro levels (C. L. Chen, 2020). Small and medium-sized enterprises (SMEs), in particular, grapple with the uncertainty surrounding the substantial investment costs associated with acquiring new technologies and the overall impact on their business models. A number of studies and interviews with businesspeople from various companies have revealed that many companies have significant difficulties comprehending the entire notion and concept of Industry 4.0 (Schumacher et al., 2016). On the one hand, they are unable to link it to their specific domain and business strategy. On the other hand, they experience difficulties determining their readiness concerning the Industry 4.0 vision and therefore fail to establish concrete strategies, action plans, programs, and projects (Schumacher et al., 2016). For SMEs, embracing Industry 4.0 presents a formidable set of challenges. These challenges vary from financial constraints, such as a lack of capital, to deficiencies in managerial and operational skills, which are crucial for effective organization and marketing. Furthermore, the adoption of advanced computer technology, which is central to leveraging Industry 4.0, often does not take precedence in these businesses due to its perceived high cost and complexity. A significant barrier to SMEs in implementing Industry 4.0 technologies lies in the skillset of their workforce, which frequently lacks the necessary qualifications for operating such advanced systems. This skills gap hinders SMEs' ability to explore new product areas and production techniques, compounded by the high investment risks and costs associated with these technologies. To navigate these obstacles, SMEs are in dire need of targeted training programs that can equip them with the knowledge and tools required to harness the potential of Industry 4.0, thereby optimizing their production processes and enhancing their competitive edge in the market (Baron & Armstrong, 2008; Deegan, 2002a; Moeuf et al., 2018; M. N. A. Rahman et al., 2011).

A defining feature of Industry 4.0 is the emergence of disruptive technologies, which evolve at an unprecedented pace. These advancements not only pose a significant challenge to established industry giants by reshaping competitive dynamics but also redefine the traditional notion of company scale. In the era of Industry 4.0, the size of a company becomes less indicative of its competitive advantage or market power. Instead, agility, innovation, and the ability to swiftly adapt to technological changes determine a company's success, irrespective of its physical scale (Akhter & Sultana, 2018). This condition is the right opportunity for small businesses to achieve business opportunities in the Industry 4.0 era. During these conditions, the presence of the industrial revolution 4.0 is both a hope and a challenge for the development of the agricultural sector going forward. This expectation arises when the industrial revolution 4.0 is able to increase the productivity of the small business in the utilization of natural resources effectively and efficiently in terms of time and cost with the advancement of existing technology. On the other hand, the lack of skilled workers with information and technology expertise is one of its own challenges (Müller, Kiel, et al., 2018).

SMEs play a crucial role in Indonesia's economy, significantly contributing through their extensive number of companies and employment opportunities (Tumiwa & Nagy, 2021; Tumiwa & Tuegeh, 2019). In the current era of globalization, SMEs are demanded to be able to compete in marketing their business. Empowerment of SMEs becomes very strategic because of its high potential in driving economic activity, and at the same time, being a source of income for most people in improving their welfare (Karadag, 2016). SMEs are required to make changes to improve their competitiveness (Man et al., 2002). According to the Head of the Department of MSME Development at Bank Indonesia (BI) Yunita Resmi Sari, currently, the condition of MSMEs in Indonesia dominates business units by 99.9% from the total business 57.89 million. Other contributions of MSMEs are to the employment of 96.9%, gross domestic product (GDP) 57.56%, and exports 15.68%. However, behind the rapid growth of MSMEs, Indonesia is currently faced with facts about the environmental damage caused by business activities carried out by MSMEs, especially for Manufacturing SMEs. Even the Indonesian Central Bank (2020), in its final report on the study states that SMEs are one of the contributors to environmental damage. Environmental problems carried out by business entities in Indonesia indicate weak environmental management and low levels of environmental performance, as well as low interest by entities in environmental conservation (pelakubisnis, 2019). Despite the environmental problem, the issue of Industrial Revolution 4.0, the geopolitical issue, and current Covid-19 has been arisen, becoming a new challenge to utilize and, at the same time, to preserve the natural resource (Bonacini et al., 2021; Djalante et al., 2020; Han et al., 2020; Laborde et al., 2020; Olivia et al., 2020; Tisdell, 2020).

In addition, the small business sector in Indonesia is still far behind in utilizing the use of information technology. The main weaknesses are the lack of quality human resources and inadequate network infrastructure (Tuegeh et al., 2021). In the era of industry 4.0, the company's maturity is not seen from the company size but the aspect of mastery and use of information technology inside the organization or company (Müller, Buliga, et al., 2018). Companies that are agile in applying information technology will emerge as winners in business competition. This is because they will have access to a broader, faster, more organized, and unbiased range of data for analysis. Such data makes it easier for leaders and/or company owners to directly monitor SWOT aspects (Strengths, Weaknesses, Opportunities, and Threats), enabling them to delegate and make quick, accurate decisions in all business activities.

Therefore, SMEs need to invest in IT infrastructure/business digitalization and human resources. This investment is crucial for capitalizing on opportunities and addressing potential threats. Conventional accounting cannot predict whether the investment in human resources will produce commensurate profits in the future because human resources are intangible assets as investments in new technology. The new technologies in the industrial revolution can connect and transform industrial units from one industrial unit to another through the fast availability of information by data processing, analysis, and fulfillment of activities carried out by software (C. L. Chen, 2020; Dressler & Paunovic, 2021). Industry 4.0 introduces transformative benefits to the business landscape that align closely with the principles of Environmental Management Accounting (EMA), particularly for SMEs. These benefits include enhanced data quality and credibility, increased transparency through digital and real-time data analytics, and a reduction in greenwashing and brownwashing. Such advancements support EMA practices by enabling more accurate and timely environmental cost tracking and sustainability reporting, thereby facilitating better environmental decision-making and performance improvement within SMEs (R. L. Burritt et al., 2019; Carey, 2015; Müller, 2019).

In addition, many businesses are finding that they can offset the environmental costs they generate by selling waste as a product. Businesses can control environmental costs by implementing appropriate environmental cost accounting treatment for SMEs. Thus, there is no shortage or excess budget in waste management activities (Datsii et al., 2021; Meidiana & Gamse, 2010; Viswanathan & Telukdarie, 2021). This EMA management tool will create added value for the business (Hutman falih Chichan et al., 2021; Mayndarto & Murwaningsari, 2021). It manages the surrounding environment and society to get legitimacy from the community where the business operates (Scagnelli et al., 2013). Under the legitimacy theory, environmental disclosure through annual financial reports is an attempt to communicate the responsibility for the environment that the business has carried out to gain legitimacy from the community to guarantee the company's survival (Bonsón et al., 2020; Cho & Patten, 2007; Deegan, 2002a; Scagnelli et al., 2013). Legitimacy theory states that public practice must be carried out so that the company's activities and achievements can be accepted by the community. Small businesses tend to use environmental performance-based and environmental information moreover to operate using local community resources, and the market should make disclosures to justify their activities for public responsibility. Thus, SMEs' investment in human resources and new technology can be denied.

In the contemporary business landscape, marked by rapid technological advancements and heightened environmental consciousness, small and medium-sized enterprises (SMEs) face a complex array of challenges and opportunities. The intersection of economic principles, environmental sustainability, and the advent of Industry 4.0 technologies necessitates a nuanced understanding of how these factors coalesce to impact business practices.

Therefore, we conduct a table summarizing how this dissertation addresses the identified research gaps, as shown in Table 1. It compiles key insights from recent studies, pinpointing the current lacunae in our collective knowledge and application. Specifically, the table foregrounds the pivotal role of Environmental Management Accounting (EMA), the adoption of Industry 4.0 technologies, and the criticality of sustainability reporting as mechanisms to boost financial performance while fulfilling the increasing expectations of stakeholders.

Table 1. **Research Gap**
Empirical and Theoretical

No	Previous Findings	Research Gaps	Addressing the Gaps
1	Violation of economic, accounting, and opportunity cost principles leading to environmental damage.	Lack of comprehensive strategies integrating economic, environmental, and social sustainability.	Implementing Environmental Management Accounting (EMA) and adapting to Green Accounting principles.
2	Geopolitics and pass global pandemic direct impact on the economy and businesses, especially SMEs.	Insufficient attention to the environmental impact of pandemic response measures.	Balancing economic recovery with environmental sustainability, leveraging lockdowns to reduce pollution.
3	Rapid technological advancements in Industry 4.0 affecting business processes and SMEs.	SMEs facing challenges in adapting to new technologies and environmental sustainability requirements.	Training and investment in IT infrastructure for SMEs, focusing on environmental sustainability in the Industry 4.0 era.

No	Previous Findings	Research Gaps	Addressing the Gaps
4	The emergence of Industry 4.0 technologies transforming business operations and management.	Difficulty in quantifying the impact of Industry 4.0 on financial performance and sustainability.	Developing a new PLS-SEM model to analyze the relationships between Industry 4.0 technology adoption, EMA practices, financial performance, and sustainability reporting in SMEs.
5	Growing awareness and demand for environmental sustainability in business practices.	Lack of effective tools and models for SMEs to integrate sustainability into their business strategies.	Utilizing EMA as a strategic tool for SMEs to align their operations with environmental sustainability goals.
6	Increasing role of digital finance and fintech in the business sector.	Need for SMEs to adapt to digital financial technologies while maintaining sustainability.	Encouraging SMEs to adopt fintech solutions that support sustainable business practices and reporting.
7	The importance of environmental disclosure for legitimacy and stakeholder trust.	SMEs struggle with transparent and effective environmental reporting.	Implementing comprehensive sustainability reporting frameworks that enhance transparency and stakeholder trust.

Sources: Author archives data processing, 2022.

1.1. Research Questions

In this section, we try to reveal the intricacies of integrating Environmental Management Accounting (EMA) and Industry 4.0 technologies within Small and Medium-sized Enterprises (SMEs) to achieve sustainability, particularly in the wake of economic challenges posed by economic recovery due to the past global pandemic and the geopolitical issue. Therefore, to investigate how these elements synergistically influence financial performance, environmental responsibility, and overall sustainability, we focus on how to develop or identify a conceptual model for SMEs that integrates EMA and Industry 4.0 technologies along with other pertinent factors, providing a structured framework to improve sustainability. Moreover, it involves a confirmatory analysis to identify key determinants of sustainability within the SME context, encompassing both internal and external elements. We also pertain to employing Partial Least Squares Structural Equation Modeling (PLS-SEM) to quantitatively assess the impact of EMA and Industry 4.0 technologies on SME sustainability, aiming to empirically demonstrate the relationship between these variables and their collective influence on sustainability outcomes in SMEs. Therefore, in a connection with analysis, we formulate the research objectives as follows:

1. How do SMEs utilize Industry 4.0 technologies to achieve sustainability? Specifically, what specific technologies are employed, and what impact do they have on sustainable practices, as examined through descriptive analysis?
2. What conceptual model can SMEs utilize to achieve sustainability? How can various constructs, based on prior research and integrated using the literature review method, contribute to this model?
3. How does the proposed conceptual model, developed to enable SMEs to achieve sustainability, perform when tested using statistical methods, specifically Partial Least Squares Structural Equation Modeling (PLS-SEM)?

1.2. Research Objectives

The research objectives of this study are to unravel the complexities involved in integrating Environmental Management Accounting (EMA) and Industry 4.0 technologies within Small and Medium-sized Enterprises (SMEs) for achieving sustainability. The objectives include:

1. To investigate the utilization of Industry 4.0 technologies by SMEs to achieve sustainability, examining the specific technologies employed and their impact on sustainable practices using descriptive analysis.
2. To develop a conceptual model that SMEs can utilize to achieve sustainability, focusing on integrating various constructs based on prior research using the literature review method.
3. To test the conceptual model using statistical methods using PLS-SEM, with further details of this objective described through the following sub-objectives:
   (1). To analyze the direct relationship of Environmental Management Accounting on Financial Performance and Sustainability Reporting in SMEs.
   (2). To examine the indirect relationship of EMA on Sustainability Reporting within SMEs.
   (3). To investigate the direct relationship of Industry 4.0 technologies on Environmental Management Accounting, Financial Performance, and Sustainability Reporting in SMEs.

(4). To analyze the indirect relationships between Industry 4.0 technologies and Financial Performance and Sustainability Reporting mediated by Environmental Management Accounting and Financial Performance.

(5). To assess the direct relationship between Financial Performance and Sustainability Reporting in the context of SMEs.

1.3. Research Approach and Structure of the Dissertation

In this dissertation, we adopt a structured approach to explore the integration of Environmental Management Accounting (EMA) and Industry 4.0 technologies in Small and Medium-sized Enterprises (SMEs) for achieving financial performance and sustainability. The structure of this dissertation is designed to methodically address the research questions and objectives, ensuring a comprehensive understanding of the topic.

The introduction section sets the stage for the dissertation, providing an overview of the key concepts such as EMA, Industry 4.0, financial performance, and sustainability reports in SMEs. It presents the specific research questions that guide the study and outlines the research's objectives, aligning with these questions. This section also includes an explanation of the overall structure and approach of the dissertation, offering a roadmap for what follows.

Following the introduction, the literature review brings into various theories relevant to the study, including agency, legitimacy, and institutional, and how they apply to EMA, Industry 4.0, Financial Performance, and sustainability in SMEs. This section also includes a detailed review of Environmental Management Accounting and the latest advancements in Industry 4.0, investigating their implications for SMEs. The relationship between sustainability practices and financial performance, the importance of sustainability reporting, and the formulation of hypotheses based on the literature review are also explored.

The 'Materials and Methods' section of the dissertation delineates the research methodology employed, systematically outlining the steps undertaken during the study. This section clarifies the dissertation's scope, articulates the criteria for selecting the study's population and sample, and details the operational definitions and measurement techniques for the variables under investigation. Furthermore, it explicates the data analysis methodologies adopted, with a particular emphasis on the use of Partial Least Squares Structural Equation Modeling (PLS-SEM) for data interpretation.

In the research findings and evaluations section, we present the basic descriptive statistics of the data and detail the findings from the PLS-SEM analysis. This section also includes a discussion of the implications of the results concerning the existing literature and explores the practical and theoretical implications of the research.

The dissertation concludes with a summary of the key findings and provides recommendations based on the research. It also highlights any novel findings that emerged from the research and provides a concise summary of the entire dissertation.

The appendices of the dissertation include a comprehensive list of all sources cited, detailed lists of tables, figures, and publications for easy reference, and any supplementary material relevant to the research. We have structured this dissertation to ensure a logical flow, guiding the reader through the complexities of integrating Environmental Management Accounting (EMA) and Industry 4.0 technologies in Small and Medium-sized Enterprises (SMEs) for sustainability. Each section builds upon the previous one, leading to a comprehensive understanding of the subject matter.

1.4. Research Hypothesis

In this section, we present our hypotheses that encapsulate the complex relationships between the adoption of Environmental Management Accounting (EMA), the emergence of Industry 4.0, and how they impact Financial Performance and Sustainability Reporting, based on the research background, research gap, and objectives. We organized and grouped the hypotheses as follows:

Hypothesis 1: Direct Relationship of Environmental Management Accounting (EMA)

Hypothesis 1 consist of two hypotheses to capture the relationship between EMA and other construct in this dissertation. The grouped hypotheses as follows:

$H_{1.1}$: EMA has positive relationship on FP.

$H_{1.2}$: EMA has positive relationship on SR.

The integration of Environmental Management Accounting (EMA) within organizational practices is posited to exert a positive influence on both Financial Performance (FP) and Sustainability Reporting (SR). Hypotheses $H_{1.1}$ and $H_{1.2}$ suggest that EMA, as a strategic tool, enhances an organization's financial outcomes and its commitment to sustainable practices. This is predicated on the notion that EMA's focus on environmental costs and savings leads to more efficient resource use and operational improvements, thereby improving FP. Concurrently, EMA's role in identifying and communicating environmental impacts bolsters the quality and scope of SR, reflecting an organization's sustainability achievements and challenges.

Hypothesis 2: EMA has indirect positive relationship on SR

Hypothesis H_2 introduces the concept of an indirect pathway, proposing that EMA enhances SR through its positive impact on FP. This hypothesis underscores the interconnected nature of financial and environmental performance, suggesting that financial gains from EMA practices enable and motivate further investments in sustainability initiatives, subsequently enriching the content and credibility of SR. This mediated relationship highlights the strategic value of integrating financial and environmental objectives.

Hypothesis 3: Direct Relationship of Industry 4.0 on Key Performance Indicators

Hypothesis 3 is divided into three separate hypotheses that intend to describe how Industry 4.0 relates to other concepts addressed in this dissertation. The three hypotheses are grouped as follows:

$H_{3.1}$: Industry 4.0 has a positive relationship on EMA.

$H_{3.2}$: Industry 4.0 has a positive relationship on FP.

$H_{3.3}$: Industry 4.0 has a positive relationship on SR.

The advent of Industry 4.0 technologies is posited to have a direct positive relationship with EMA, FP, and SR (Hypotheses 2.1 to 2.3). The rationale behind this group of hypotheses lies in the transformative potential of Industry 4.0, which can enhance operational efficiencies, reduce environmental impact, and improve financial outcomes through automation, data analytics, and interconnected systems. Moreover, these technologies can provide accurate and timely data, facilitating better environmental management accounting practices and more comprehensive sustainability reporting.

Hypothesis 4: Indirect Relationship of Industry 4.0 through EMA and FP

Hypothesis 4 is segmented into four distinct propositions that aim to delineate the relationship of Industry 4.0 with the other constructs discussed in this dissertation. These propositions are organized into the following group:

$H_{4.1}$: Industry 4.0 has an indirect positive relationship with Financial Performance through EMA.

$H_{4.2}$: Industry 4.0 has an indirect positive relationship with Sustainability Report through EMA.

$H_{4.3}$: Industry 4.0 has an indirect positive relationship with Sustainability Report through Financial Performance.

$H_{4.4}$: Industry 4.0 has an indirect positive relationship with Sustainability Report through EMA and Financial Performance.

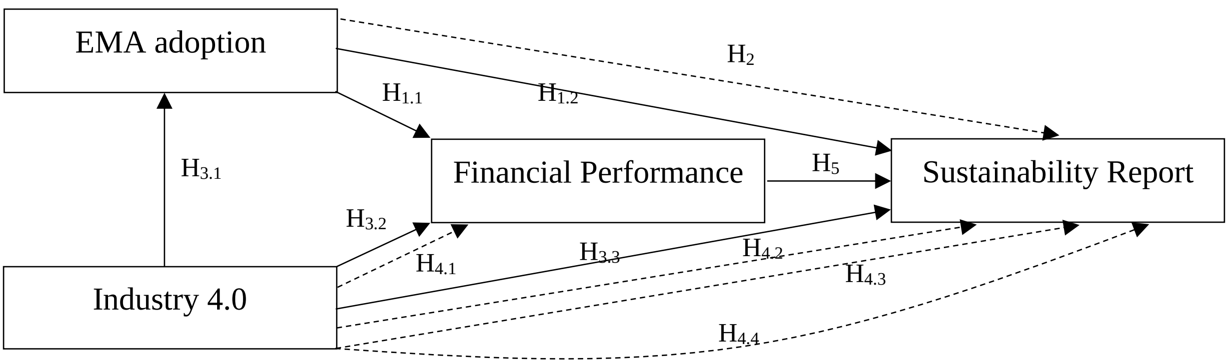
Hypotheses 4.1 to 4.4 explore the nuanced pathways through which Industry 4.0 may indirectly influence FP and SR, mediated by EMA and potentially FP itself. These hypotheses acknowledge the complex interplay between technological adoption, environmental accounting, financial performance, and sustainability reporting. For instance, Industry 4.0's facilitation of better EMA practices could lead to improved FP, which in turn could enhance SR. Similarly, the integration of EMA and FP as mediating factors offers a deeper understanding of how Industry 4.0 can drive sustainability outcomes beyond direct impacts.

Hypothesis 5 : Direct Relationship between Financial Performance and Sustainability Reporting

Hypothesis 5 suggests a direct positive relationship between FP and SR, which points to the critical link between economic and sustainable performance. The premise is that financially robust companies are better positioned to invest in sustainable practices, which are then reflected in their sustainability reporting. This relationship underscores the symbiotic nature of financial health and sustainable development, suggesting that improvements in one area can directly benefit the other.

All the hypotheses relationship are further explain in the figure 2 below:

Figure 2. **Research Model**
Conceptual Framework of EMA Adoption, Industry 4.0, Financial Performance, and Sustainability Reporting in SMEs



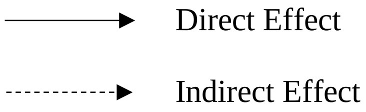


Figure 2 shows that EMA adoption is posited as a strategic organizational move towards enhancing environmental responsibility and economic efficiency. Its direct impact on Financial Performance is based on the premise that systematic accounting for environmental costs leads to more informed decision-making, resulting in cost savings and improved profitability. The influence of EMA on Sustainability Reporting is also expected to be positive, reflecting the belief that a detailed understanding of environmental costs and benefits can lead to more transparent and comprehensive reports on an organization's sustainability practices.

Industry 4.0 is introduced as a transformative force, enabling higher operational efficiency and data-driven decision-making. Its implementation is theorized to have a direct positive effect on EMA adoption, providing the tools and data necessary for more accurate and comprehensive environmental accounting. Furthermore, Industry 4.0's potential to optimize production processes and reduce waste is believed to enhance Financial Performance directly. Its impact on Sustainability Reporting could be indirect, mediated through improvements in EMA and Financial Performance. Through the lens of this framework, Industry 4.0 emerges as a catalyst for advancing both the economic and environmental performance of organizations, subsequently influencing the quality and substance of sustainability reports.

2. LITERATURE REVIEW

In this dissertation, we utilize a hybrid approach for the literature review. Rather than strictly adhering to a systematic literature review process, we have tailored our approach to specifically filter articles related to Environmental Management Accounting (EMA), Industry 4.0, Financial Performance, and Sustainability in Small and Medium-sized Enterprises (SMEs). This approach is designed to ensure rigor and replicability, thereby upholding the validity of our research. We applied methodologies and techniques in our articles filtering method, including specific keyword combinations, search syntax, and coding processes.

This chapter stems from the grand theories of agency, legitimacy, and institutional theory, exploring their applicability to adopting EMA, integrating Industry 4.0 technologies, and impacting financial performance and sustainability in SMEs.

2.1. Agency Theory

Agency theory, a cornerstone in economics and organizational studies, offers a vital perspective for understanding the variables in this dissertation. This theory primarily explores the relationship between principals (like shareholders or owners) and agents (such as managers or executives), focusing on resolving conflicts of interest and aligning their goals. It originates from the agency theory, as articulated by Jensen and Meckling (1976), which describes the relationship between principals (owners) and agents (managers) in the context of the separation of ownership, control, and risk-bearing in companies. According to Morris (1987), an agency relationship arises when principals delegate responsibilities for work and decision-making to agents. However, this delegation often leads to a conflict of interest, as managers may have personal goals that do not align with the shareholders' aim of maximizing welfare, a central tenet of agency theory.

Agency theory in EMA addresses aligning the incentives of principals (owners) and agents (managers) to mitigate problems such as moral hazard and adverse selection. Lambert (2001) notes that this includes addressing information aggregation for compensation and valuation purposes. Eisenhardt (1989) adds that agency theory provides insights into outcome uncertainty, incentives, and risk, emphasizing its empirical validity when combined with complementary perspectives. The interaction of monitoring and incentive alignment to control agency costs, suggesting a substitutive relationship between the two for mitigating weaknesses (Martin et al., 2019). Importantly, Cordeiro and Sarkis (2008) argue that top management compensation should be explicitly linked to environmental performance, thereby aligning management incentives with environmental goals.

Agency theory also plays an important role in EMA. It reduces the information gap between agents and principals, such as reconciling predictions of different agency-based theories in EMA (Umanath et al., 1996). Morris (1987) points out the consistency between signaling and agency theories, emphasizing favorable monitoring costs implied by agency theory. Leung & Ilsever (2013) further suggest that corporate governance mechanisms such as IFRS adoption can aid in controlling information asymmetry within EMA frameworks.

Agency theory also emphasizes the risk management in EMA includes considerations for managing environmental and business risks, such as in understanding outcome uncertainty, incentives, and risk management, especially considering the environmental influences on organizations (Christopher, 2010; Eisenhardt, 1989). Hoskisson et al. (2017) state that agency theory presupposes the need for compensating or monitoring top managers to manage risks in decision-making. Sundin & Brown (2017) underscore the importance of integrating environmental issues into management control systems, which aligns agents' interests with environmental risk management.

Agency theory often highlights the conflict between agents' short-term objectives and principals' long-term sustainability goals. This tension is particularly evident in funding decisions within theater organizations (Loots, 2019). Agents, often in managerial roles, may prioritize their immediate interests, potentially misusing company resources and diverging from the interests of shareholders (Alim & Destriana, 2019). This misalignment poses a challenge to the principals' long-term sustainability objectives. However, introducing intelligent agents offers a potential solution (Moloi & Marwala, 2020). These intelligent agents can facilitate the resolution of conflicts by providing insightful information enhancing the updateability and connectivity of decision-making processes. Incorporating sustainability metrics into corporate performance evaluations is another strategy to align agents with the company's longer-term sustainability goals. By doing so, agents are encouraged to adopt a perspective that extends beyond immediate gains and aligns with the broader sustainability objectives of the organization.

When integrated with stakeholder theory, agency theory broadens its focus to include the significance of multiple stakeholders, encompassing environmental and societal impacts beyond traditional shareholder-centric perspectives. This integration is seen as a synthesis of ethics and economics within the agency theory framework (T. M. Jones, 1995). Shankman (1999) further elaborates that agency theory can be subsumed under a general stakeholder model of the firm, encompassing a broader range of impacts, including environmental and societal considerations. The interplay between agency and stakeholder theories significantly influences the relationship between board structure and firm performance. This relationship considers financial and social performance (Bachiller et al., 2015). An integrated paradigm of agency and stakeholder theories provides insights into various aspects of a firm's strategic behavior, including management-stakeholder contracts and institutional structures (Hill & Jones, 1992). Moreover, Mamun, Yasser, & Rahman (2013) argue that combining theories such as agency theory and stakeholder theory offers a more comprehensive approach in describing effective corporate governance. This integrated approach is essential for addressing both the economic objectives of shareholders and the broader ethical responsibilities towards other stakeholders, thus promoting more holistic and sustainable corporate governance practices.

2.2. Legitimacy Theory

Legitimacy theory completes the agency theory that has been described previously. The idea of legitimacy is a discovery in modern thought, well represented in Rousseau's (1762) premise in the Social Contract, which shows how political authority can be called legitimate. However, this theory is based on the biblical and has been discussed further by Odgers (1916). The idea of legitimacy was further developed by Weber (1947) in the perspective of a modern theory which states that there is an assumption that legitimacy must have a relationship with authoritative, legal, feeling, binding, or truth characteristics attached to an order, government, or state. Weber's theory's earliest formulation occurs in the second part of *Wirtschaft und Gesellschaft* was completed before 1914 but not published because of the outbreak of the war. After that, many researchers discussed Max Weber's research in the following years (Beetham, 1991; Matheson, 1987; Schmidhauser et al., 1973; Wolin, 1981). Furthermore, the legitimacy is explained as the organization that runs its operations, where the company is in running a business must pay attention to the norms that apply in society (Brown & Deegan, 1998; Deegan, 2002a). They must take action socially responsible is supported by disclosure, publishing, and reporting in company annual report (Magness, 2006).

Now, research on legitimacy theory based on an accounting perspective has been directed to the issue of sustainability (Al-Abrrow et al., 2022; Cho & Patten, 2007; Suddaby & Greenwood, 2005). Legitimacy is an important factor for companies to develop the company in the future as matters relating to business ethics, attention and development of employee performance, the impact on the company's environment contributes to increasing legitimacy (Blanco-González et al., 2021). Thus, the company or business entity should concern toward social and environment protection then shown through environmental disclosures (Bonsón et al., 2020). The process of legitimacy theory moves towards an understanding of the organization or business entity that is seen as a legitimate authority (Jansen et al., 2018). Organizations seek to ensure that they operate within the boundaries and norms of society where each activity is considered legitimate (Toinpre et al., 2018). Boundaries and norms are not static, thus requiring organizations to be responsive, relying on the notion of a social contract.

Based on the classical legitimacy theory that based on a social contract between the company and the community (Stentoft et al., 2020) and it's relation to Stakeholder theory and Signaling theory to intellectual capital disclosure (Neysi et al., 2012), conclude that the future of the organization depends on whether or not the organization provides welfare to the community (Van Oers et al., 2018). The greater manager's ownership makes the manager think more the interests and welfare of shareholders. Its performance is more productive for a sustainability company and shareholder welfare that managers will provide relevant information for wider stakeholders. Management that owns company shares will certainly align its interests with interests as shareholders so that the greater the ownership managers within the company, company managers will increasingly reveal social information (Bergfeld et al., 2021; Parés et al., 2015). Fama and Jensen (1983) found that if managerial ownership in a company is high then management tends to do sustainability disclosures. This concept is related to SMEs because most of the owner are the manager.

2.3. Institutional Theory

The institutional theory explains an organization's formation because of the pressure from the institutional environment that causes institutionalization. According to Rothenberg (2007), business organizations exist in two environments: the technical environment and the institutional environment. The technical environment is an environment where the transaction process takes place, in which the goods and services produced are exchanged for rewards received by the organization. The institutional environment is an environment in which the organization must obey various rules, such as social and cultural rules. In return, the organization will gain legitimacy and continuance. The two environments need to stay in harmony to avoid conflict. Thus, an organization needs to adapt to the isomorphic, which is the adaptation process carried out by an organization to its institutional environment (Efferin & Hartono, 2015). The suitability between the organization and the environment will determine the legitimacy and survival of the organization. DiMaggio and Powell (1983) stated that types of isomorphs include coercive, mimetic, and normative pressure. This theory is needed because an organization tendentious will not adopt EMA, especially when the benefits derived from adopting EMA are not visible (DiMaggio & Powell, 1983).

Institutional pressures, particularly those of a coercive nature, play a significant role in the adoption of Environmental Management Accounting (EMA) in manufacturing companies (Yassin & Ali, 2020). The development of EMA is not only influenced by direct regulatory pressures but also by a combination of normative and cognitive institutions. These include social environmental movements, professional structures, and environmental mimicry, all of which are integral components of Institutional Theory (Qian & Burritt, 2008).

The framework for adopting EMA integrates business actors with EMA tools, promoting their adoption. This concept aligns with Agency Theory, which focuses on the relationships and behaviors among different organizational actors (R. L. Burritt et al., 2002). In the context of small and medium enterprises (SMEs), coercion is identified as a dominant factor in practicing EMA. This observation is consistent with the coercive aspect of Institutional Theory, suggesting that external pressures and mandates are key drivers in the adoption of EMA (Jamil et al., 2015).

Institutional isomorphism, encompassing coercive, normative, and mimetic pressures, plays a crucial role in the adoption of Environmental Management Accounting (EMA) across various industries and regions. This phenomenon illustrates the extensive impact of institutional forces in shaping environmental accounting practices globally. Coercive isomorphism, often propelled by government regulations, is a significant factor in the adoption and implementation of EMA practices. Research has demonstrated that this form of isomorphism, particularly from governmental bodies, is a predominant influence on EMA practice among firms different regions (Iredele et al., 2020).

In connection with institutional isomorphism, normative and mimetic pressures are integral parts of isomorphism that substantially affect EMA adoption. These pressures, along with factors such as education, training, political forces, and legitimacy, have been identified as critical in the adoption of EMA practices (Chathurangani & Madhusanka, 2019). Another influential form of isomorphism is self-regulatory normative isomorphism, which significantly impacts sustainable manufacturing practices, including EMA. Studies by Shubham, Charan, & Murty (2018) suggest that internal standards and industry norms can drive EMA practices within organizations. In the developing countries, coercive isomorphism has been found to significantly influence the implementation of EMA practices in non-financial listed firms, highlighting the role of external pressures in shaping environmental accounting practices (Asiri et al., 2020). Furthermore, the influence of institutional isomorphism on EMA adoption is not solely external; it is also shaped by internal organizational factors such as diversity, risk aversion, and relative performance (1998).

2.4. Industry 4.0

2.4.1. Industry 4.0 Definition

The development and research stages carried out by several experts gave rise to diverse perceptions about the meaning of Industry 4.0. The industrial revolution is a comprehensive amalgamation of aspects of information technology and the internet on all aspects of production in an industry. The industrial revolution was able to connect and transform industrial units from one industrial unit to another through the fast availability of information by (C. L. Chen, 2020; Dressler & Paunovic, 2021). Industry 4.0, also known as the fourth industrial revolution, represents a new era in industrial development, characterized by a variety of definitions and perspectives. It signifies a strategic shift in industrial evolution, moving from machine-dominant manufacturing to a digital manufacturing landscape where technologies such as robots, 3D printing, and implanted technologies play a pivotal role (Schumacher et al., 2019). This revolution is not just about technological advancements; it encompasses the integration of diverse processes like production, logistics, and personnel management with smart objects, aiming to enhance the value chain and create innovative business models (Egor, 2020).

At its core, Industry 4.0 is a new level of organization and management of production systems, driven by automation, data exchange, cyber-physical systems, the Internet of Things (IoT), and cloud computing. This revolution brings about disruptive changes in production organization and value creation, compelling companies to innovate their processes and business models for improved efficiency, sustainability, customization, and flexibility in manufacturing (Savastano et al., 2019).

Digital transformation within Industry 4.0 involves moving to digital business models by using digital technologies to modify business processes, thereby opening new avenues for development and revenue generation (Savytska & Salabai, 2021). It's a phenomenon that merges the real and virtual worlds, revolutionizing industries through platform-based cooperation and dual innovation strategies, while also incorporating sustainability to an extent (Beier et al., 2020; Kagermann, 2015).

The digitization involved in Industry 4.0 transforms business models, production systems, machines, operators, products, and services, enabling real-time engagement and altering the manufacturing environment with enabling technologies and systems (Alcácer &

Cruz-Machado, 2019). For the manufacturing sector, these technologies bring about enhancements in productivity, asset performance, reduced inefficiencies, lower production and maintenance costs, and increased system agility and flexibility (Butt, 2020). The integration of processes shortens production cycles, speeds up delivery times, and facilitates the faster market introduction of new, feature-enhanced products (Egor, 2020).

Industry 4.0 also incorporates sustainability functions like economic production efficiency, business model innovation, energy sustainability, emission reduction, and social welfare improvement (Ghobakhloo, 2020). However, for Small and Medium-sized Enterprises (SMEs), undergoing this digital transformation successfully often requires external support in digitalization, operations technology readiness, and change management capabilities (Ghobakhloo & Iranmanesh, 2021).

Connecting machinery and digital twins to capture and analyze data across manufacturing stages reduces downtime and maintenance costs, a key aspect of Industry 4.0 (DallaOra et al., 2022). This revolution emphasizes the importance of digital transformation for organizations, promoting digital change and capabilities (Ulusoy, 2020). Known as the Industrial Internet of Things, it challenges existing business models of industrial manufacturers, necessitating the development of adequate strategies for digital transformation (Müller et al., 2020). It presents an opportunity to align sustainable development goals with the ongoing digital transformation in industrial development (Beier et al., 2020).

Despite the various perspectives on Industry 4.0, it's important to note the lack of a universally agreed-upon definition, leading to ambiguities and confusion about its exact scope and characteristics (Culot et al., 2020). Data processing, analysis, and fulfillment of activities are carried out by software. Portals, e-signature tools, document managers, workflow tools, and client-server blogs are examples of automation in the data processing. Since 2015 for the audit process, KPMG has used McLaren Applied Technologies (MAT) in analyzing unstructured data. Deloitte uses Kira for its consulting division. People are starting to use mobile accounting to get real-time data. Financial Process Automation (FPA) usage for payments, issuing invoices, and checking excel (Pokharkar, 2019). Since 2013 the Securities & Exchange Commission (SEC) has used "RoboCop" as an audit and securities analysis tool; PwC has used RON. Artificial Intelligence (e.g. Alex, Cortana, Siri) which can classify accounts and report taxes.

On the other hand, Industry 4.0 brings positive changes to the accounting environment, including better data quality, higher data credibility, transparency, and digital real-time data and will benefits on SME (R. L. Burritt et al., 2019; Carey, 2015; Müller, 2019). However, according to Nagy, Oláh, Erdei, Máté, & Popp (2018), several factors are obstructing factors for the development of Industry 4.0.

In the context of Small and Medium Enterprises (SMEs), Industry 4.0 technologies present a scalable and adaptable opportunity to enhance the authenticity and reliability of environmental and social claims, thereby reducing the incidences of greenwashing and brownwashing (R. Burritt & Christ, 2016; Vergara & Agudo, 2021; Yang et al., 2021). Greenwashing is the practice where companies make misleading or unsubstantiated claims about the environmental benefits of their products, services, or practices, often to appeal to eco-conscious consumers and stakeholders. Brownwashing, on the other hand, refers to the deceptive portrayal of a company's social responsibility efforts, where claims regarding social initiatives or ethical practices are exaggerated or falsely represented to enhance a company's image.

For SMEs, the journey towards integrating Industry 4.0 technologies might seem daunting due to perceived resource constraints and technical complexities. However, these technologies offer modular and flexible solutions that can be tailored to specific needs and capacities, allowing SMEs to embark on digital transformation at their own pace (Masood & Sonntag, 2020; Yusuf et al., 2022). For example, simple IoT devices can monitor energy usage or waste generation, providing data to support genuine environmental claims. Similarly, basic AI tools can analyze operational data to identify areas for improvement in social practices or environmental impact, ensuring that SMEs' claims are grounded in data.

The potential of Industry 4.0 to reduce greenwashing and brownwashing in SMEs hinges on the democratization of technology and the development of accessible, user-friendly tools tailored to the needs of smaller businesses. By embracing even basic components of Industry 4.0, SMEs can take significant strides towards transparent, accountable, and verifiable reporting of their environmental and social practices. This not only helps in building trust with consumers, investors, and partners but also positions SMEs as responsible actors in the global market, capable of making genuine contributions to sustainable development.

As SMEs increasingly adopt these technologies, the collective impact on reducing greenwashing and brownwashing can be substantial, fostering a more transparent and sustainable business ecosystem. However, achieving this requires support from technology providers, policymakers, and industry associations to ensure that SMEs have access to affordable, scalable solutions and the knowledge to implement them effectively. Furthermore, establishing clear guidelines and standards for environmental and social reporting can aid

SMEs in utilizing Industry 4.0 technologies to convey their sustainability efforts accurately and reliably.

In several previous research, readiness measurement and maturity measurement are often considered as one thing and can replace one another (Maasouman & Demirli, 2015; Ngai et al., 2008; Schumacher et al., 2016; Stentoft et al., 2020). However, in this study, the researcher took an approach by distinguishing between readiness measurement and maturity measurement.

2.4.2. Industry 4.0 Measurement

The progression of Industry 4.0 and digital transformation relies on interconnected indicators such as technology adoption rate, data quality, and digital maturity. Each of these plays a crucial role in shaping industries in the new digital era. A successful approach to managing Industry 4.0 and digital transformation involves a mix of traditional management practices like lean and agile methodologies, digital platforms for collaboration, strategic human resource management, and a focus on safety culture and high-performance management. These elements are essential for effectively navigating the complexities of digital transformation and integrating new technologies into existing business models.

The technology adoption rate is vital in the evolution of Industry 4.0 and digital transformation. Enhanced productivity and reliability are seen in sectors like aeronautics due to the adoption of Industry 4.0, creating reconfigurable and sustainable spaces (Ruiz et al., 2021). However, barriers like low digital literacy and unawareness of technology potential can hinder adoption (Pereira et al., 2021). Different sectors, including ICT services, finance, and manufacturing, vary in their adoption rates, with technologies like cloud and big data being more widely adopted than AI (G. Lee et al., 2022). Adopting Industry 4.0 technologies can improve operational performance and supply chain competency despite barriers (Chauhan et al., 2021).

Data quality significantly impacts Industry 4.0 and digital transformation initiatives. Uninterrupted service and real-time streaming are ensured by dataspace connectors, which provide secured data usage (Gan et al., 2021). Digital tools enhance product and service quality, while digital shadow cloud-based applications improve quality control (Bilad et al., 2022; Santolamazza et al., 2020). In connection with digital transformation initiatives, the Digital maturity is fundamental in transitioning to Industry 4.0, guiding companies in utilizing advancements in information and communication technology. Assessing current capabilities and developing a strategy for further development is part of achieving digital maturity (Dikhanbayeva et al., 2020).

FPA plays a significant role in Industry 4.0 by enhancing financial operations and strategies (Pokharkar, 2019). It aids in credit risk management, financial data analytics, and digital finance, streamlining operations (Bisht et al., 2022). FPA contributes to the automation and digitalization of production processes, transforming conventional centralized applications (Shyriaieva & Adamkevych, 2021). However, it also creates new threats to financial and economic security, necessitating a security-oriented strategic management approach (Zachosova et al., 2022). Thus, employee digital skills are crucial in adapting to Industry 4.0, affecting recruitment practices and necessitating continuous improvement and new knowledge acquisition (Bolek et al., 2021). The new digital skill requirements require reskilling current employees and redesigning work processes (Karacay, 2018).

In managing Industry 4.0, lean management tools are integral, contributing to the quality and reliability of products and services (Sanders et al., 2017). Digital platforms revolutionize purchasing and buyer-supplier relationship management, enabling enhanced performance management (Ocicka, 2021). Human resource management prepares the workforce for changes, with effective people management practices showing a strong correlation with productivity and innovation (Llinas & Abad, 2020). Implementing a preventive and participatory safety culture is essential, especially in SMEs, to overcome barriers like fear among employees (Digmayer & Jakobs, 2019). Agile methodologies are crucial in Industry 4.0 projects, aligning the transformation process with the dynamic nature of digital technologies (Yanık & Işıklı, 2019).

2.5. Environmental Management Accounting (EMA) Adoption

2.5.1. EMA Definition

The application of EMA has evolved significantly since its early days in the late 1980s. The definition of Environmental Management Accounting (EMA) put forward by the International Federation of Accountants (2005) is as follows:

> "Identification, collection, analysis, and use of two types of information for internal decision making: (1) physical information on the use, flows, and decision of energy, water, and materials (including wastes) and (2) monetary information on environment-related cost, earnings, and savings."

Physical information is information about the inputs used in the production process in the form of materials, water, and energy as well as information about the outputs produced in the form of products and non-products (waste and emissions). Input and output information is closely related to environmental control, while monetary information is cost information related to inputs and outputs issued by companies to minimize environmental impacts. Physical information is needed by management to determine the level of the environmental impact that is generated so that it can be controlled. Information such as the level of gas emissions produced, the amount of waste generated, and the amount of waste treated is important for determining targets for reducing emissions, waste, and others. Environmental cost information is useful for management in order to control costs to achieve efficiency (Jamil et al., 2015; Zou et al., 2019).

EMA is a specialized form of accounting that focuses on tracking and analyzing both financial and environmental information. It aims to help businesses understand the cost of their environmental impact and find ways to improve both their financial and environmental performance (Mbedzi et al., 2020). Example: such as waste management costs, material costs for environmental purposes, and potential savings from environmental initiatives. EMA looks at things like the cost of using resources (like water and energy) (Yusoh & Mat, 2020), the expenses related to waste management (Mbedzi et al., 2020), and the savings that can come from more eco-friendly practices (Burrit & Saka, 2006). It is a tool mainly used internally by companies to make better decisions that are good for both income and the planet. Conventional Accounting, on the other hand, sticks to the financial side of things. It is all about recording, summarizing, and reporting a company's financial transactions (Reeve et al., 2009). The main goal here is to provide a clear financial picture of the company to its stakeholders, like investors and regulatory agencies. This type of accounting does not typically factor in the environmental costs or benefits directly unless they have a clear financial impact. In essence, while EMA integrates environmental information with financial accounting to help businesses make more sustainable decisions, Conventional Accounting focuses solely on the financial aspect, tracking and reporting on the economic health of a business. EMA is about looking at the bigger picture and considering how financial decisions impact the environment, whereas conventional accounting keeps its eyes on the financial stability and performance of the company.

The EMA has been developed to overcome the limitations of traditional management accounting. EMA helps managerial activities and decisions involving environmental issues such as environmental costs and their impacts. These Environmental costs refer to the financial impacts associated with a company's environmental activities, including both direct costs tied to the production processes and indirect costs related to environmental damage and remediation. These costs can be quantified and managed through EMA, which helps businesses make more informed decisions regarding their environmental and economic performance. The following are some examples of environmental costs:

- Direct Costs:
    - Pollution Control: Costs for installing and operating pollution control equipment like scrubbers, filters, and wastewater treatment plants.
    - Waste Management: Expenses related to the collection, treatment, and disposal of waste products, including hazardous waste.
    - Resource Consumption: Costs of raw materials that are consumed or transformed due to environmental measures, such as water, energy, and other natural resources.
- Indirect Costs:
    - Environmental Remediation: Costs incurred for the cleanup of contaminated land, water, or air, and for restoring natural habitats affected by the company's operations.
    - Regulatory Compliance: Expenses associated with ensuring that operations meet environmental regulations and standards, including monitoring, reporting, and management systems.
    - Opportunity Costs: Lost revenue opportunities from not utilizing resources more efficiently or from choosing environmentally friendly operations that might have a higher upfront cost but lower long-term costs.
- Contingent Costs:
    - Fines and Penalties: Financial penalties imposed for non-compliance with environmental laws and regulations.
    - Liability Costs: Potential costs associated with future claims for damages caused by the company's environmental impact, such as health problems or property damage.
- Less Tangible Costs:
    - Reputational Damage: Decrease in consumer trust and brand value due to negative environmental impacts or practices, potentially leading to loss of sales.
    - Employee Morale and Health: Costs related to health issues of employees due to poor environmental practices or low morale from working in a company with a negative environmental impact.

- EMA helps organizations identify, assess, and manage these costs more effectively, enabling them to reduce waste, improve environmental performance, and ultimately achieve cost savings through more sustainable practices.

(Jasch, 2003, 2006a; Rasit et al., 2022b)

In internal decision-making procedures, conventional management accounting practices may not provide adequate environmental costs. This traditional accounting occurs as a result of failure to disclose some environmental costs (Fuzi et al., 2019; Latan et al., 2018; Wachira & Wang'ombe, 2019). Classification of costs functionally (direct costs, direct labor costs, and overhead costs) causes environmental costs to tend to be included and hidden in overhead costs. Thus, it is difficult to find and control them. Therefore, companies need to adopt EMA by establishing a new management and environmental cost accounting system.

EMA is a multifaceted concept that integrates environmental considerations into traditional management accounting. Broadly defined, EMA involves identifying, collecting, estimating, analyzing, and utilizing material and energy flow information for decision-making within organizations. The following is the phase of EMA according to the prior research:

- Identifying: The identification phase in EMA focuses on pinpointing the environmental aspects of organizational operations that have significant impacts. This involves recognizing the materials and energy inputs, along with the waste and emissions outputs, across the entire lifecycle of a product or service. The goal is to identify areas where environmental improvements can lead to financial savings or performance benefits. This step is crucial for setting the baseline from which improvements can be measured.
- Collecting: Once the key environmental aspects have been identified, the next step is to gather data on material and energy usage. This involves detailed tracking of the quantities and costs associated with these inputs and outputs. The collection of this data requires a systematic approach, often involving the integration of environmental data collection into existing accounting and operational processes. This step ensures that there is reliable information to analyze and act upon.
- Estimating: In many cases, precise data may not be readily available or may be too costly to obtain. Here, EMA employs estimating techniques to fill in gaps in data, allowing for a more complete picture of environmental impacts and costs. This can include estimations based on standard industry practices, previous organizational data,

or calculated assumptions. These estimates allow organizations to make informed decisions even in the face of data uncertainty.

- Analyzing: The analysis stage involves making sense of the collected and estimated data to identify opportunities for environmental and economic improvements. This can include cost-benefit analysis, life cycle costing, and the assessment of potential savings from reduced material and energy usage or waste generation. The analysis aims to highlight areas where investments in environmental performance can lead to cost savings, risk reduction, or even new market opportunities.
- Utilizing: Finally, the information gleaned from EMA is utilized to inform strategic and operational decisions. This can involve implementing process changes to reduce waste and improve efficiency, investing in cleaner technologies, or redesigning products to minimize environmental impacts. The utilization of EMA information can also extend to external communications, such as environmental reporting and green marketing, helping to enhance the organization's reputation and comply with regulatory requirements.

(R. L. Burritt et al., 2002; Jasch, 2003, 2006b; Schaltegger et al., 2008)

EMA is a combined approach that integrates data from financial accounting, cost accounting, and mass balances. This integration is crucial for increasing material efficiency, reducing environmental impacts, and managing environmental protection costs (Jasch, 2006b). EMA functions as a framework for assessing corporate environmental costs and material flows, guiding organizations in managing their environmental impacts and associated costs effectively (Jasch, 2006a). It is vital to note that the principle of sustainability in EMA is not solely about addressing social and environmental concerns but also includes the economic or income sustainability aspect. EMA focuses on this economic dimension as a crucial element of sustainable development, highlighting the financial aspect of environmental decision-making (Abou Taleb et al., 2015).

Perceived as a broader concept of accounting, EMA aids internal management decision-making on environmental issues within companies, emphasizing the impact of these decisions on company performance. Doorasamy (2015) highlights EMA's role in strategic environmental management, pointing out its significance in influencing company performance positively. EMA supports company-internal management decision-making on environmental issues and their impact on company performance. This broader concept of accounting uses tools and practices to facilitate informed decision-making. EMA involves the generation, analysis, and use of financial and non-financial information. Bennett, Rikhardsson, &

Schaltegger (2005) expand on this by defining EMA as the generation, analysis, and use of financial and non-financial information to optimize corporate environmental and economic performance to achieve sustainable business. This process is crucial for optimizing corporate environmental and economic performance, thereby contributing to sustainable business practices. This definition also relates to the idea that technological development can provide significant advantages and support businesses adopting EMA.

EMA's versatility is also evident in its application across different sectors. For instance, EMA is used as a multi-level analysis tool in the agricultural sector. It assesses the overall contribution of a system to its environment at various levels, such as whole-farm, dairy-system, and herd levels (Vigne et al., 2013). This adaptability of EMA across different levels and sectors underscores its effectiveness as a comprehensive tool for environmental and economic analysis, aiding organizations in achieving sustainable outcomes.

2.5.2. EMA Adoption Measurement

Environmental Management Accounting provides essential benefits for companies to provide complete information for decision making. This information reveals hidden opportunities, such as better waste management processes, reduced energy consumption, or opportunities to recycle. This information is also used to gain more efficient processes that lead to innovation; actual environmental information to develop better internal control systems; and lead to better decision making (Burrit & Saka, 2006; R. L. Burritt et al., 2019; Ferreira et al., 2010).

IFAC (2005) divides the three uses and benefits of EMA. First, **compliance**, where EMA is useful to support environmental protection through compliance with environmental regulations and internal environmental policymaking. This policy can be done by planning and implementing investments that control pollution, replace toxic materials, and report the resulting waste and emissions to regulators. Second, **eco-efficiency**, where the benefits provided are in the form of simultaneous support for reducing costs and environmental impacts through the more efficient use of energy, water, and materials in the company's operations and products. This is done by tracking the flow of energy, water, materials, and waste accurately, planning and implementing efficient energy, water, and materials, and determining the annual return on investment from eco-efficiency activities. Third, the **strategic position**, where the benefits are in the form of support in the evaluation and implementation of environmentally friendly and cost-effective programs to ensure the company's strategic position in the long term. This can be done by working with suppliers to design products and services for the green market, assessing the internal costs of regulations that may arise in the future, and reporting to stakeholders such as customers, investors, and local communities (Vasile & Man, 2012).

The concept of EMA is utilized on both the national and corporate levels (Meiryani et al., 2019). On the SMEs level, the factors that influence non-financial performance measurement are a coercive factor, compliance factor, and mimetic factor (Jamil et al., 2015; Jasch, 2015; Karvonen, 2000; Latif et al., 2020; Mohamed & Jamil, 2020; Muhammad-Jamil & Mohamed, 2017; Saeidi et al., 2018; A. Susanto & Meiryani, 2019). According to previous research applying environmental management accounting to be more effective requires several forces that encourage an organization to take environmental management actions (Asiri et al., 2020; R. L. Burritt et al., 2019; Hussain & Gunasekaran, 2002; Jalaludin et al., 2011; Jamil et al., 2015; Johnstone, 2020; Latif et al., 2020). These factors include:

Coercive is a form of invitation coercion or threats to implement EMA. Coercive pressure reflects regulatory aspects in enforcing a rule in a particular institution and is an essential determinant of organizational structure and function. A force from regulation drives organizations to change their practices to be consistent with the institutional mandate. Some of the items that fall under coercive factors such as laws regulating pollution, government pollution standards, government regulations, organizational shareholders, media (newspapers and tv), environmental regulations, communities, customers, environmental groups, corporate headquarters, financial institutions, and labor unions.

Normative is a form of behavior that adheres to the prevailing norms or conditions. Normative pressure comes primarily from professionalization, which can occur either through formal education or the creation of professional associations. Two aspects of professionalization are the main drivers for change in organizational practice and professional behavior. This means that the rules or norms in society encourage organizations to care about the environment by implementing EMA. The indicator of normative factors, such as motivation from staff training and membership of accounting bodies. Normative also depend on Human capital that also can be viewed as company assets.

The Human Capital concept focuses on investing in human resources which brings added value to the organization (Baron & Armstrong, 2008). The intended value added is added value in the form of new ideas or perspectives that the organization has never thought or done before. Creativity will then transform into innovations that are useful for increasing the productivity of the organization, leads to entrepreneurship orientation.

The Human Capital concept also emphasizes the importance of human resources in organizations as active assets or current assets (Baron & Armstrong, 2008). Human resources cannot be treated as treating machines in the industry. Human resources should be active in determining their work in the organization. The leadership should be able to facilitate the needs and aspirations of workers, especially those related to the progress of the organization. Workers must be active describe ideas and commitments and good performance to the leadership.

So far, mathematical calculations or human resource accounting cannot predict whether investment in human resources will produce commensurate profits in the future. This is because human resources are intangible assets. The output produced by human resources according to the human capital approach is adding value in the form of ideas, ideas, and creativity. Challenge or even the task of managing human resources in the organization to identify human resources in organizations that have the potential to generate innovation in the organization. Creative human resources can help companies in sustainability report disclosures without making the company suffer a decrease in regular income (D’Amato et al., 2009). The presence of quality human resources in the managerial process of the company can be a good intermediary for the relationship between the company's internal and external companies along with successful of corporate social responsibility.

Mimetic is a form of imitation of something. Organizations tend to copy or imitate each other as well as other institutions in society. Suppose a practice has a value that is recognized or is believed to be the new industry standard. In that case, the organization can imitate rather than question the importance of this practice. It can be thought of as a mimetic process that results from standard responses to environmental uncertainty. In this case, it means that the organization is encouraged to implement EMA because it imitates other organizations that have already implemented EMA. The indicators of mimetic factors such as competitors, other industrial organizations, other industry leaders, and multinational organizations.

2.6. SME Financial Performance

2.6.1. SME Financial Performance Definition

Financial performance is a key indicator of a firm's financial health over a specific period. It can be defined and measured in various ways, each highlighting a different aspect of financial health. For instance, measures like profitability gauge returns, while others, such as sales growth and market share growth, assess a firm's growth. There are measures for profitability (like return on investment and return on equity), liquidity (such as quick ratio and current ratio), and solvency (like gearing). Some measures indicate commercial success (like growth and market share), while others reflect financial success (like profitability). It is important to recognize that different firms have diverse financial goals, so a single indicator may not accurately measure success as perceived by the firm.

Financial performance also is defined as a multifaceted concept that assesses a business's creditworthiness, profitability, and overall success using financial statement data (Miljković et al., 2013). It serves as a measure of an enterprise's efficiency, with profit being the primary indicator of business efficacy and resource recovery (Lopatovskyi & Krasutskyi, 2022). This performance is indicative of how effectively a company utilizes its assets to generate revenue, and it is measured against standards of completeness and costs (Desiyanti & Kassim, 2020). It also encompasses the financial stability of a firm, its health, and its ability to generate revenues and settle debts (Xue et al., 2020).

Financial performance in businesses encompasses both financial aspects, like investment appreciation and company value increase, and socio-economic systems, which include complex networks of internal and external relations (Janošková et al., 2018). Furthermore, the balanced scorecard approach by Kaplan & Norton (2007) includes financial measures alongside operational measures such as customer satisfaction, internal processes, and learning and improvement capabilities, offering a holistic view of business performance.

The discourse on financial performance comprehensively integrates the recognition of Other Comprehensive Income (OCI) alongside its recycling to foster a more nuanced understanding of a company's financial performance (Nishikawa et al., 2016). OCI is pivotal as it encompasses specific gains, losses, and adjustments excluded from the net income presented on the income statement, in alignment with Generally Accepted Accounting Principles (GAAP) or International Financial Reporting Standards (IFRS).

OCI items find their place in a distinct section within the comprehensive income statement, dedicated to showcasing the shifts in a company's equity resultant from non-traditional earnings activities. This nuanced approach to accounting underscores the importance of OCI in offering a holistic view of a company's financial performance and overall condition, extending beyond the sole examination of net income. It accounts for unrealized or deferred items, which play a critical role in delineating the aggregate modifications in equity despite their non-immediate effect on cash flow. Examples of OCI include unrealized Gains and Losses on Available-for-Sale (AFS) Securities, Foreign Currency Translation Adjustments, Gains and Losses on Derivative Instruments in Cash Flow Hedges, and Adjustments for Defined Benefit Pension Plans.

However, it is crucial to emphasize that within the scope of our dissertation, the relevance of OCI to financial performance, while broadly significant, only partially applies to

SMEs in Indonesia, which constitutes our research focus. Indonesian SMEs' financial dynamics and reporting practices diverge from the contexts where the implications of OCI are most pronounced. Thus, while acknowledging OCI's overall importance in financial accounting, our investigation does not establish a direct correlation between OCI practices and the financial performance of SMEs in Indonesia. This distinction is essential for aligning our research objectives with the specific characteristics and regulatory environments influencing Indonesian SMEs.

A comprehensive analysis of financial and economic performance involves formulating business objectives, forming an information basis, analyzing data, and producing a comprehensive rating score (Dudnyk & Lozovska, 2015). The concept of Integrated Company Efficiency has been proposed as a method to measure the comprehensive efficiency of companies operating across various industries (Kogan & Pristavka, 2020). Additionally, corporate carbon performance indicators like carbon intensity, dependency, exposure, and risk provide a systematic view of a company's financial performance in relation to its environmental impact (Hoffmann & Busch, 2008)

Thus, from the financial performance definition, in this dissertation, we define SME Financial Performance to encapsulate overall financial health, efficiency, and success over a certain period, assessed through a variety of metrics. This includes profitability indicators like return on investment, liquidity measures such as current ratios, and solvency metrics like gearing. The concept extends beyond traditional financial measures to include a firm's operational effectiveness, gauged through customer satisfaction, internal processes, and learning and improvement capabilities, as presented in the balanced scorecard approach. Additionally, it involves assessing a firm's creditworthiness and ability to generate revenue and settle debts, while also considering socio-economic impacts and environmental factors like carbon performance indicators. SME Financial Performance thus represents a comprehensive, multi-dimensional evaluation, intertwining financial stability, commercial success, and environmental responsibility, tailored to the unique goals and contexts of small and medium-sized enterprises.

2.6.2. SME Financial Performance Measurement

Revenue development is seen as an indicator of a firm's growth and as a competitive strategy (Baumol, 1967). Baumol argued that many enterprises prioritize growth-related factors such as sales revenue, unit sales, or market share. Similarly, profit maximization leads many firms to focus on the development of profits as an indicator of financial performance. In examining the relationship between financial performance and sustainability, different dynamics are proposed for the relationships between revenues and sustainability and between profit and sustainability (Boutillier, 2020). A firm can differentiate its products by being environmentally sustainable, thereby increasing its revenue. Similarly, by saving costs on resources, regulatory costs, capital, and labor, a firm can increase its profits. The following is the measurement use in this dissertation:

Financial statements are essential for business management, analysis, and stakeholder communication. They evaluate financing, investment, and operational activities, inform management decisions, and provide external parties with insights into profitability and management efficiency (Hasanaj & Kuqi, 2019). For financial statements for SMEs in Indonesia, it is pivotal to integrate a detailed examination of the Indonesian Financial Accounting Standards (SAK – *Standar Akuntansi Keuangan*) (Yanto et al., 2017). SAK represents a comprehensive framework established to guide the recording, reporting, and disclosure of financial transactions and events within Indonesia. The development and publication of SAK are overseen by the Indonesian Financial Accounting Standards Board (DSAK IAI - *Dewan Standar Akuntansi Keuangan IAI*), an integral component of the Indonesian Institute of Accountants (IAI - *Ikatan Akuntansi Indonesia*). Over the years, SAK has undergone significant evolution, propelled by the imperative for credible financial reporting and the aspiration to achieve congruence with international benchmarks like the International Financial Reporting Standards (IFRS).

The Indonesian Financial Accounting Standards Board (DSAK IAI) was established in Jakarta on December 23, 1957. The development of SAK in Indonesia commenced in 1973 with the formation of a committee tasked with compiling materials and structuring the General Accepted Accounting Principles (GAAP) and Generally Accepted Auditing Standards (GAAS). Subsequently, in 1974, the Indonesian Accounting Principles Committee was constituted to draft and enhance the Financial Accounting Standards. This committee was later transformed into the Financial Accounting Standards Committee in 1994.

During the eighth congress on September 23-24, 1998, in Jakarta, the Committee for SAK was renamed to the Financial Accounting Standards Board (DSAK) for the term of 1998-2002, granted special autonomy to formulate and ratify the Indonesian Financial Accounting Standards (PSAK) and Interpretations of Financial Accounting Standards (ISAK) (Narsa et al., 2012). Furthermore, the Sharia Accounting Committee (KAS) and the Financial Accounting Standards Advisory Council (DKSAK) were established, with KAS being initiated on October 18, 2005, to support the development of PSAK related to the accounting treatment of sharia transactions by DSAK.

Given the distinctive requirements and obstacles faced by SMEs, Indonesia has introduced SAK for SME (Narsa et al., 2012; Yanto et al., 2017). This SAK is vary across Indonesia, but the common general used is SAK EMKM (Standar Akuntansi Keuangan Entitas Mikro, Kecil, dan Menengah), a specialized version of SAK designed for SMEs. This framework aims to streamline the more intricate aspects of SAK to align with the operational scale and resources of SMEs, emphasizing the core principles of financial reporting while minimizing compliance complexities.

It is noteworthy that the majority of SMEs in Indonesia do not publicize their financial reports except for tax-related purposes, primarily due to the prevalent inclination among SME owners to circumvent tax obligations. In response, the Indonesian government, through DSAK IAI, has established specific SAK guidelines for SMEs to facilitate more accessible and relevant financial reporting practices for this sector. Summarizing business activities and financial outcomes, these statements ensure accountability and transparency. They detail assets, liabilities, and equity, crucial for assessing a company's financial health and planning future operations. Essentially, they are key to business decision-making and strategic planning.

One factor in measuring SME performance is the **firm/business value**, often referred to as enterprise value, which represents the total value of a company, taking into account its entire market value rather than just its equity value (Afful, 2023; Bolton, 2004; Cowling et al., 2018; Le & Ikram, 2022; Wolff & Pett, 2006). SME financial performance and firm value are influenced by a combination of financial literacy, effective marketing strategies, innovation, firm age, and entrepreneurial experience, financial management practices, and firm reputation. After conducting previous research, there are several reasons why the value of a firm is considered a significant indicator of a business's financial performance:

- **Comprehensive Financial Health Indicator:** Firm value encompasses not only equity but also debt and cash levels. This provides a more holistic view of a company's financial health and performance, as it considers both the sources of funding and liquidity. Unlike market capitalization, which only looks at the equity value, firm value accounts for the company's actual obligations (debt) and its operational liquidity (cash and cash equivalents), offering a fuller picture of its financial standing.
- **Comparability Across Companies:** By incorporating debt and cash into its calculation, firm value allows for a more apples-to-apples comparison among companies with different capital structures. This is particularly useful in industries

where companies may have varying levels of debt financing, enabling analysts and investors to compare companies on a more equal footing.

- **Acquisition Price Indicator:** When considering mergers and acquisitions, firm value is a crucial metric because it essentially represents the cost to acquire the company in its entirety, not just its equity. It provides a clearer picture of what an acquirer would have to pay to take over the company, considering both equity and debt levels minus cash and cash equivalents.
- **Indicates Growth Potential and Efficiency:** A high or increasing firm value can indicate that a company is growing and is efficient in generating revenue from its total pool of resources and liabilities. It reflects not only the current financial performance but also the future earning potential as perceived by the market.
- **Influence of Leverage:** Since firm value includes debt, it reflects the effects of leverage on a company's performance. A company might use debt financing to fuel growth, which could increase its firm value if the market perceives that the debt is used efficiently to generate higher returns. Conversely, a high level of debt might be seen as risky if not managed properly, which could affect the firm value negatively.
- **Cash Position Awareness:** Firm value subtracts cash and cash equivalents, which highlights the company's net obligations and operational efficiency. A company with a strong cash position might have a lower firm value but in a positive context, as it indicates the company has significant liquidity to cover its debts and invest in growth opportunities.

To measure firm value to bridge to SMEs, we tailored the measurement of Firm value based on selling property in Indonesia and from the prior research by Belo et al. (2018), Park and Byun (2022), and (López-Pérez et al. (2017).

Financial ratios are critical in assessing business efficiency and formulating planning and control strategies. Used for analyzing financial performance and management evaluation, these ratios cover liquidity, leverage, asset management, and profitability (Anupama & Kesava Rao, 2019). They forecast future performance and aid in investment planning. Financial ratios are instrumental in predicting business distress and failure, offering insights into a company's financial position and operational efficiency.

Sales turnover is a crucial indicator in business, representing the volume of business generated (Dvouletý et al., 2021). It sheds light on business activity dynamics, development prospects, and the enterprise's sectoral significance. Major expenses are associated with sales turnover, impacting job satisfaction and sales performance (Kato & Tsoka, 2020). Crucial for meeting company objectives, its analysis informs business strategy and operations, including product pricing, promotion, quality control, and customer satisfaction. Factors like advertising, strategic management, and digital marketing strategies influence high sales turnover, a sign of business success (Hossain et al., 2022).

Market expansion for SMEs hinges on factors such as productivity for modest expansion and factors like size, capacity, and business partner relationships for more significant growth (Nugraha et al., 2022). Strategies like entrepreneurial orientation and international networking are vital for SMEs to thrive in foreign markets. Adopting new technologies, customer focus, and market diversification are key (Isaak, 2002; Sahaym et al., 2021). Successful market expansion often results in growth in employment, investment, and sales turnover (Ruslianti & Mulyaningrum, 2020). Cooperative relationships with business partners facilitate market entry, underscoring the importance of partnerships and planning in international ventures. SMEs require access to funding, market information, and a conducive regulatory environment to enhance competitiveness and explore potential (Funabashi, 2013).

Efficient **working capital** management is essential for SMEs' financial performance (Afrifa, 2016). It is linked to profitability, as seen in Malaysian SMEs, where holding inventory, extending trade credit, and prolonging the cash conversion cycle boosted profitability. Easy access to working capital loans, especially from banks, is crucial (Tumiwa & Tuegeh, 2019). Effective working capital management positively impacts SMEs' performance, influencing profitability and growth (Binti Mohamad et al., 2017). The high adoption and significant impact of working capital management practices on financial performance in SMEs demonstrate their importance. Effective management of components like inventory, accounts receivable, and payable is associated with better financial performance in SMEs.

2.7. Sustainability Report

2.7.1. Sustainability Report Definition

Many definitions that consider different aspects or approaches to the field of sustainability have emerged in recent years. However, almost all bibliographic sources identified in the systematic review carried out refer to the concept of the "Triple Bottom Line" as a fundamental principle of sustainability (Elkington, 1998). The concept of sustainability defines companies that create value at the level of strategies and practices to move towards a more sustainable world, with a profitability formula that is carried out by humans, through relationships with all interest groups (stakeholders) and the natural environment, face the challenge of minimizing waste from operations and reorientation their competency portfolio towards sustainable and competitive technology (French, 2008).

Godland (1995) in Moldan et. al, (2012) explain about sustainability is considered as one of the key success factors in a long-term business strategy. Companies must be able to manage the economic, social, and environmental impacts. On the other hand, integrating sustainability into companies provides many benefits, such as a better reputation, transparency and good governance, achieving better economic results, being more attractive to work, less prone to crises, and more attractive to investors. With the application of the concept of sustainability, the company's production can achieve greater quality in commercial offerings, in the quality of labor, ethical responsibility, environmental, social and innovation and manage to reconcile economic development with concern for the social environment and environmental protection (Raharjo, 2019).

SR plays a pivotal role in contemporary business, elucidating an organization's environmental and financial metrics (Biondi et al., 2020). It assesses corporate social responsibility within managerial contexts, bolsters legitimacy, and, through integrated reporting, provides a holistic perspective of organizational performance, and assurance further validates its veracity (Habib, 2023; Miotto et al., 2020). Sustainability encompasses diverse accounting definitions, with this study focusing on the concept through sustainability reporting (SR) (Biondi et al., 2020; Muslichah et al., 2020). Elkington's (1998) framework defines SR as including financial and non-financial details on social and environmental activities fostering sustainable growth. This voluntary report provides economic, environmental, and social information essential for long-term business strategy success (Dvouletý et al., 2021; Ssenyonga, 2021). The integration of sustainability offers multifaceted benefits, enhancing reputation, transparency, governance, economic outcomes, attractiveness to employees, crisis resilience, product quality, ethical responsibility, environmental and social aspects, innovation, and investor appeal (Ascani et al., 2021; Kimanzi & Gamede, 2020; Muslichah et al., 2020; Thuy et al., 2021).

Small businesses are expected to be able to compete in the new high level of global competition to meet the environmental challenges by still earning profits by doing this. Some previous studies explain how small businesses can obtain greater profits, be able to compete in local and international markets, and a high level of business continuity by applying the concept of sustainability and it's relation to accounting and industry 4.0 (R. L. Burritt et al., 2019; Cairns, 2000; Müller, Kiel, et al., 2018; Tiwari & Khan, 2020).

A sustainability report in the context of SMEs typically refers to a document or set of disclosures that outlines the company's impacts on various sustainability aspects, including environmental, social, and governance (ESG) factors (Muslichah et al., 2020). This report provides insights into how the SME is addressing issues related to sustainability, such as reducing environmental footprints, ensuring ethical labor practices, and maintaining transparent governance structures. These reports often encompass a range of topics, including the company's energy use, waste management, social initiatives, employee welfare, community engagement, and ethical business practices (Borga et al., 2009; Kimanzi & Gamede, 2020). The goal of such reporting is to communicate to stakeholders, including customers, employees, investors, and the community, how the SME is contributing to sustainable development and managing its responsibilities towards society and the environment.

ESG reporting focuses on three critical areas: environmental conservation, social responsibility, and governance practices. The environmental component assesses a company's performance and impact on the natural environment, covering issues such as climate change, resource depletion, waste management, and biodiversity. The social dimension examines how a company manages relationships with its employees, suppliers, customers, and communities, touching on human rights, labor standards, community engagement, and customer satisfaction. Governance involves the systems and practices that govern the company, including corporate governance structures, executive pay, audits, internal controls, and shareholder rights.

For SMEs, ESG reporting is increasingly becoming a crucial element of their business strategy, driven by several factors. Firstly, there's a growing recognition that SMEs have a substantial collective impact on environmental and social issues. Secondly, consumers, investors, and regulatory bodies are demanding more transparency and accountability from businesses of all sizes. Lastly, ESG reporting can open up new market opportunities for SMEs, including access to green finance, partnerships with larger corporations seeking sustainable supply chains, and enhanced brand loyalty among socially conscious consumers.

In the domain of sustainability reporting, the connection between Environmental, Social, and Governance (ESG) reporting and the Global Reporting Initiative (GRI) standards, especially in the context of SMEs, is a critical intersection. The work of Permatasari and Kosasih (2021) on proposing tailored GRI guidelines for SMEs represents a significant advancement in making sustainability reporting more accessible and relevant to smaller businesses. This tailored approach not only acknowledges the unique challenges faced by

SMEs but also underlines the importance of inclusive sustainability practices that can be adopted by organizations of all sizes.

To effectively integrate ESG reporting into their operations, SMEs can take several steps:

- **Start Small**: Focus on the most relevant ESG issues to their business and stakeholders, gradually expanding their reporting scope over time.
- **Leverage Technology**: Utilize affordable digital tools and platforms to streamline data collection and reporting processes.
- **Engage Stakeholders**: Involve employees, customers, and suppliers in sustainability initiatives to build a culture of transparency and accountability.
- **Seek Guidance**: Utilize resources from industry associations, sustainability organizations, and government bodies designed to support SMEs in ESG reporting.

(Buallay, 2022; J. Lee & Kim, 2023; Yun & Lee, 2022)

These tailored GRI Guidelines for SMEs give several benefits, including:

1. **Increased Accessibility**: Making the GRI standards more accessible to SMEs ensures that more organizations can participate in sustainability reporting, leading to a broader understanding of the collective impact of SMEs on sustainable development.
2. **Enhanced Relevance**: By focusing on the aspects of sustainability that are most pertinent to SMEs, the tailored guidelines ensure that the reported information is highly relevant to the stakeholders of these enterprises.
3. **Resource Efficiency**: Tailored guidelines help SMEs to allocate their limited resources more efficiently, focusing their efforts on collecting and reporting information that provides the most significant insights into their sustainability performance.
4. **Stakeholder Engagement**: With more SMEs able to report on their sustainability practices, there is an increased opportunity for engaging with stakeholders on sustainability issues, fostering greater transparency and accountability.

(Permatasari & Kosasih, 2021)

Therefore, sustainability reporting for SMEs is typically less formal and less standardized compared to larger corporations, given the smaller scale and resources of SMEs. However, the core principle remains the same: to transparently communicate the company's efforts and performance in terms of sustainability.

2.7.2. Sustainability Report Measurement

Currently, the Global Reporting Initiative (GRI) framework is the preferred method, especially the GRI-G3 guidelines. Mihai and Aleca (2023) have researched leading Romanian organizations, observing their compliance with the GRI's sustainability standards, which aligns with the findings of Thuy et al. (2021). GRI standards are frequently adopted by businesses to focus on aspects of corporate responsibility, expanding the perspective to view sustainability reporting as an integral part of Corporate Social Responsibility (CSR) (Ortiz-Martínez & Marín-Hernández, 2021; Prashar, 2019; Steinhofel et al., 2019).

Companies listed on the SRI-KEHATI index of the Indonesia Stock Exchange demonstrate the highest compliance with GRI Standards, underscoring the significance of principles such as sustainability context, completeness, and balance in their sustainability reports (C. Susanto et al., 2022). This adherence highlights the growing importance of detailed and balanced sustainability reporting.

SMEs adopting GRI reporting standards can significantly boost their legitimacy and reputation. The use of the best-worst multi-criteria decision-making method aids these companies in prioritizing the implementation of these standards effectively (Rodríguez-Gutiérrez et al., 2021). Moreover, a process-based operational framework specifically designed for SMEs aligns sustainability reporting with their unique characteristics and challenges, ensuring a comprehensive approach (Arena & Azzone, 2012).

Incorporating economic, environmental, and social dimensions into sustainability reporting enhances corporate decision-making and contributes to a sustainable society (Lozano & Huisingh, 2011). The introduction of the Global Reporting Initiative Standards (GRI 207: Tax 2019) brings sustainability, transparency, and tax considerations together, incentivizing companies to integrate tax aspects into their sustainability frameworks (Schnitger et al., 2021). The adoption of international sustainability and integrated reporting guidelines has positively influenced non-financial disclosure transparency, environmental awareness, and overall firm transparency (Wachira et al., 2019). This adoption reflects a global shift towards more transparent and environmentally conscious business practices, contributing to greater corporate accountability.

SMEs have developed an integrated multi-attribute decision analysis model for evaluating sustainability development. This model identifies key indicators crucial for enhancing sustainable performance, including economic performance metrics, highlighting their importance in sustainable growth (A.-Y. Chang & Cheng, 2019). Similarly, SMEs are incorporating a combination of sustainable social and environmental practices to boost their legitimacy and overall sustainability (Crossley et al., 2021). This approach demonstrates their commitment to a wide range of environmental and social responsibilities, as reflected in their sustainability reports. A new framework by Labuschagne, Brent, and Van Erck (2005) for assessing the sustainability of manufacturing operations has been proposed, focusing on social equity, economic efficiency, and environmental performance. This framework underscores the need to integrate environmental and social aspects into sustainability reporting.

The adoption of sustainability practices by SMEs has been positively linked to financial performance, marked by increased turnover and business growth. This adoption not only enhances their reputation but also solidifies their legitimacy in the business world (Malesios et al., 2018). Thus, specific guidelines are needed for SMEs to create SME-oriented sustainability reports. These guidelines aim to enhance their reputation and legitimacy through effective sustainability reporting (Borga et al., 2009).

SMEs enhance their attractiveness to potential employees, even during financial crises, by adopting core values, leadership models, and communication channels that foster a sustainable culture (Ketprapakorn & Kantabutra, 2019). This culture development is crucial in making them appealing workplaces. Key factors that contribute to the resilience and competitiveness of SMEs include their operations strategies, technology use, and globalization efforts. These elements collectively bolster the organization's ability to withstand and recover from crises effectively (Gunasekaran et al., 2011). During the lockdown, SMEs in the "Food and Drink" sector showcased resilience and corporate social responsibility. They achieved this through effective communication strategies, demonstrating adaptability in challenging times (García-Santiago, 2022).

Product quality is also identified as a crucial area for improvement in SME, highlighting its importance in sustainability reports for manufacturing SMEs (Vinodh & Rathod, 2010). In manufacturing SMEs, using the embedded or embodied carbon indicator is pivotal for adopting sustainable supply chains. This indicator is crucial in measuring environmental improvement and pollution control, which are integral to product quality (Nartey & van der Poll, 2021; Schaltegger & Csutora, 2012). Similarly, a multi-attribute decision analysis model developed for manufacturing SMEs highlights key indicators for enhancing sustainable performance, including factors related to product quality (A.-Y. Chang & Cheng, 2019). The Averaging Quality Rating method is effective in aggregating various sustainability indicators for SMEs, enabling comparable assessments of product quality despite differing measurement methods (Kosacka et al., 2015). Furthermore, integrating ECQFD and LCA approaches in product design underscores the significance of product quality in sustainable product development and sustainability reporting (Vinodh & Rathod, 2010). The fuzzy inference system-based model for evaluating manufacturing sustainability in SMEs recognizes product quality as a key indicator for boosting overall sustainability (Singh et al., 2014).

Innovations in products, services, processes, and marketing are significant in improving business sustainability in SMEs. Sustainability reports play a vital role in driving or highlighting these organizational innovations (Hanaysha et al., 2022). The similar finding by Klewitz and Hansen (2014) found that SMEs exhibit a range of strategic sustainability behaviors, from resistance to anticipation. Their capacity for sustainability-oriented innovations is enhanced through interactions with external actors, showing the importance of external collaboration for innovative growth.

2.8. Research Variable Relationship

2.8.1. The relationship between Environmental Management Accounting (EMA) adoption, Financial Performance, and Sustainability Report

Numerous studies have explored the relationship between Environmental Management Accounting (EMA) and financial performance (FP), consistently revealing a significant positive correlation. For example, Deb et al. (2023) discovered a notable positive association between EMA and both environmental and financial performance. Similarly, Le, Nguyen, and Phan Le et al. (2019) observed that EMA implementation enhances both financial and environmental efficiency, particularly when reinforced by government policies. Nuleg et al. (2021) also found that EMA practices and financial competitive advantages contribute positively to corporate sustainability and FP. Additionally, Yuniarti et al. (2023) demonstrated that in Indonesia's manufacturing sector, EMA plays a mediating role in the relationship between innovation and FP.

The relationship between EMA and Sustainability Report (SR) has consistently shown a significant positive relationship. Jasch and Lavicka (2006) pointed out that EMA is instrumental in assessing the financial impacts of sustainability, thereby enhancing the accuracy of investment appraisals and performance indicators. EMA also enables managers to effectively identify, measure, evaluate, and report on environmental costs, which significantly influences a company's sustainability in its business processes (Maughan, 2022; Mihai & Aleca, 2023). Bennett et al. (2003) elaborated that EMA plays a key role in optimizing both environmental and economic performance, with the ultimate goal of achieving sustainable business operations. Additionally, Nyahuna and Doorasamy (Nyahuna & Swanepoel, 2022) found a positive and significant correlation between return on equity and EMA adoption, underscoring the importance of EMA in effective SR.

This hypothesis is anchored in the recognition that EMA practices, which include compliance with environmental regulations, eco-efficiency, and strategic positioning for long-term sustainability, directly contribute to the operational and financial efficiency of organizations (International Federation of Accontants (IFAC), 2005; Vasile & Man, 2012). The Global Reporting Initiative (GRI) framework, especially the GRI-G3 guidelines, is instrumental in guiding organizations towards comprehensive sustainability reporting, which is increasingly seen as an integral part of Corporate Social Responsibility (CSR) (Mihai & Aleca, 2023; Ortiz-Martínez & Marín-Hernández, 2021; Prashar, 2019; Steinhofel et al., 2019; Thuy et al., 2021). The compliance of companies, particularly those listed on indices like the SRI-KEHATI of the Indonesia Stock Exchange, with GRI standards emphasizes the relevance of principles such as sustainability context, completeness, and balance in their reports (C. Susanto et al., 2022).

For SMEs, the adoption of GRI reporting standards is linked to increased legitimacy and reputation (Arena & Azzone, 2012; Rodríguez-Gutiérrez et al., 2021). Moreover, integrating economic, environmental, and social dimensions into sustainability reporting is seen as enhancing corporate decision-making and contributing to a sustainable society (Lozano & Huisingh, 2011; Schnitger et al., 2021; Wachira et al., 2019). This comprehensive approach to sustainability reporting is exemplified in frameworks such as the one proposed by Labuschagne, Brent, and Van Erck (2005), focusing on social equity, economic efficiency, and environmental performance.

The link between the adoption of sustainability practices, such as SR and EMA, and financial performance in SMEs is well-documented (Borga et al., 2009; Malesios et al., 2018). Adopting core values, leadership models, and communication channels that foster a sustainable culture enhances the attractiveness of SMEs to potential employees, even during financial crises (García-Santiago, 2022; Gunasekaran et al., 2011; Ketprapakorn & Kantabutra, 2019). Furthermore, the emphasis on product quality and sustainable supply chains, as well as innovations in products, services, processes, and marketing, are significant in driving business sustainability and are reflected in SR (A.-Y. Chang & Cheng, 2019; Hanaysha et al., 2022; Klewitz & Hansen, 2014; Kosacka et al., 2015; Nartey & van der Poll, 2021; Schaltegger & Csutora, 2012; Singh et al., 2014; Vinodh & Rathod, 2010). FP indicators, such as financial statements, financial ratios, sales turnover, market expansion, and working capital management, are critical in assessing the business efficiency and operational activities of SMEs, that believed would enhance the SR (Binti Mohamad et al., 2017; Dvouletý et al., 2021; Hasanaj & Kuqi, 2019; Nugraha et al., 2022).

Thus, these relationship between EMA and FP, particularly in the context of SP, can be explored through a comprehensive hypothesis that integrates various indicators and research findings in this domain. The hypothesis proposed here posits that the adoption and effective implementation of EMA practices, as influenced by the coercive, normative, and mimetic factors, significantly enhance the financial performance of organizations, particularly SMEs, and contribute to the quality and effectiveness of their SR.

2.8.2. The direct relationship of Industry 4.0 with Environmental Management Accounting adoption, Financial Performance, and Sustainability Report.

Research indicates a significant and positive relationship between Industry 4.0 and Environmental Management Accounting (EMA) adoption, highlighting EMA's crucial role in utilizing Industry 4.0's technological advancements to boost environmental performance and sustainability. This interplay shows that the advanced technologies of Industry 4.0 positively impact EMA, enhancing environmental performance. Studies by Rasit et al. (2022b), as well as Burritt and Christ (2016), reinforce this idea, with EMA serving as a catalysator in the process and demonstrating its potential to revolutionize environmental accounting.

In the context of small and medium-sized enterprises (SMEs), the positive influence of Industry 4.0 on EMA is also evident. Research by Rasit et al. (2022b) and Mohamed (2018) confirms that advanced technology in Industry 4.0 significantly boosts EMA and, consequently, environmental performance in SMEs. Gunarathne and Cooray (2018) further highlight the role of EMA systems in aiding sustainability-related strategies in SMEs, marking a shift from compliance-oriented approaches to achieving higher-order sustainability outcomes.

Moreover, Novićević Čečević et al. (2021) discuss the necessity for EMA practices to evolve in response to Industry 4.0, noting its impact on company and environmental performance. This evolution suggests that EMA adoption in the era of Industry 4.0 leads to improved environmental and economic efficiencies, establishing EMA as an indispensable tool for ensuring organizational sustainability.

Expanding upon the hypothesis that there is a significant relationship between Industry 4.0 and Environmental Management Accounting (EMA), numerous studies corroborate the positive impact of Industry 4.0 on financial performance. This impact is manifested in enhanced revenue, profitability, and overall organizational performance. Research by Atif et al. (2021) underscores that the adoption of Industry 4.0 technologies bolsters financial performance by promoting sustainability, energy, and resource efficiency. During the COVID-19 pandemic, Gyurák Babeľová et al. (2022) observed a positive effect of Industry 4.0 on organizational performance, reflecting in improved financial conditions.

Sevinç et al. (2018) have indicated that SMEs adopting Industry 4.0 technologies facilitate a transition to more efficient resource utilization, which supports financial performance. Similarly, Asmolov and Ledentsov (2022) discovered that Industry 4.0 components like big data and the Internet of Things enhance long-term business performance in SMEs by encouraging the use of information technology. Haseeb et al. (2019) reported that Industry 4.0 is instrumental in fostering sustainable business performance among SMEs, enhancing operational effectiveness and productivity. Chonsawat and Sopadang (2020) also found that Industry 4.0 adoption in SMEs leads to increased production efficiency, reduced energy consumption, and lower manufacturing costs.

Further, Buchi et al. (2020) concluded that greater engagement with Industry 4.0 technologies is linked to improved financial performance in micro-level local units. Additionally, H.-L. Chen (2021) highlighted the significant effect of Industry 4.0 maturity on internal business process performance, which consequently influences customer performance and financial outcomes. These studies collectively illustrate the substantial benefits of embracing Industry 4.0 technologies, especially for SMEs, in enhancing various aspects of financial performance.

Industry 4.0 technology transcends the enhancement of financial performance, significantly impacting sustainability reporting by improving transparency, control, and reporting capabilities on sustainability and circular economy aspects. Takhar and Liyanage (2020) observed that Industry 4.0 technologies support the reporting needs for sustainability and circular economy models. Furthermore, Tavares and Azevedo (2021) explored the potential influence of Industry 4.0 and Society 5.0 on accounting and sustainability reporting, emphasizing the integration of digital technologies and the promotion of quality of life. Related to the strategy in the production, Portna (2021) emphasized the strategic interactions within Industry 4.0 that facilitate sustainable reporting development among industry players. Asserted that Industry 4.0 offers unprecedented levels of transparency and control, paving the way for enhanced sustainability across various sectors (Jonak et al., 2020).

In the SME sector, Asmolov and Ledentsov (2022) pointed out that Industry 4.0 elements, such as big data and the Internet of Things, are instrumental in promoting the use of information technology, thereby boosting sustainable business performance. Haseeb et al.

(2019) also noted the positive influence of Industry 4.0 on the implementation of information technology in SMEs, contributing to their sustainable performance. The core components of Industry 4.0 aid SMEs in achieving sustainability and competitive advantage through the adoption of smart technologies in production systems (D. S. Jayashree et al., 2020). Additionally, Philbin (2022) observed that while SMEs' adoption of Industry 4.0 technologies facilitates sustainable development, the direct relationship with sustainability reporting continues to be an area of ongoing exploration. This suggests that as Industry 4.0 technologies evolve, their role in enhancing sustainability reporting and overall business performance becomes increasingly significant.

2.8.3. The indirect relationship of Industry 4.0 with Environmental Management Accounting adoption, Financial Performance, and Sustainability Report.

In the realm of Industry 4.0, research indicates an indirect positive relationship with financial performance, where Environmental Management Accounting (EMA) emerges as a crucial mediating variable. This relationship highlights EMA’s significant role in augmenting the positive effects of Industry 4.0 on financial outcomes. Advanced technologies in Industry 4.0 could improve environmental information, thereby influencing the adoption of EMA (Rasit et al., 2022a). Despite this study is limited to the Malaysia's electrical and electronic industry, however the study’s finding suggests that EMA might serve as a pivotal mediator in the nexus between Industry 4.0 and financial performance. Furthering this line of inquiry, Kumar and Bhatia (2021) observed that environmental dynamism propels firms towards Industry 4.0, which in turn positively influences performance outcomes. They identified organizational and technological factors, potentially inclusive of EMA, as mediators in this relationship.

In the realm of Industry 4.0, Financial Process Automation (FPA) emerges as a critical component, enhancing financial operations and strategies. FPA contributes to the automation of production processes, although it also presents new challenges to financial and economic security (Bisht et al., 2022). Thus, Employee digital skills are increasingly vital, necessitating continuous improvement and reskilling to meet the demands of Industry 4.0 (Bolek et al., 2021; Karacay, 2018). Subsequently, EMA plays a crucial role in this context, providing comprehensive information for decision-making. EMA highlights opportunities for innovation, better waste management, and reduced energy consumption (Burrit & Saka, 2006; R. L. Burritt et al., 2019; Ferreira et al., 2010). The threefold benefits of EMA, encompassing compliance, eco-efficiency, and strategic positioning, are instrumental in aligning environmental and financial goals (International Federation of Accontants (IFAC), 2005;

Vasile & Man, 2012). The coercive, normative, and mimetic factors influence the adoption of EMA at the corporate level, with a particular focus on human capital as a driver of innovation and sustainability (Chathurangani & Madhusanka, 2019; Imtiaz Ferdous et al., 2019; Staniskis & Stasiskiene, 2006). Therefore the financial performance indicators, as measured through financial statements, ratios, sales turnover, and market expansion, is an essential outcome for businesses engaging with Industry 4.0 and EMA. These measures reflect the company's health, strategic planning, and operational efficiency (Dvouletý et al., 2021; Mihai & Aleca, 2023; J. Nagy et al., 2018; Nugraha et al., 2022; Rasit et al., 2022a).

Slightly different with the other research, Kamble et al. (2020) noted that technologies associated with Industry 4.0 exert both direct and indirect impacts on sustainable organizational performance, with lean manufacturing practices identified as a strong mediating factor. This insight opens up the possibility of a similar mediating role for EMA in transmitting the impact of Industry 4.0 on financial performance. Adding complexity to the interplay, Saeidi et al. (2018) found that while both product and process innovations positively correlate with financial performance, EMA exhibits a negative moderating effect on the relationship between process innovation and financial performance. This outcome underscores the intricate and multifaceted role EMA plays in the dynamics between Industry 4.0 and financial performance, suggesting that the influence of EMA is nuanced and may vary depending on the specific aspects of Industry 4.0 being implemented.

In this dissertation, we explore the intricate relationship between Industry 4.0 and sustainability reporting, positing that Industry 4.0 has an indirect positive relationship with sustainability reporting, mediated by Environmental Management Accounting (EMA). Research by Rasit et al. (2022b) supports this, showing that advanced Industry 4.0 technology positively influences EMA and environmental performance, with EMA serving as a crucial intermediary. This implies that EMA could be the key to linking Industry 4.0 with enhanced sustainability reporting. Similarly, Burritt and Christ (2016) suggest that Industry 4.0 could bolster environmental accounting, particularly through significant investments in digitized business infrastructure. Industry 4.0 technologies significantly affect sustainable organizational performance, both directly and indirectly, with lean manufacturing practices as a strong mediating variable (Kamble et al., 2020). This implies that EMA, as a component of environmental accounting, might mediate the relationship between Industry 4.0 and sustainability reporting.

The integration of EMA with Industry 4.0 technologies significantly influences sustainability reporting. The Global Reporting Initiative (GRI) framework, particularly the

GRI-G3 guidelines, serves as a benchmark for sustainability reporting, emphasizing corporate responsibility and transparency (Jasch & Lavicka, 2006; Mihai & Aleca, 2023; Ortiz-Martínez & Marín-Hernández, 2021). SMEs adopting GRI standards enhance their legitimacy and reputation, thereby aligning their operations with sustainable practices (Arena & Azzone, 2012; Rodríguez-Gutiérrez et al., 2021). The adoption of sustainability practices, as reflected in sustainability reports, has a profound impact on various aspects of business operations. This includes economic performance, social responsibilities, environmental improvement, product quality, and innovation, all of which contribute to the overall sustainability of SMEs (Borga et al., 2009; Klewitz & Hansen, 2014).

Further, Oláh et al. (2020) and Bonilla et al. (2018) discuss how Industry 4.0 integrates with sustainable development goals, suggesting a mediating role for EMA in this relationship. Focusing specifically on the SME sector, Rasit et al(2022a) found that Industry 4.0 technology might indirectly relate to the adoption of EMA and improved environmental performance in SMEs, indicating EMA's mediating role in this context. As mediator, EMA can leverage the advantages of Industry 4.0 for enhanced sustainability reporting in SMEs. For example, Kamble et al. (2020) noted the significant effects of Industry 4.0 on sustainable organizational performance, with EMA potentially mirroring the mediating role of lean manufacturing practices. Another study also by Burritt and Christ (2016) argued for the enhancement of environmental accounting in SMEs through Industry 4.0, facilitating better quality in both environmental management accounting and external reporting. Jayashree et al. (2021) emphasized that the effective implementation of Industry 4.0 technologies mediates the relationship between innovation characteristics and sustainability goals in SMEs, again underscoring the role of EMA in this process.

The role of Industry 4.0 is increasingly recognized as having a varied impact, believed to influence multiple variables. In this dissertation, we explore the argument from previous research that Industry 4.0 has an indirect positive relationship with Sustainability Reporting, mediated through Financial Performance. We begin with the premise that the rapid adoption of technology drives enhanced operational efficiency and competitive advantage, which in turn directly boosts financial performance by increasing both efficiency and productivity (Atif et al., 2021; Claudy et al., 2016). Elements such as superior data quality, digital maturity, and Financial Process Automation (FPA) play a pivotal role in streamlining operations (Pokharkar, 2019), thus bolstering financial health (Bisht et al., 2022; Jardak & Ben Hamad, 2022). Moreover, the proficiency of a workforce adept in digital technologies, coupled with effective management strategies, further propels a company's financial standing (Bosman et al., 2019).

This enhancement in financial performance resulting from embracing Industry 4.0 subsequently influences Sustainability Reporting. As organizations register improved financial outcomes through Industry 4.0, characterized by increased sales and market expansion, they gain the capability to invest more in comprehensive sustainability initiatives. This integration of financial success with environmental and social responsibilities is increasingly evident in sustainability reports. These reports, adhering to GRI Standards and encompassing a blend of financial and non-financial aspects, not only reflect an organization's commitment to sustainability but also bolster its reputation and financial success (Mihai & Aleca, 2023). The financial stability and success brought about by Industry 4.0 allow organizations to embrace more robust and expansive sustainability practices. These practices are then transparently communicated in sustainability reports, highlighting the interplay between operational efficiency and sustainable practices. Furthermore, a robust sustainability report can enhance a company's reputation, attract quality talent, and assure investors and customers (Legendre & Coderre, 2013; Yun & Lee, 2022), thereby contributing to financial growth and market success.

Jayashree et al. (2020) contend that Industry 4.0 technologies are instrumental in achieving Triple Bottom Line sustainability, with financial performance serving as a mediating factor. They suggest that enhancements in financial performance, driven by Industry 4.0, could lead to improved sustainability reporting. This perspective aligns with the findings of Kamble et al. (2020), who discovered that Industry 4.0 technologies exert significant direct and indirect effects on sustainable organizational performance. They indicate that financial performance, as a facet of overall performance, could be a mediating link between Industry 4.0 and sustainability reporting.

Further supporting this view, Kumar and Bhatia (2021) reported that environmental dynamism propels firms towards adopting Industry 4.0, positively affecting performance outcomes. They imply that financial performance, as part of these outcomes, may act as a mediator influencing sustainability reporting. In a similar vein, Bonilla et al. (2018) acknowledge that Industry 4.0 is expected to have both positive and negative impacts on sustainability. However, they highlight that the positive effects could be channeled through improved financial performance, leading to enhanced sustainability reporting.

Finally, Oláh et al. (2020) emphasize the importance of integrating Industry 4.0 with sustainable development goals to boost environmental sustainability. This integration, they argue, could be reflected in sustainability reporting, with financial performance acting as a crucial mediator. These diverse perspectives highlight the crucial role of Industry 4.0 in shaping sustainability reporting, predominantly through its impact on financial performance. As such, advancements in Industry 4.0 indirectly enhance the quality and breadth of Sustainability Reporting by offering the essential financial and operational backing needed for underpinning sustainable practices.

Stems from the premise from the previous hypotheses, to provide more novel insights, our research aims to establish the relationship among various variables, seeking evidence from previous studies that Environmental Management Accounting (EMA) and Financial Performance indeed serve as mediators between Industry 4.0 and Sustainability Reporting. This is done through the calculation of their indirect effects. For instance, Jasch and Lavicka (2006) conducted a pilot project in the Styrian automobile cluster, revealing that Industry 4.0 can lay the groundwork for enhanced corporate sustainability by promoting the adoption of environmental accounting. This is complemented by Tiwari and Khan's (2020) research, which suggests that the advanced technologies of Industry 4.0 can improve environmental information, thereby influencing the adoption of EMA, impacting both financial performance and sustainability reporting.

Linking these studies, we conceptualize the impact of Industry 4.0 on sustainability and find support in the work of Beltrami et al. (2021). They argue for a significant indirect relationship between Industry 4.0 technologies and sustainability practices and performance, mediated through EMA and financial performance. This relationship corroborates our hypothesis, underscoring the interconnected nature of these elements. Industry 4.0 also shows potential in promoting quality of life and sustainable development through environmental management accounting and financial performance, highlighting its broad impact on various sustainability aspects, including reporting, (da Costa Tavares & do Carmo Azevedo, 2021).

In the context of SMEs, Burritt and Christ (2016) discuss how Industry 4.0 could enhance environmental accounting, leading to improved corporate sustainability. This suggests that Industry 4.0 influences EMA, which in turn affects sustainability reporting. Furthermore, Rasit et al. (Rasit et al., 2022b) found that advanced technology in Industry 4.0 positively influences EMA and environmental performance in SMEs, with EMA acting as a mediator. This indicates EMA's role in bridging Industry 4.0 and sustainability reporting.

Nyahuna and Doorasamy (2023) report a positive and significant relationship between return on equity and EMA practices in SMEs, suggesting a connection between financial performance, EMA, and sustainability reporting. Additionally, Gunarathne and Cooray (2018) highlight that EMA systems can guide SMEs towards higher-order sustainability outcomes, implying that EMA mediates the relationship between Industry 4.0 and sustainability reporting in SMEs. This body of research collectively illustrates the intricate relationship between technological advancement, environmental management, financial health, and sustainable practices in the context of Industry 4.0.

2.8.4. The direct relationship of Financial Performance with Sustainability Report..

In the realm of Sustainability Reporting and Financial Performance, Buallay (2022) unveils a significant correlation between sustainability reporting and financial outcomes. This finding suggests that firms actively engaged in sustainability reporting often experience improved financial performance, lending credence to the hypothesis of a direct and significant relationship between the two. Complementing this, Buallay et al. (2021) further reveals a positive association between Environmental, Social, and Governance (ESG) reporting and both operational and financial performance in smart cities, thereby underscoring that enhanced sustainability reporting, particularly through ESG standards, positively correlates with financial success in these environments.

Delving into the dynamics of Corporate Social Responsibility and Financial Performance, Lee and Hu (2018) highlight how corporate financial performance (CFP) not only bolsters corporate social responsibility (CSR) but also mediates the relationship between corporate reputation and CSR. This research illuminates the direct influence of financial performance on sustainability-related endeavors like CSR. In a similar finding, Zhou et al. (2022) explore the interplay between Sustainable Development, ESG Performance, and Market Value, concluding that improvements in ESG performance among listed companies can elevate their market value, with financial performance playing a pivotal mediating role. Thus further implies a strong connection between sustainability reporting, as manifested through ESG performance, and financial performance.

Focusing on SMEs, Malesios et al. (2018) identify a significant positive link between certain sustainability practices and financial performance in SMEs. The adoption of sustainability reporting, in this context, is suggested to directly influence financial performance, indicating a clear relationship between these factors in SMEs. Similarly, Masocha (2019) reports that social sustainability practices in South African SMEs are positively and significantly associated with financial performance, thus highlighting the direct impact of sustainability (specifically social sustainability) on financial performance.

McMahon (2001) discusses how enhanced financial reporting practices in Australian manufacturing SMEs correlate with improved growth and performance. Although other factors contribute more significantly to overall management, this study suggests a linkage between financial performance and reporting practices. The international financial reporting standards practices significantly affect financial performance among SMEs, supporting the notion that adherence to certain reporting standards positively influences financial performance (Otieno et al., 2021).

Lastly, Burlea-Schiopoiu and Mihai (2019) note the potential for SMEs to use training and innovation to amplify the impact of CSR on their sustainability, which positively correlates with profitability metrics. This indicates a direct relationship between sustainability practices, including reporting, and financial performance. Collectively, these studies provide robust support for the hypothesis positing a positive relationship between Financial Performance and Sustainability Reporting, particularly in the context of SMEs.

3. MATERIAL AND METHOD

3.1 Type of Research

Our research, rooted in quantitative methods, utilizes partial least squares structural equation modeling (PLS-SEM) and descriptive analysis. PLS-SEM, chosen for its effectiveness in modeling complex relationships between variables and its adaptability to small sample sizes without the need for multivariate normality, is crucial for our theory-driven exploratory research. In this process, we will meticulously develop and validate measurement models before scrutinizing the structural model. Alongside PLS-SEM, descriptive analysis will be employed to glean insights into SMEs and environmental issues in Indonesia and to examine respondent data.

3.2 Research Procedure

This dissertation is a descriptive confirmatory investigation focusing on the impact factors on SMEs' sustainability during the Industrial Revolution 4.0, viewed through environmental management accounting. The research unfolds in three stages, each building upon the previous one.

In the first stage, we gather initial data from scientific journals, previous studies, and internet sources to form a foundational understanding of the problem. This preliminary study synthesizes literature to create a state-of-the-art overview, identifying key research variables and constructing a research model. The collected theories, focusing on Industry 4.0 from an accounting perspective, include agency, institutional, and legitimacy theories, culminating in the concept of Environmental Management Accounting (EMA). We delve into EMA, guided by IFAC's 2005 framework, which categorizes EMA's uses and benefits as compliance, eco-efficiency, and strategic positioning. Additionally, we explore the pressures - coercive, normative, and mimetic - influencing SMEs to adopt EMA. This stage culminates in merging the benefits and challenges of Industry 4.0 with those of EMA. The findings are then presented at an international conference for feedback, ensuring the robustness of our conceptual model.

The second stage involves developing a questionnaire based on this conceptual model. The questionnaire undergoes scrutiny in a Focus Group Discussion (FGD) with experienced researchers, particularly to refine its sensitivity and address potential social desirability bias. Once finalized, the questionnaire is distributed to SMEs via random sampling, ensuring its validity and reliability. If any questionnaire items prove invalid, this stage is repeated. Primary data is gathered from SME owners through structured interviews, prioritizing ethical considerations. The Faculty of Economics, Sam Ratulangi University's ethics review committee, approved the study instrument, emphasizing data confidentiality and voluntary participation without inducements.

In our approach to minimize Common Method Variance (CMV) and Social Desirability Bias (SDB), we employ Balanced Keying, use positively and negatively worded items, and assure anonymity to foster honest responses. Indirect questioning techniques in interviews facilitate a more open expression of views. To further ensure measure validity, we implement strategies like reverse coding, temporal separation, and marker variables for specific variables (Saxena et al., 2022). We assess the respondents' willingness for follow-up surveys at the questionnaire's start, emphasizing anonymity, and conclude interviews with queries to identify ambiguous or challenging items.

When we collect data using the nominal approach, respondents must write down the nominal values of their net income, non-cash expenses, and changes in working capital, which are used to measure the operating cash flow indicator. However, we have found that respondents often leave out one of these components, making it difficult to calculate the Operating Cash Flow and other financial performance indicators. Additionally, when we ask respondents to provide financial information, they may mistake the surveyor for a tax officer, leading to a tendency to reject the interview or provide inaccurate answers. To address this issue, we opted to reconstruct the financial performance indicator using an ordinal scale instead of a nominal scale. We conducted focus group discussions to develop a solution that would enable us to accurately measure operating cash flow and other financial indicators.

3.3 Research Object

Our research will take place in both urban and suburban areas across multiple cities and regions within several provinces of Eastern Indonesia. In this endeavor, we will collaborate with urban and local government bodies. Their support is crucial for documenting and facilitating our research team's efforts in primary data collection in the field. We anticipate that the village government will play a pivotal role as a mediator between our research team and the city's SMEs, who may initially exhibit skepticism and distrust. This partnership aims to bridge the gap between the research team and local businesses, ensuring smooth data collection and fostering trust within the community.

We categorize our objectives into four regions based on their specification that offer a diverse range of economic activities and developmental stages, making them suitable for a comprehensive study of SME sustainability practices in the context of the Industrial Revolution 4.0.

1. **Papua**: Rich in natural resources and diverse agricultural products, Papua is an ideal location for studying the manufacturing and agricultural sectors, especially given its growing economic development.
2. **Maluku**: Known for its agricultural produce, especially spices, and a burgeoning manufacturing sector, Maluku offers a unique context for understanding SMEs' environmental management practices in these industries.
3. **East Nusa Tenggara (Nusa Tenggara Timur)**: This province has a strong agricultural base, with significant activities in corn, rice, and livestock farming, alongside a growing manufacturing sector, making it a relevant area for your research.
4. **Sulawesi**: With a diverse economy that includes agriculture, manufacturing, and mining, Sulawesi provides a comprehensive setting to study the environmental management accounting practices among SMEs in these sectors.

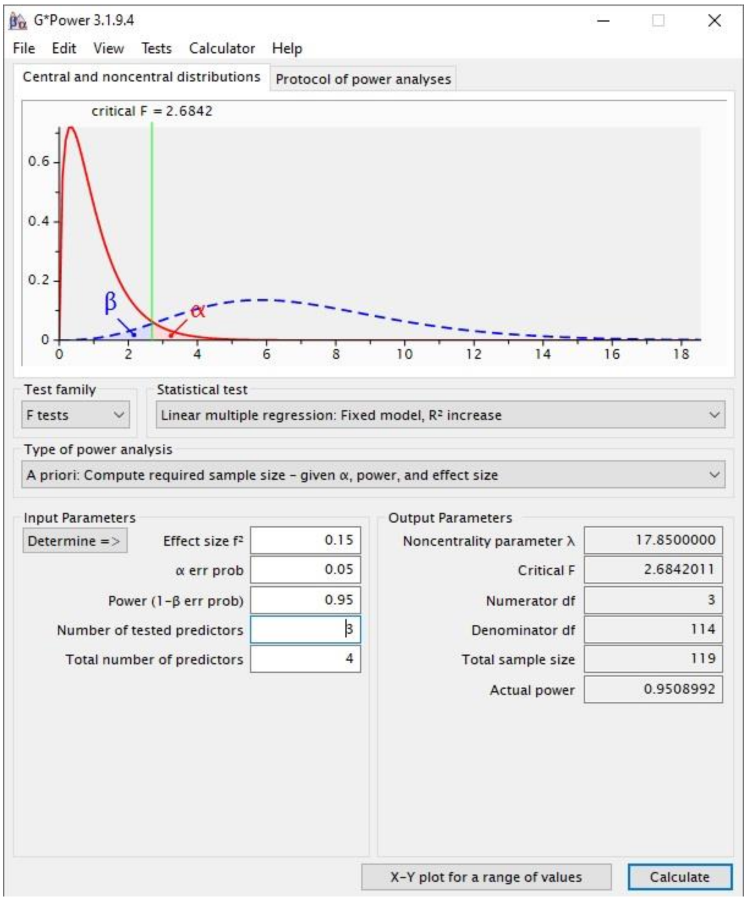
3.4 Population and Sample

In this dissertation, we have employed purposive sampling to target SMEs within the manufacturing and agriculture sectors across Eastern Indonesia. This approach aligns with our objective of focusing on these particular sectors, as highlighted in the introduction. Our target population is SMEs in the manufacturing and agriculture sectors, chosen due to their critical role in the current global economic landscape. The disruptions in the global supply chain underscore the importance of strengthening these sectors to meet national needs effectively.

Our sampling method was meticulously designed to include SME owners or managers who are either familiar with Environmental Management Accounting (EMA) practices or have substantial knowledge about environmental cost considerations. This selection criterion ensures that our respondents possess a keen awareness of the value of environmental costs. Additionally, we aim to include individuals who are involved in producing sustainability reports or equivalent documents, such as environmental impact assessments. These documents are vital for various purposes, including tax reporting, governmental compliance, and stakeholder engagement, making them relevant to our study's focus on environmental management and sustainability practices in SMEs.

However, during our analysis, we faced challenges in determining the exact size of the study population within each country. While some nations provide accurate and dependable statistical data, others national central statistics that can be ambiguous or even questionable (Sensuse et al., 2021). This uncertainty made it difficult to gauge the complete population of SMEs in agriculture, especially when adhering to the specific criteria set for purposive sampling. Addressing the complexities of data requirements, we reference the suggestions the "10 times rule", which stipulates a sample size of at least 10 times the maximum number of formative indicators of a given construct. Given the 22 indicators in this study, this results in a minimum recommended sample size of approximately 220. However, it is essential to note that this is a broad-based guideline (Hair et al., 2012). In light of more robust recommendations, we align with the advice of Hair et al. (2016), emphasizing adjustments to the sample size based on power analysis. We employed the G*Power software delineated by Ferine et al. (2021) to ascertain an appropriate sample size, setting type I and II error rates at α = 0.05 and β = 0.95, respectively. The anticipated effect size was set at 0.15. The model, as conceptualized by this research, contains 4 predictors (constructs). Detailed configurations used for this power analysis and the resultant findings can be viewed in Figure 3.

Figure 3. **Sample Size Based on Power Analysis**
G*Power for F_{test} Fix Model for Increasing in R^2



Source: G*Power software, 2023

While G*Power is not explicitly designed for PLS-SEM or similar structural models, interpreting the model in terms of path analysis allows us to approximate requirements. Within our model, the primary predictors are Industry 4.0, EMA, and Financial Performance.

Specifically, the focus is on the incremental variance elucidated by the subsequent inclusion of Four constructs: Industry 4.0, EMA, Financial Performance, and the Sustainability report. Consequently, we defined the number of tested predictors as 3 for our power analysis, emphasizing the latter 4 constructs. The overall model encompasses 4 constructs, with an error probability set at 0.05, effect size f^2set at 0.15, and a 95% confidence level; the required minimum sample size is 119. We distributed around 1,000 questionnaires but received only 582 in return. Not all of these questionnaires were suitable for further statistical analysis due to issues such as missing values, incomplete answers, and outlier data. After eliminating these issues, we were left with 543 final data sets for further statistical analysis.

3.5 Operational Definition and Measurement of Latent Variables

3.5.1 Operational Definition and Measurement of Industry 4.0

Industry 4.0 / Digital Transformation (DT) is defined as the integration of information technology, automation, data analytics, and artificial intelligence into various aspects of industrial and organizational processes. It aims to enhance operational efficiency, data quality, transparency, and real-time decision-making. Industry 4.0 is characterized by its impact on accounting, manufacturing, strategic management, and human resources.

Indicator Measurements:

- Technology Adoption Rate: The speed and extent to which new technologies are adopted within the organization.
- Data Quality: The accuracy, credibility, and real-time availability of data generated or processed.
- Financial Process Automation (FPA): The extent of automation in financial processes like payments, invoicing, and data analysis.
- Employee Digital Skills: The proficiency of the workforce in using digital tools and platforms.
- Management Approach: The effectiveness of organizational decision-making in the context of DT.

3.5.2 Operational Definition and Measurement of EMA

Environmental Management Accounting (EMA) is defined as the identification, collection, analysis, and utilization of both physical and monetary information for internal decision-making. The physical information pertains to the use, flow, and destination of energy, water, and materials, including waste. The monetary information relates to environment-related costs, earnings, and savings. EMA aims to overcome the limitations of traditional management accounting by providing comprehensive data for managerial activities and decisions involving environmental issues.

Indicator Measurements:

- Compliance: The extent to which EMA supports environmental protection through compliance with environmental regulations and internal environmental policymaking.
- Eco-Efficiency: The degree to which EMA helps in reducing costs and environmental impacts through the efficient use of energy, water, and materials.
- Strategic Position: The extent to which EMA supports the evaluation and implementation of environmentally friendly and cost-effective programs to ensure the company's long-term strategic position.
- Coercive Pressures: The influence of regulatory aspects and external pressures like laws, environmental groups, and media on the adoption of EMA.
- Normative Pressures: The influence of societal norms, staff training, and membership of accounting bodies on the adoption of EMA.
- Mimetic Pressures: The extent to which the organization adopts EMA practices by imitating competitors or industry leaders

3.5.3 Operational Definition and Measurement of SMEs Financial Performance (FP)

SME financial Performance (FP) is defined as the comprehensive evaluation of a small and medium-sized enterprise's financial health, as reflected in its financial statements, income statements, cash flows, and other financial reports. This evaluation is crucial for internal decision-making and attracting investor interest. Financial performance is often measured through financial ratios and includes parameters such as sales, market expansion, productivity, asset utilization, sales turnover, and net profit.

Operating Cash Flow (OCF):

$$OCF = NI + NCE + \Delta WC$$

Net Income (NI)	: Total revenues minus total expenses.
Non-Cash Expenses (NCE)	: Depreciation and amortization.
Changes in Working Capital (ΔWC)	: Increases or decreases in current assets and liabilities.

Debt-to-Equity Ratio (D/E):

$$D/E = \frac{L}{E}$$

Total Liabilities (L)

Owner Equity (E)

Assets Turnover (AT):

$$AT = \frac{S}{A}$$

Total Sales (S)

Total Assets (A)

Net Profit Margin (NPM):

$$NPM = \frac{NI}{S}$$

Net Income (NI)

Total Sales (S)

Business Value/Firm Value:

$$FV = EBITDA + CSR + \left(\left(\frac{NJOP}{m^2} \times MV_{adjust}\right) \times (Building + Land)\right) + CF_{adjust}$$

Operational Profitability (EBITDA): Based on EBITDA or net profit margins, adjusted for the size and industry of the SME.

CSR Contribution Premium (CSR): An added value derived from CSR activities that enhance corporate reputation and brand image, potentially leading to increased customer loyalty, market differentiation, and potentially higher sales or pricing power.

NJOP: This is a starting point for understanding the base value of business property according to the government's assessment provided by the local tax authority.

Market Value Adjustment (MV_{adjust}): Compare the business property's NJOP to recent sales of similar properties in the local area to understand the market value for exp. if the NJOP is IDR 2,000,000 per m^2, and market trends suggest a 20% premium on NJOP, adjust the value accordingly.

Land and Building Size: Include the size of business land and buildings in the calculation. For instance, with a building of $100m^2$ and land of $200m^2$, we will calculate their values separately and then add them.

Condition and Features (CF_{adjust}): Adjust the price based on the condition of the building and any special features or amenities it has. This can either increase or decrease the value.

Working Capital (WC):

$$WC = CA - CL$$

Current Assets (CA)

Current Liabilities (CL)

Therefore, we use the adjustment from the financial ratio tailored using the ordinal scale method. The following is the indicators measurement:

- **Operating Cash Flow (OCF):** direct measure of a company's financial health than just income, as it accounts for actual cash movements rather than accounting income.
- **Debt-to-Equity Ratio (D/E):** This measurement measures the company's financial leverage and indicates how much of the company is financed by debt compared to owned funds.
- **Assets Turnover (AT):** This is the total sales (revenue) generated by a business within a specific period based on Assets.
- **Net Profit Margin (NPM):** This measurement uses sales compare to the net income
- **Business Value/Firm Value:** This measurement using an approach how the owner value their business based on the explanation from the formula given.
- **Working Capital (WC):** This measures a company's operational efficiency and short-term financial health by indicating whether a company has enough short-term assets to cover its short-term liabilities

3.5.4 Operational Definition and Measurement of SMEs Financial Performance (FP)

Sustainability Reporting (SR) is defined as a voluntary disclosure that provides a comprehensive account of an organization's financial and non-financial performance, focusing on social, environmental, and economic activities that contribute to sustainable growth. SR serves multiple purposes, including enhancing corporate legitimacy, bolstering managerial decision-making in the context of corporate social responsibility (CSR), and providing a holistic perspective of organizational performance. The Global Reporting Initiative (GRI) framework, particularly the GRI-G3 guidelines, is often used as the standard for SR.

Indicator Measurements:

- Economic Outcomes: The SR's focus on long-term business strategy success, including economic performance metrics.
- Environmental and Social Aspects Report: The depth and breadth of environmental and social responsibilities covered in the SR.

- Employee Attractiveness: The SR's role in making the organization more appealing to potential employees.
- Product Quality and Innovation: The SR's focus on the quality of products or services offered in driving or highlighting organizational innovation.
- Transparency and Governance: The clarity and comprehensiveness of the SR in disclosing governance structures and practices.

Table 2. **Variable Measurement**
Latent and Manifest Variables with Corresponding Items in the PLS-SEM Model

Latent Variable	Manifest Variable	Items
Industry 4.0	Technology Adoption Rate	Ind4_1
	Data Quality	Ind4_2
	Financial Process Automation	Ind4_3
	Employee Digital Skill	Ind4_4
	Management Approach	Ind4_5
Environmental Management Accounting (EMA) adoption	Compliance	EMA1
	Eco-efficiency	EMA2
	Strategic Position	EMA3
	Coercive Pressures	EMA4
	Normative Pressures	EMA5
	Memetic Pressures	EMA6
Financial Performance	Operating cash flow	FP1
	Debt-to-Equity Ratio	FP2
	Assets Turnover	FP3
	Net Profit Margin	FP4
	Business Value/Firm Value	FP5
	Working Capital	FP6
Sustainability Report	Economic Outcomes Report	SR1
	Environmental and Social Aspects Report	SR2
	Employee Attractiveness	SR3
	Product Quality and Innovation	SR4
	Transparency and Governance	SR5

3.6 Data Analysis

3.6.1 Descriptive Analysis

In our first descriptive analysis, we utilize secondary data to build a foundational understanding of SMEs, environmental issues, and the status of digitalization in Indonesia. This data, sourced from reliable databases like Statista, provides a comprehensive and current statistical overview. Our analysis aims to quantitatively summarize and interpret data pertaining to Indonesian SMEs, focusing on aspects like the number of SMEs by sector, their contribution to the GDP, and their environmental impact. Furthermore, we explore the degree of digitalization within these enterprises, examining digital infrastructure availability, the adoption of digital tools in operations, and how digitalization influences productivity and environmental sustainability. This analysis is crucial for identifying trends, discerning patterns, and pinpointing areas for potential improvement, setting a solid baseline for our primary research and contextualizing our findings.

The second descriptive analysis will concentrate on the demographics and characteristics of the survey respondents, including variables such as geographic region, gender, age, education level, business age, type of business, and educational background of the business owners or managers. This analysis will provide insights into the diverse profiles of SME operators in Indonesia, offering a detailed understanding of the population that forms the core of our study.

3.6.2 Structural Equation Modeling

In this dissertation, the data analysis employs the Partial Least Square (PLS) approach, initially developed by Herman O. A. Wold (1963), to test the confirmatory model. PLS is advantageous in handling multiple independent variables and is robust against multicollinearity. It serves as an alternative to Ordinary Least Square (OLS) regression and Structural Equation Modeling (SEM), particularly useful in scenarios with small sample sizes, missing data, and multicollinearity (Sarstedt et al., 2017).

PLS, a component-based SEM, differs from covariance-based SEM, which primarily tests causality or theory. Instead, PLS focuses on prediction, not constrained by assumptions of normal data distribution, large sample sizes, or specific data scales. This method combines elements of Principal Component Analysis (PCA) and regression modeling, executed in two stages: first, establishing latent variables to explain covariances between independent and dependent variables, and second, predicting the dependent variable using decomposed independent variables.

Despite debates around selecting the right causal-predictive model, as discussed by Chin et al. (2020) and Chin (1998) PLS-SEM, based on the frameworks of Henseler and Sarstedt (2013) and Tenenhaus et al. (2000), is particularly effective for research in emerging markets like Indonesia. This is due to its flexibility in handling smaller sample sizes and non-normalized data. In PLS-SEM, model fit assessment is crucial for validating the model's effectiveness and predictive accuracy. Unlike covariance-based SEM, PLS-SEM lacks a singular overall goodness-of-fit index. Instead, it evaluates model efficacy through individual path coefficients, R^2 values, and effect sizes (F^2), which collectively determine the model's explanatory power. Additionally, Stone-Geisser's Q^2 statistic assesses predictive relevance, particularly in models with reflective endogenous variables, where a Q^2 value above zero signifies predictive relevance for these constructs.

3.6.2.1 Outer model measurement

In this dissertation, the outer model focuses on reflective indicators. The evaluation of the outer model with reflective indicators involves assessing convergent and discriminant validity, as well as the composite reliability of each indicator block.

Reflective indicator validity is tested by examining the correlation between individual indicator scores and overall construct scores. In reflective measurement, a change in one indicator within a construct typically implies changes in other indicators of the same construct. Convergent validity is determined by the correlation between item scores and construct scores, as calculated by PLS. A high reflective measurement is indicated by a correlation exceeding 0.7 with the intended construct. However, in the initial stages of developing a measurement scale, a loading value between 0.5 and 0.6 is deemed adequate (W. W. Chin, 1998; Hair et al., 2020).

Discriminant validity, on the other hand, is established when two distinct instruments measuring two theoretically uncorrelated constructs yield uncorrelated scores. This is assessed through cross-loading measurements with the construct and comparing the square root of the Average Variance Extracted (AVE) for each construct with the correlation of that construct with others in the model. Adequate discriminant validity is achieved if the AVE root for each construct exceeds its correlations with other constructs (W. W. Chin, 1998; Fornell & Larcker, 1981; Sarstedt et al., 2017). The Fornell-Larcker Criterion, Heterotrait and Monotrait Ratio

(HTMT), and Cross Loading are employed in this dissertation for measuring discriminant validity.

Additionally, the PLS methodology includes a reliability test to evaluate the internal consistency of the measurement instrument. Composite reliability is used to ascertain the overall reliability of a construct, with a general benchmark of over 0.7, although a value of 0.6 is also acceptable (Hair et al., 2020).

3.6.2.2 Inner model evaluation

In this dissertation, the inner or structural model elucidates the causal relationships between latent variables, grounded in theoretical substance. The PLS algorithm focuses on estimating coefficient values, while significance testing is conducted via bootstrapping analysis. This involves calculating t-statistic parameters to predict causal relationships. The inner model also assesses direct, indirect, and total effects of constructs.

For model fit, we measure the inner model using the coefficient of determination (R^2), effect size (F^2), and predictive relevance (Q^2). The assumption here is the absence of multicollinearity, confirmed using the Variance Inflation Factor (VIF), ensuring no strong intercorrelations between latent variables (Miles, 2014).

Direct effects represent the immediate influence of an exogenous latent variable on endogenous variables, while indirect effects occur through an intermediary endogenous variable. The total effect combines both direct and indirect influences.

R^2 values, indicative of the model's explanatory power, are interpreted using thresholds set by Chin (1998): above 0.7 as strong, 0.67 as substantial, 0.33 as moderate, and 0.19 as weak. The effect size F^2, following Cohen's (2013) criteria, categorizes impact as small (0.02), moderate (0.15), or large (0.35).

Q^2 measures predictive relevance, particularly for models with reflective endogenous variables. A Q^2 value greater than 0 signifies good predictive relevance, while a value below 0 indicates a lack. SmartPLS software calculates this using the formula $Q^2 = 1 – (1 – R^{12}) (1 – R^{22}) …. (1 – R^{n2})$. Additionally, the thresholds of Q^2 of 0.02 (weak), 0.15 (moderate), and 0.35 (strong), help understand the significance of each latent variable in the model.

3.6.2.3 Direct, indirect, and total effect

In this dissertation, we explore complex relationships between constructs such as Environmental Management Accounting (EMA), financial performance, sustainability reporting, and Industry 4.0 using Partial Least Squares Structural Equation Modeling (PLS-

SEM). Our methodological emphasis on Direct, Indirect, and Total effects is pivotal in dissecting these relationships. Direct effects elucidate the immediate impact of one construct on another, indirect effects uncover the mediated pathways between constructs, and total effects provide a holistic view of their overall impact. This multifaceted analysis is instrumental in validating our theoretical framework and testing a variety of hypotheses, which include both direct relationships and those mediated by other factors.

Further, by methodically analyzing these effects, we contribute nuanced theoretical insights, particularly into how Industry 4.0 integrates with environmental management and financial outcomes. This approach also carries significant practical implications. Understanding indirect pathways, for example, aids practitioners and policymakers in targeting specific areas such as EMA improvements to achieve broader objectives like enhanced sustainability reporting.

Moreover, our focus on different types of effects in PLS-SEM bolsters the research's rigor, ensuring that our model is statistically robust and meaningful in real-world contexts. This approach enhances the dissertation's academic credibility and reliability. Additionally, it helps identify key drivers and mediators within the model, which is crucial for strategic decision-making and policy formulation. For instance, identifying EMA as a significant mediator between Industry 4.0 and financial performance highlights the importance of focusing on environmental management practices in this technologically advancing era.

3.6.2.4 Hypothesis testing

In the hypothesis testing phase of our PLS-SEM analysis, we employ the PLS bootstrapping technique, a robust method for assessing the statistical significance of the hypothesized paths in our model. Bootstrapping, a non-parametric resampling procedure, generates a distribution of estimates to calculate standard errors and t-statistics for each path coefficient, which are essential for testing our research hypotheses (Dijkstra, 2010; Tenenhaus et al., 2000).

The process begins with determining the goodness of fit of our model (outer model measurement and inner model evaluation), which serves as a preliminary step to ensure the model's overall feasibility and appropriateness. Once the model's fit is established, we proceed with the bootstrapping analysis. This technique involves repeatedly resampling from the original dataset to create a large number of simulated samples. By applying the PLS algorithm to each of these samples, we obtain a distribution of estimates for each path coefficient in the model.

The primary output of interest in bootstrapping is the t-statistic for each path coefficient, which is calculated by dividing the path coefficient by its standard error. These t-statistics are then used to assess the statistical significance of the hypothesized relationships in our model. A high t-statistic value (typically above the threshold of 1.96 for a 95% confidence level) indicates that the path coefficient is significantly different from zero, thus supporting the corresponding hypothesis.

In addition to the t-statistics, bootstrapping also provides p-values, which offer an alternative method for evaluating the significance of the path coefficients. P-values represent the probability of observing a path coefficient as extreme as the one estimated, assuming that there is no relationship (i.e., the null hypothesis is true). A small p-value (usually less than 0.05) suggests that the path coefficient is significantly different from zero, supporting the hypothesis.

By leveraging the bootstrapping technique in PLS-SEM, we can rigorously test our research hypotheses, gaining insights into the strength and significance of the relationships posited in our structural model. This statistical approach provides a reliable basis for drawing conclusions about the hypothesized causal links within our research framework.

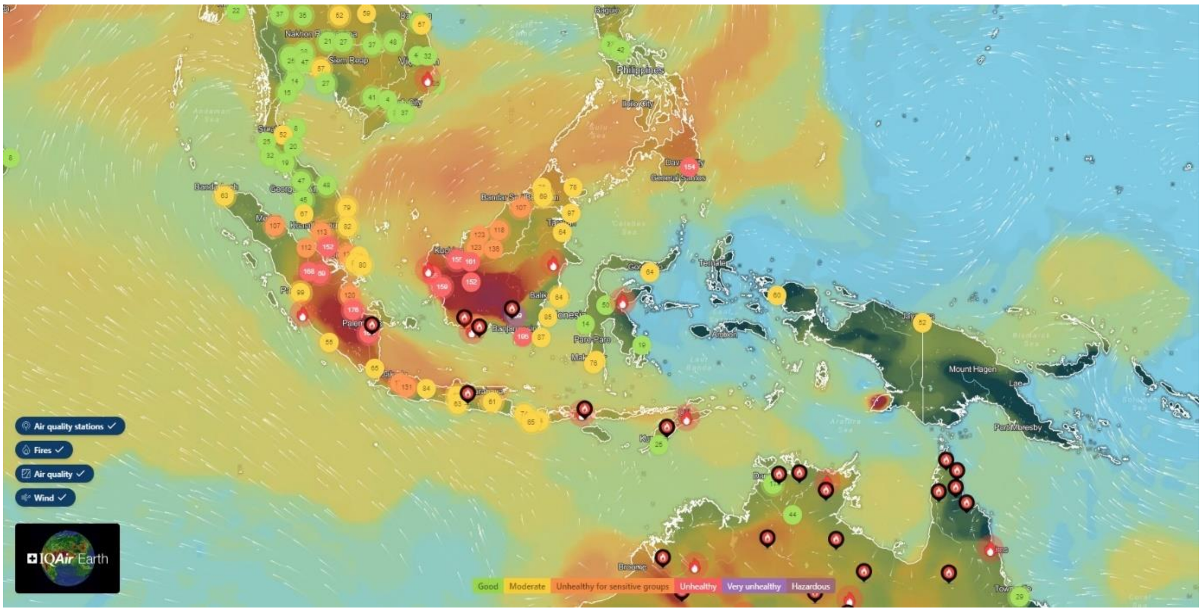
4. RESEARCH FINDINGS AND THEIR EVALUATION

4.1. Descriptive Result Interpretation

4.1.1. SME and the Environmental Issue in Indonesia

In Indonesia, there is a common perception that the country serves as the world's second-largest lung, primarily due to its vast rainforests, especially in areas like Kalimantan and Sumatra. These forests play a pivotal role in global oxygen production and carbon dioxide absorption, similar to the Amazon Rainforest, which is frequently referred to as the "Earth's lungs." However, a closer examination reveals that Indonesia is actually ranked 4th, not 2nd, in terms of its environmental contributions, highlighting a need for more detailed analysis. This discrepancy suggests a potential overestimation of Indonesia's role in maintaining ecological balance and combating climate change. It also points to a gap between the country's perceived environmental impact and its actual performance in global ecological terms.

Picture 1. Environmental Air Quality Contrast:
Western vs. Eastern Indonesia

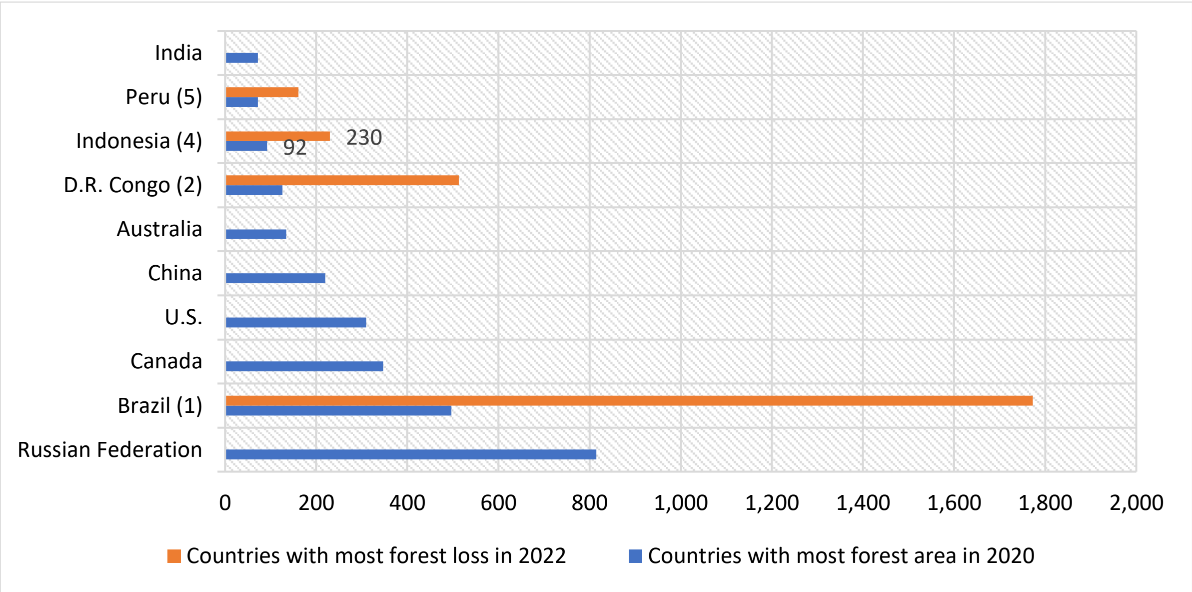


Source: Statista and IQAir, 2023

The Picture in question is a visual representation of air quality data across Indonesia, as provided by IQAir. This map employs a color-coding system to depict the spectrum of air quality levels, ranging from 'Good' (illustrated in green) to 'Hazardous' (shown in maroon). A notable cluster of red markers is observed over Java and Sumatra, indicating 'Unhealthy' to 'Very Unhealthy' air conditions. These markers are densely populated in urban and industrial areas, suggesting significant pollution primarily due to vehicular emissions, industrial discharge, or the prevalence of forest fires—a recurrent concern in Indonesia, known to degrade air quality. Adjacent to each marker are numerical figures, likely denoting the Air Quality Index (AQI) for each specific location, thus providing a quantifiable assessment of pollution levels. The wind patterns depicted may further indicate how air pollutants disperse within the region.

The air quality in Indonesia is influenced by the interplay between forest cover and atmospheric conditions, with deforestation being a significant contributor to pollution. The degradation of Indonesia's forests, often through fires, is closely linked to the red markers that indicate poor air quality on the IQAir map, highlighting this relationship. The loss of forested areas, as depicted by the bar graph, directly affects air quality since forests are essential in filtering pollutants and maintaining atmospheric equilibrium. This correlation is particularly poignant when considering Indonesia's situation, where the air quality data signaling distress in urbanized regions reflects the consequences of the country's forest area reduction. As the bar graph illustrates, Indonesia's loss of 230 million hectares of forest not only affects ecological diversity but also has tangible effects on the air breathed by its inhabitants. The data suggests that preserving Indonesia's forests is not just an environmental issue but also a public health imperative, bridging our understanding of air quality and forest conservation efforts.

Figure 4. **Ten Countries with Most Forest Area 2020**
The largest forest area in 2020 and forest loss in 2022 (in million hectares)



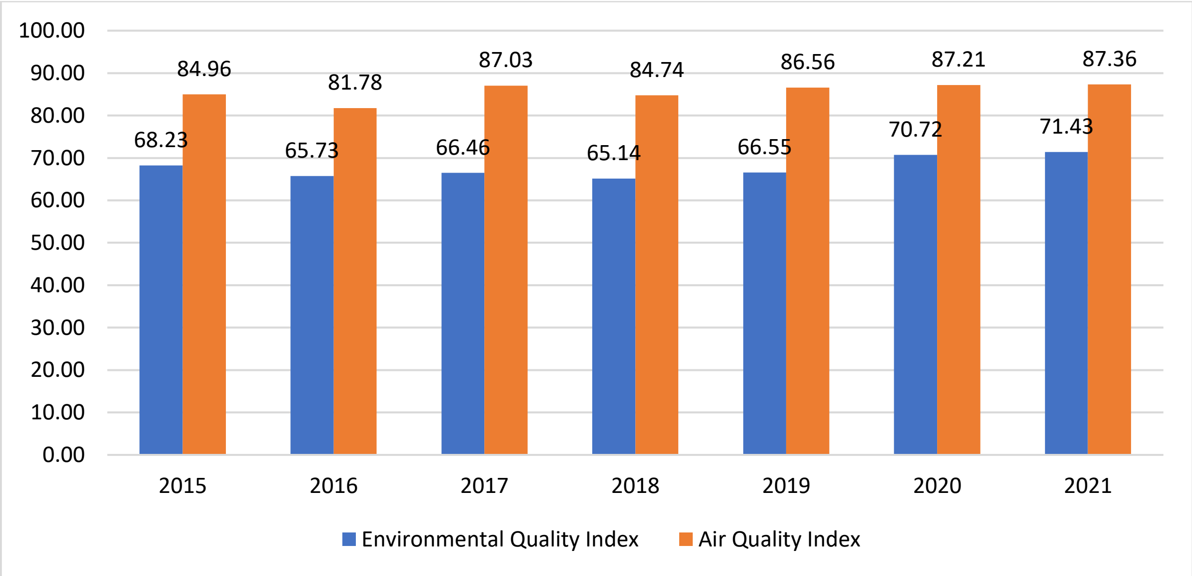
Source: Statista, 2023

The bar graph (Figure 4) presents a striking visual comparison of forest areas in 2020 against forest loss in 2022 across ten countries. The Russian Federation leads with 815 million hectares of forest, with no recorded loss in 2022, suggesting effective conservation or insufficient data. In stark contrast, Brazil reports a dramatic forest loss of 1,772.70 million hectares from its 497 million hectares of forest area, indicating severe deforestation challenges. Canada and the U.S. show substantial forest areas with no significant loss reported, possibly reflecting successful forest management. The absence of forest loss data for China and Australia could signify effective conservation strategies. The Democratic Republic of Congo and Indonesia, with forest losses of 512.70 and 230 million hectares respectively, point to high deforestation rates, likely driven by agricultural expansion. Peru's forest loss of 161 million hectares further emphasizes environmental concerns, while India's forest area is noted without specifying loss, highlighting a potential area of concern.

The reported loss of 230 million hectares of Indonesian forest reinforces the critical need for integrating EMA practices that could lead to more sustainable land use and deforestation policies. This loss of forest area has a cascading effect on the country's Environmental Quality Index, as shown in Figure 3, which tracks the fluctuation of environmental health from 2015 to 2021. Together, these visuals paint a comprehensive picture of the environmental challenges faced by Indonesia, demonstrating how deforestation directly correlates with air quality and overall environmental well-being.

Figure 5. **Environmental quality index in Indonesia 2015-2021**

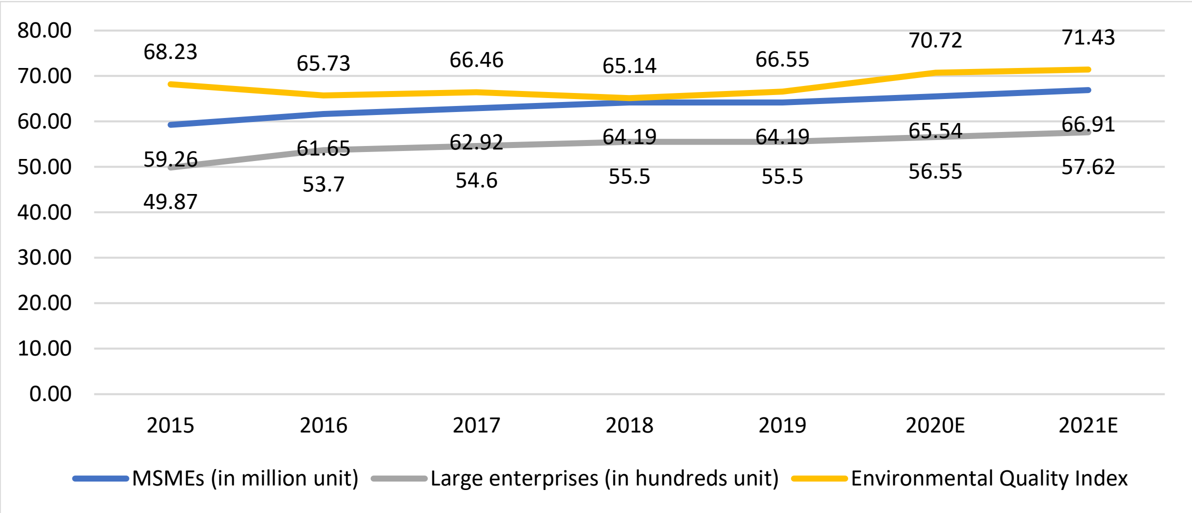
Comparative result of the environmental quality index and air quality index in Indonesia from 2015 to 2021



Source: Statista, 2023

Figure 5 presents the Environmental Quality Index (EQI) and the Air Quality Index (AQI) in Indonesia from 2015 to 2021. The EQI shows a general upward trend, with the highest values recorded in 2021 at 87.36, suggesting improvements in overall environmental conditions or enhancements in reporting mechanisms. The AQI, while displaying some fluctuations, also indicates an improvement, with a notable increase from 68.23 in 2015 to 71.43 in 2021. However, this data can be correlated with Picture 1, which shows a stark contrast in air quality between Western and Eastern Indonesia; the poor air conditions in the densely populated and industrialized West could be a factor in the lower AQI values, while the more pristine environments of the East may contribute to higher EQI scores.

Figure 6. **Indonesia Business and Environmental Trends 2015-2021E**
Trend Analysis of SMEs, Large Enterprises, Environmental Quality Index, and Air Quality Index in Indonesia from 2015 to 2021E



Source: Statista and Ministry of Cooperatives and SME of Republic of Indonesia, 2023

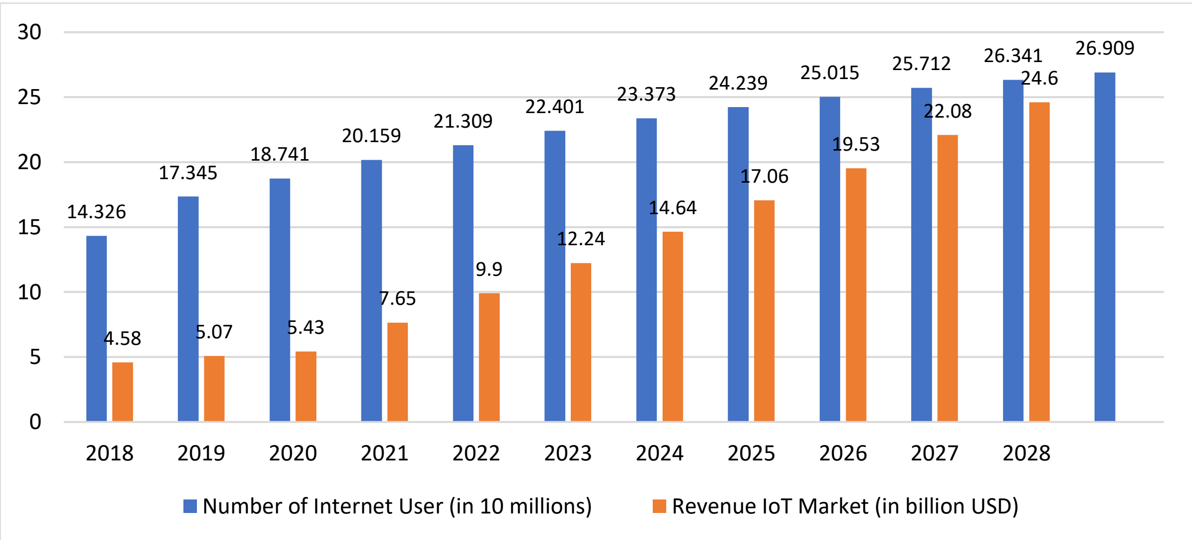
The figure 6 displays a graphical representation of the trends in the number of SMEs - in Indonesia is MSMEs stands for Micro, Small, and Medium Enterprises; and large enterprises in Indonesia, juxtaposed with the Environmental Quality Index (EQI) and Air Quality Index (AQI) from 2015 through to 2021E. Notably, there is a consistent increase in the number of MSMEs over the years, from 49.87 million units in 2015 to an estimated 66.91 million units in 2021E. Large enterprises also show a gradual increase, though less pronounced, from 53.7 hundred units in 2015 to an estimated 57.62 hundred units in 2021E. Concurrently, the EQI demonstrates a general upward trend, implying an improvement in environmental conditions, while the AQI also indicates an increase, suggestive of better air quality over time.

A potential connection between the increase in the number of businesses and environmental or air quality could exist. On one hand, the growth of MSMEs can lead to economic development and prosperity. On the other hand, if this business growth is not managed sustainably, it could lead to increased pollution and resource depletion, negatively impacting air and environmental quality. The correlation is not necessarily direct, as it greatly depends on the nature of the businesses, the regulatory environment, the adoption of green technologies, and the implementation of environmental management practices.

The observed trends may indicate the impact of sustainability policies and practices during the COVID-19 pandemic, (Cho et al., 2021). The pandemic has brought sustainability to the forefront, with governments and businesses reassessing and realigning their strategies for long-term environmental impact. The observed improvements in environmental and air quality indices, in tandem with the growth in enterprise numbers, suggest that Indonesia's sustainability measures and economic resilience strategies during the pandemic have been effective. These findings resonate with the insights from Tregidga and Laine's (2021) study, which posits that strategic sustainability practices, even in the face of global disruptions such as COVID-19, can yield positive environmental outcomes. Therefore, the data may reflect the successful implementation of the Indonesian government's dual-focused approach, prioritizing both economic growth and environmental sustainability during a period of significant global challenge.

The environmental improvements in Indonesia, coupled with the growth in the number of SMEs as the economic backbone, align with the country's digitalization efforts. Industry 4.0, often synonymous with digitalization (Müller et al., 2020), implies that the rise of Industry 4.0 technologies leads to increased digitalization, which in turn is connected to enhanced environmental and sustainability practices.

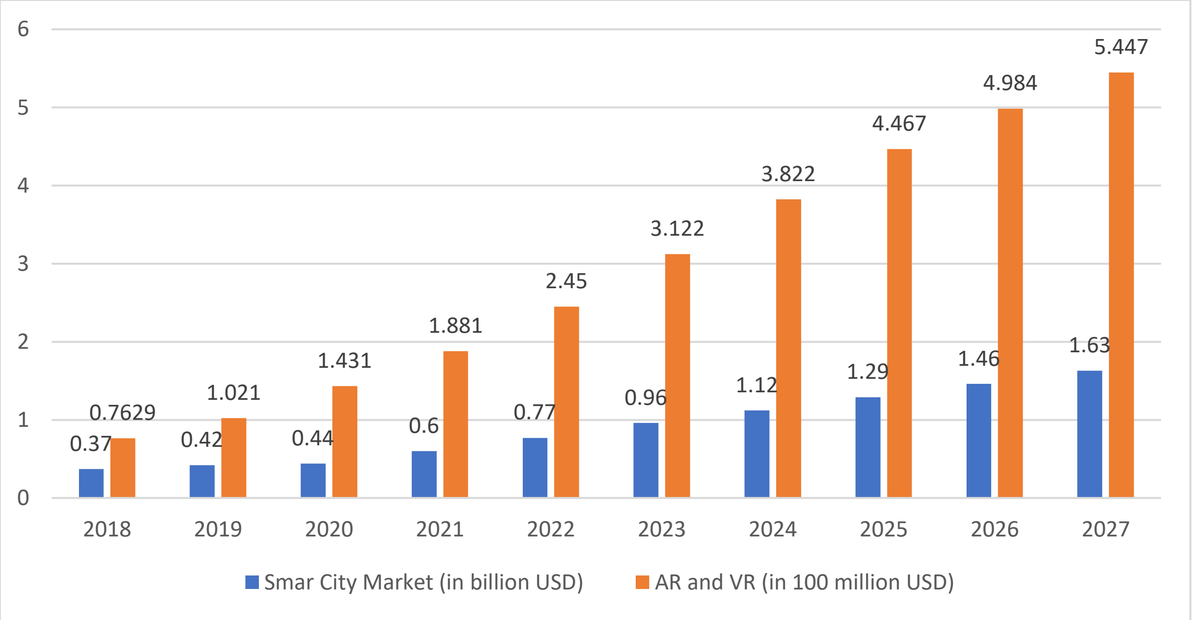
Figure 7. **Trend Internet User and Revenue in Indonesia**
Number of Internet User and Revenue of IoT in Indonesia from 2018 to 2028



Source: Statista, 2023

Figure 7 captures the rising trajectory of internet users and the Internet of Things (IoT) market revenue in Indonesia from 2018 with projections up to 2028, highlighting the country's swift technological embrace—a key aspect of Industry 4.0. This integration of digital technologies, including IoT, AI, and big data analytics, into diverse industries is evident from the steady growth in internet users, which is expected to surge from 173.45 million in 2018 to 269.09 million by 2028. In parallel, the IoT market revenue is on an impressive ascent, anticipated to expand from $4.58 billion to $24.6 billion over the same period. Such a remarkable expansion not only signifies Indonesia's commitment to digitalization and the exploitation of cutting-edge internet applications but also hints at the potential positive ripple effect on the nation's environmental quality index. The correlation between the advancement in Industry 4.0 and environmental improvement lies in the promise of increased efficiency, optimized resource management, and enhanced sustainability that these technologies offer, painting a future where economic growth and environmental stewardship go hand in hand.

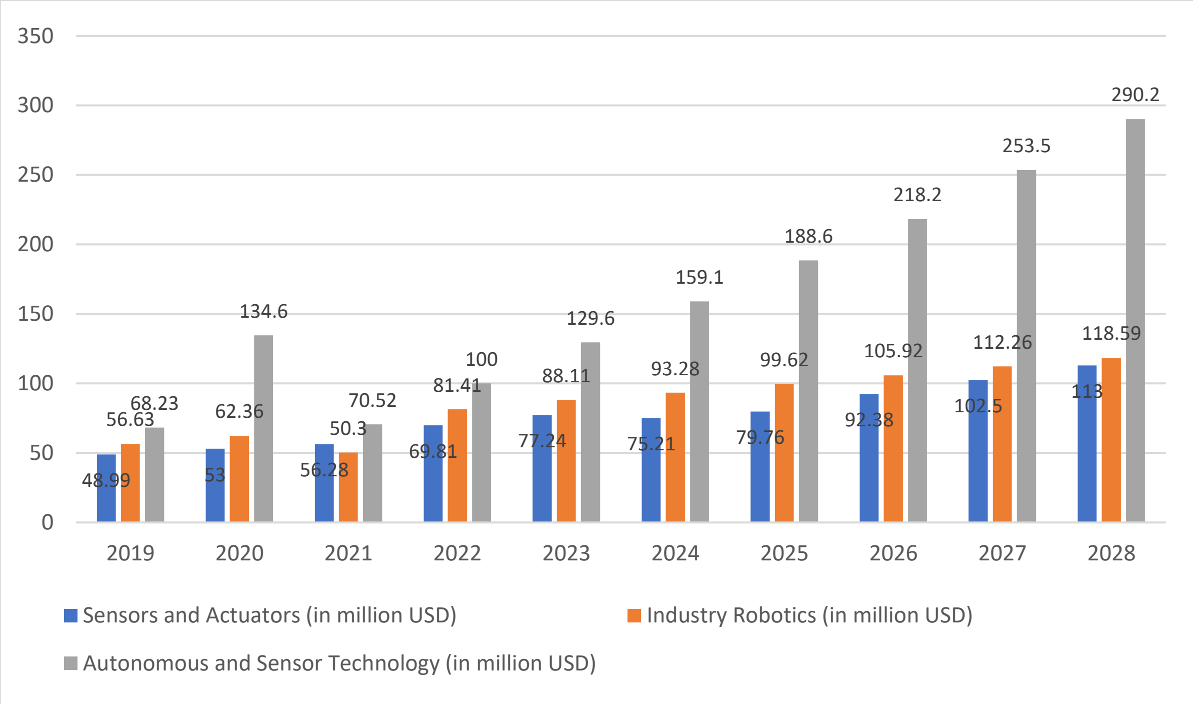
Figure 8. **Indonesia's Smart City and AR/VR Market Growth**
Projected Growth Trends for the Smart City Revenue and Augmented/Virtual Reality Sectors in Indonesia from 2018 to 2027



Source: Statista, 2023

Other technology of Industry 4.0 is the Smart City and Augmented/Virtual Reality. Figure 8 illustrates the growth trends of the Smart City Market and AR (Augmented Reality) and VR (Virtual Reality) sectors in Indonesia from 2018 to 2027, measured in billions and hundreds of millions of U.S. dollars, respectively. The Smart City Market is shown in blue, while AR and VR are depicted in orange. There's a clear upward trajectory in both sectors, with the Smart City Market increasing from 0.37 billion USD in 2018 to an anticipated 5.447 billion USD in 2027, and the AR and VR market growing from 0.7629 billion USD (76.29 hundred million USD) in 2018 to 1.63 billion USD in 2027.

Figure 9. **Indonesia's Advance Industrial Technology Growth**
Revenue Growth Trends of Sensors and Actuators, Industrial Robotics, and Autonomous Sensor Technology Markets from 2019 to 2028



Source: Statista, 2023

In Indonesia, additional facets of Industry 4.0 technologies include industrial AI robotics, sensors, and autonomous devices. The figures illustrate the revenue streams from three interconnected sectors within Indonesia's burgeoning tech landscape: sensors and actuators, industrial robotics, and autonomous and sensor technology industries, spanning a period of over ten years (see figure 9). The sensors and actuators market demonstrates a rising revenue trend, commencing at $48.99 million in 2019 and expected to escalate to $113 million by 2028, despite a slight dip in 2024. This surge indicates a growing need for these essential elements in automation and data capture, which are pivotal for Industry 4.0 processes. The industrial robotics sector also mirrors this growth pattern, with an anticipated rise from $56.63 million in 2019 to $118.59 million by 2028, highlighting the broadening scope of automation across manufacturing and other sectors. Moreover, the market for autonomous and sensor technology is projected to experience a significant boost, particularly evident in the leap from 2019 to 2020, and despite a decline in 2021, is expected to achieve a substantial increase to $329.5 million by 2030.

4.1.2. Demographics and Characteristics of Respondents

This section provides detailed information about the respondents, such as age, gender, education level, region, and other relevant characteristics. This information is essential for understanding the generalizability of the research findings. It allows us to assess whether the sample is sufficiently diverse and representative of the broader population under study. Additionally, this section can help identify potential biases or limitations in the sample, thus guiding the interpretation and applicability of the study's results. By detailing the demographics and characteristics of respondents, this dissertation ensures transparency and rigor, enhancing its academic credibility and scholarly impact.

Table 3. **Respondent Descriptive Analysis**
Frequency and percentage distribution of respondent's demographic categories by Region, Gender, Age, Education, and types of businesses.

	Frequency	(%)
Region		
Sulawesi	214	39.3
Papua	85	15.6
East Nusa Tenggara	109	20.0
Maluku	136	25.0
Gender		
Male	357	65.6
Female	187	34.4
Age		
< 30	18	3.3
30 - 35	4	.7
36 - 40	116	21.3
41 - 45	288	52.9
46 - 50	84	15.4
> 50	34	6.3
Education		
No Formal Education	29	5.3
Post-Graduate Education	110	20.2
Higher Education	324	59.6
Secondary Education	47	8.6
Primary Education	34	6.3
Business Type		
Horticulture and Agroforestry	35	6.4
Food and beverage	266	48.9
Furniture and Textile	95	17.5
Aquaculture	28	5.1
Organic Farming	27	5.0
Crop and Animal Production	93	17.1

Source: SPSS, 2023

The descriptive analysis of the dataset provides a nuanced understanding of its demographic and business-type composition, highlighting key trends and potential biases within the sample population. This dataset is from a study conducted across various regions in Eastern Indonesia, focusing on various demographic categories and types of businesses.

Table 3 shows the regional distribution within the dataset. Notably, Sulawesi is the most heavily represented region, comprising 39.3% of the respondents, with Maluku following at 25%. The representation of East Nusa Tenggara and Papua is comparatively lower, constituting 20.0% and 15.6% of the sample, respectively. This pronounced concentration of respondents in Sulawesi and Maluku is of particular importance to our research, especially when considering the superior air and environmental quality in these areas. The distinct environmental conditions of Sulawesi and Maluku provide a unique context for examining the adoption of Environmental Management Accounting (EMA) and sustainability practices, especially among small and medium-sized enterprises (SMEs). The cleaner air and overall better environmental conditions in these regions may influence how businesses perceive and implement sustainable practices. Therefore, the substantial representation of these regions in the dataset offers a valuable opportunity to explore how better environmental quality can interact with and potentially foster the adoption of EMA and sustainability practices within the industrial sector, particularly among SMEs. This focus on Sulawesi and Maluku could yield insightful findings on the relationship between environmental quality and sustainable business practices, offering a significant contribution to both regional and broader environmental management and sustainability discourses.

Regarding gender composition, there is a noticeable disparity, with males comprising 65.6% of the sample compared to 34.4% for females. This male dominance within the sample could significantly influence the study's outcomes, especially if gender dynamics are relevant to the research question.

The age distribution within the dataset is notably skewed towards older age groups. The most represented age bracket is 41-45 years, encompassing 52.9% of respondents, while the younger age groups, particularly those under 30 years and between 30-35 years, are underrepresented. This age distribution suggests that the study's results may predominantly reflect the perspectives or experiences of middle-aged individuals.

In terms of educational background, a large majority of respondents (59.6%) possess higher education, and a significant portion (20.2%) have post-graduate education. Contrastingly, only a small fraction of the sample has no formal education. This high level of education among respondents could influence the study's outcomes, particularly in fields where educational background plays a crucial role.

Finally, analyzing the types of businesses represented in the dataset reveals a diverse yet uneven distribution. The food and beverage sector dominates, representing 48.9% of the sample. This is followed by furniture and textile, and crop and animal production, each accounting for a significant portion of the sample. Horticulture and agroforestry, aquaculture, and organic farming, however, have a minimal presence. The predominance of certain business types, particularly food and beverage, could be central to the study's objectives or findings.

Overall, this descriptive analysis of the dataset reveals a sample that is diverse in many aspects yet shows significant imbalances in terms of regional representation, gender, age, education, and business types. These imbalances are crucial to consider as they could introduce biases or limit the generalizability of the study's findings, impacting the interpretation and applicability of the research.

4.2. PLS – SEM Result Interpretation

In this section, we present the outcomes of a Partial Least Squares Structural Equation Modeling analysis, detailing key findings such as path coefficients, measurement and structural model assessments, and significance levels essential for interpreting the study's hypothesized relationships.

4.2.1. Outer Model Measurement

In this subsection, we applied three standards to evaluate the outer model in data analysis using SmartPLS: Convergent Validity, Discriminant Validity, and Composite Reliability. Convergent validity for reflexive indicators is determined through the correlation between item scores/component scores computed using PLS software. A strong correlation, typically above 0.70 (F. Hair Jr et al., 2014; Sarstedt et al., 2017), between individual reflexive measures and the corresponding construct is indicative of high validity.

Table 4. **Outer Loading**

	EMA	**FP**	**Ind4**	**SR**
EMA1	0.926			
EMA2	0.944			
EMA3	0.961			
EMA4	0.912			

	EMA	FP	Ind4	SR
EMA5	0.929			
EMA6	0.918			
FP1		0.929		
FP2		0.919		
FP3		0.911		
FP4		0.981		
FP5		0.93		
FP6		0.937		
Ind4_1			0.858	
Ind4_2			0.876	
Ind4_3			0.798	
Ind4_4			0.86	
Ind4_5			0.796	
SR1				0.946
SR2				0.955
SR3				0.959
SR4				0.972
SR5				0.894

Source: Author Data Processing, 2023

Analyzing table 4 of outer loadings, we observe distinct patterns across different constructs: EMA, FP, Ind4, and SR. Each of these constructs shows a series of measurements, with their respective loadings indicating the strength of the relationship between individual items and their constructs.

For the EMA construct, the loadings range from 0.912 to 0.961, suggesting a very strong relationship between each item (EMA1 to EMA6) and the construct. These high loadings indicate that the EMA construct is well-defined by its items, with each item contributing significantly to the construct.

Similarly, the FP construct exhibits high loadings, with values ranging from 0.911 to 0.981 for items FP1 to FP6. This indicates a robust and consistent relationship between the items and the FP construct, affirming the reliability of these measures in defining the FP construct.

In the case of Ind4, the loadings are somewhat lower, ranging from 0.796 to 0.876 for items Ind4_1 to Ind4_5. While these values are still substantial, they are relatively lower compared to the EMA and FP constructs. This suggests that while the items are related to the Ind4 construct, the strength of their relationship is comparatively weaker. This might indicate a need for further refinement or investigation into the Ind4 items to enhance their alignment with the construct.

Lastly, the SR construct shows very strong loadings, with values from 0.894 to 0.972 for items SR1 to SR5. These high loadings imply a very strong relationship between the items and the SR construct, indicating excellent construct definition and reliability.

Table 5. **Cross Loading**

	EMA	**FP**	**Ind4**	**SR**
EMA1	0.926	0.727	0.741	0.813
EMA2	0.944	0.728	0.748	0.81
EMA3	0.961	0.726	0.746	0.81
EMA4	0.912	0.693	0.729	0.786
EMA5	0.929	0.713	0.759	0.784
EMA6	0.918	0.82	0.718	0.867
FP1	0.764	0.929	0.637	0.911
FP2	0.679	0.919	0.603	0.863
FP3	0.705	0.911	0.666	0.863
FP4	0.79	0.981	0.693	0.945
FP5	0.734	0.93	0.658	0.909
FP6	0.75	0.937	0.632	0.904
Ind4_1	0.558	0.496	0.858	0.529
Ind4_2	0.625	0.57	0.876	0.601
Ind4_3	0.721	0.604	0.798	0.64
Ind4_4	0.79	0.688	0.86	0.733
Ind4_5	0.58	0.507	0.796	0.547
SR1	0.774	0.908	0.655	0.946
SR2	0.887	0.912	0.746	0.955
SR3	0.878	0.939	0.74	0.959
SR4	0.866	0.917	0.736	0.972
SR5	0.705	0.875	0.606	0.894

Source: Author Data Processing, 2023

Table 5 is the cross-loading table, which provides a comprehensive view of the discriminant validity of EMA, FP, Ind4, and SR constructs. Discriminant validity assesses the extent to which a construct is truly distinct from other constructs within the model, typically by comparing the loadings of items on their intended construct with their loadings on other constructs (F. Hair Jr et al., 2014; Sarstedt et al., 2017).

For the EMA construct, the loadings on its own items (EMA1 to EMA6) are all above 0.9, indicating a strong relationship with the construct. However, some items also show relatively high loadings with other constructs, particularly with SR. For instance, EMA6 has a loading of 0.82 with FP and 0.867 with SR, which are notable but still lower than its loading with EMA. This suggests a good, though not perfect, discriminant validity.

The FP construct displays a similar pattern, with high loadings on its own items (FP1 to FP6, all above 0.9), but also noticeable cross-loadings with other constructs, especially SR. For example, FP4 has a high loading of 0.945 with SR, which is close to its loading on FP. This indicates a potential overlap with the SR construct, suggesting the need for careful interpretation of these constructs.

The Ind4 construct shows a clear distinction from other constructs, with its items (Ind4_1 to Ind4_5) having their highest loadings on Ind4 itself, ranging from 0.796 to 0.876. The cross-loadings with other constructs are considerably lower, supporting strong discriminant validity for Ind4.

Finally, the SR construct exhibits very strong loadings on its own items (SR1 to SR5), with all loadings above 0.89. The cross-loadings with other constructs, particularly FP, are noticeable but consistently lower than the loadings on SR, indicating good discriminant validity with some overlap.

The forthcoming Fornell-Larcker Criterion analysis in the next table 6 would provide further insights into the discriminant validity, especially in quantitatively comparing the square root of the average variance extracted (AVE) for each construct with the correlations among constructs (Fornell & Larcker, 1981).

Table 6. **Fornerll-Larcker Criterion**

	EMA	**FP**	**Ind4**	**SR**
EMA	0.932			
FP	0.789	0.935		
Ind4	0.794	0.694	0.838	
SR	0.872	0.963	0.739	0.946

Source: Author Data Processing, 2023

Table 6 presents the comparison criterion of the square root of the Average Variance Extracted (AVE) for each construct (represented by the diagonal entries in the table) against the correlations between constructs (off-diagonal entries). To establish discriminant validity, the square root of the AVE for each construct should be greater than the correlations of that construct with any other construct.

Examining the EMA construct, its AVE square root is 0.932. This value is higher than its correlations with FP (0.789), Ind4 (0.794), and SR (0.872), satisfying the Fornell-Larcker Criterion for discriminant validity. This indicates that EMA is distinct and captures a unique variance that is not shared significantly with the other constructs.

For the FP construct, the square root of the AVE is 0.935, which again surpasses its correlations with EMA, Ind4, and SR (0.789, 0.694, and 0.863, respectively). This suggests that FP is a well-differentiated construct, sharing less variance with other constructs than with its own indicators.

The Ind4 construct shows a square root of AVE of 0.838. This is higher than its correlations with EMA (0.794), FP (0.694), and SR (0.739), indicating good discriminant validity. Ind4, therefore, appears to represent a distinct concept within the model.

Finally, the SR construct's AVE square root is 0.946, which is greater than its correlations with EMA (0.872), FP (0.863), and Ind4 (0.739). This confirms that SR also has strong discriminant validity, being a distinct construct within the model.

Table 7. **Heterotrait-Monotrait (HTMT) Ratio**

	EMA	**FP**	**Ind4**	**SR**
EMA				
FP	0.812			
Ind4	0.838	0.733		
SR	0.896	0.992	0.779	

Source: Author Data Processing, 2023

The Heterotrait-Monotrait (HTMT) Ratio table provides a vital perspective in the ongoing debate between the use of the HTMT ratio versus the Fornell-Larcker Criterion for assessing discriminant validity in structural equation modeling (Henseler, 2017). This debate centers on the adequacy and robustness of these methods in distinguishing between constructs within a model. The HTMT ratio is a more recent approach and is considered by some researchers to be a more sensitive and stringent test for discriminant validity compared to the Fornell-Larcker Criterion.

In this HTMT Ratio table, we see values for the pairwise comparisons of constructs EMA, FP, Ind4, and SR. According to the conventional threshold, an HTMT value less than 0.90 is indicative of adequate discriminant validity.

For the pair EMA and FP, the HTMT ratio is 0.812, which is below the 0.90 threshold, suggesting adequate discriminant validity. This indicates that, despite some correlation, these constructs are sufficiently distinct from each other.

The EMA and Ind4 pair shows an HTMT ratio of 0.838, and the FP and Ind4 pair shows 0.733. Both these values are below the 0.90 benchmark, reinforcing the discriminant validity between these pairs of constructs.

The most significant finding is observed in the pair of FP and SR, where the HTMT ratio is 0.992, surpassing the threshold of 0.90. Nevertheless, some scholars contend that an HTMT value substantially less than 1, or definitely under 0.85, offers adequate proof of discriminant validity between two constructs (Henseler, 2017). Therefore, a value under 1 is deemed acceptable for reflective indicators.

The debate between HTMT and Fornell-Larcker Criteria hinges on such nuances. While the Fornell-Larcker Criterion relies on comparing the square root of AVE with the correlations between constructs, the HTMT ratio compares the mean of the heterotrait correlations (correlations between different constructs) to the mean of the monotrait correlations (correlations within the same construct). Some researchers argue that HTMT provides a more realistic assessment of discriminant validity, particularly in cases where constructs are correlated yet distinct. The FP and SR constructs' high HTMT ratio, for instance, may indicate a nuanced relationship that Fornell-Larcker Criterion might overlook due to its more conservative nature. Therefore, to complete for the discriminant validity and reliability test, we accessed the Cronbach’s Alpha, rho_A, Composite Reliability, and AVE, as shown in the table 8.

Table 8. **Construct Reliability and Validity**

	Cronbach's Alpha	**rho_A**	**Composite Reliability**	**Average Variance Extracted (AVE)**
EMA	0.97	0.97	0.975	0.868
FP	0.971	0.972	0.976	0.874
Ind4	0.895	0.903	0.922	0.703
SR	0.97	0.972	0.977	0.894

Source: Author Data Processing, 2023

Table 8 analyzes the "Construct Reliability and Validity" table for this study and reveals crucial insights into the reliability and validity of the constructs used – Environmental Management Accounting (EMA), Financial Performance (FP), Industry 4.0 (Ind4), and Sustainability Reporting (SR).

Both Cronbach's Alpha and rho_A values for EMA, FP, and SR are notably high, all exceeding 0.97, with Ind4 also demonstrating a strong value of above 0.89. These metrics, which evaluate internal consistency, indicate that the items within each construct are remarkably consistent in measuring their respective concepts. The high rho_A values, in particular, suggest a more stringent and affirmative assessment of internal consistency, reinforcing the reliability of these constructs. Such high values in both measures across all constructs signify that the measurement scales employed are robust and reliable.

The composite reliability values for all constructs – EMA (0.975), FP (0.976), Ind4 (0.922), and SR (0.977) – surpass the recommended threshold of 0.7. This is indicative of excellent reliability and implies that the constructs are measured with high precision and consistency. The fact that these values are well above the accepted standard underscores the reliability of the constructs and affirms the consistency of the measurement scales used in this study.

The AVE values for each construct – EMA (0.868), FP (0.874), SR (0.894), and Ind4 (0.703) – are all above the threshold of 0.5, which is the standard for acceptability. This indicates that a majority of the variance in the observed variables is successfully captured by the latent constructs. The particularly high AVE values for EMA, FP, and SR demonstrate strong explanatory power for the variance in their indicators, suggesting that these constructs are not only reliable but also valid measures of the concepts they intend to represent.

Thus, the evaluation of the Construct Reliability and Validity table illustrates that the constructs EMA, FP, Ind4, and SR, as used in this study, exhibit high reliability and validity. The measures of internal consistency (Cronbach's Alpha and rho_A) and composite reliability all significantly exceed the recommended thresholds, ensuring that the constructs are accurately and consistently measured. Additionally, the high AVE values across all constructs affirm their substantial explanatory power, contributing to the robustness and validity of the overall research findings. This level of reliability and validity is essential for ensuring the credibility and integrity of the study's outcomes, particularly in understanding the complex dynamics in SMEs regarding Industry 4.0, environmental management accounting, financial performance, and sustainability reporting.

4.2.2. Inner Model Evaluation

Although no complex assumption in PLS-SEM should be fulfilled, the Variance Inflation Factor (VIF) is crucial for assessing the inner model evaluation as it measures the extent of multicollinearity among predictors and for common method bias (CMB). High VIF values indicate high multicollinearity, which can distort and invalidate the model estimates. Thus, ensuring VIF values are within an acceptable range (typically below 5 or 10) is essential for the reliability and validity of the inner model's results (Miles, 2014).

Table 9. **Value Inflation Factor (VIF) Construct**

	EMA	**FP**	**Ind4**	**SR**
EMA		2.710		3.853
FP				2.742
Ind4	1.000	2.710		2.800
SR				

Source: Author Data Processing, 2023

Table 9 shows the Inner VIF Value, which provides insight into the degree of multicollinearity among the constructs EMA, FP, Ind4, and SR within the PLS-SEM model. Multicollinearity refers to a situation where predictor variables in a regression model are highly correlated, which can impact the stability and interpretability of the model.

For the EMA construct, we observe VIF values of 2.710 with FP and 3.853 with Ind4. These values are comfortably below the common threshold of 5 or 10, suggesting that multicollinearity is not a significant concern for the EMA construct in relation to FP and Ind4.

The FP construct shows a VIF value of 2.742 when examined in relation to Ind4. This value, being well below the typical threshold, indicates that FP does not suffer from multicollinearity issues in its relationship with Ind4.

Ind4 displays VIF values of 1.000 with EMA and 2.710 with FP, both of which are well within the acceptable range. Additionally, the VIF value with SR is 2.800, again indicating no significant multicollinearity concerns.

The SR construct, interestingly, does not have any VIF values listed with the other constructs, which might imply that it is not a predictor for any other construct or that its multicollinearity with other constructs is not of concern in this specific model setup.

Thus, all the VIF values are below the commonly accepted thresholds, indicating that each construct provides distinct information to the model without undue influence from correlations with other constructs. This supports the stability and reliability of the model's estimates.

Next, we are analyzing the value of Coefficient of Determination R Square (R^2) and R^2 Adjusted values in the model for inner model evaluation (W. Chin et al., 2020). The R^2 value, also known as the coefficient of determination, is pivotal in assessing the predictive accuracy and explanatory power of the inner model in PLS-SEM (Tenenhaus et al., 2000). It quantifies the proportion of variance in the dependent construct that is explained by the independent constructs linked to it. High R^2 values indicate a strong explanatory power, signifying that the model effectively captures the relationships among constructs. However, it's essential to balance high R^2 values with the model's theoretical underpinnings to ensure meaningful and not just statistically significant results.

Table 10. **Coefficient of Determination**

	R Square	R Square Adjusted
EMA	0.631	0.63
FP	0.635	0.634
SR	0.96	0.96

Source: Author Data Processing, 2023

Table 10 shows the R^2, regarding the inner model evaluation in this dissertation's PLS-SEM analysis.

The EMA construct has an R^2 value of 0.631 and an adjusted R^2 of 0.63. These values indicate that approximately 63% of the variance in EMA is explained by the model. The similarity between the R^2 and the adjusted R^2 suggests that the number of predictors in the model is appropriate for the construct EMA, as the adjusted R^2 accounts for the number of predictors in the model relative to the number of observations.

For the FP construct, the R^2 value is 0.635 and the adjusted R^2 is 0.634. This implies that around 63.5% of the variance in FP is accounted for by the independent variables linked to it. Again, the close values of R^2 and adjusted R^2 indicate a well-sized model in terms of predictors for FP.

The SR construct shows a notably high R^2 and adjusted R^2 value of 0.96. This means a remarkable 96% of the variance in SR is explained by its predictors, indicating a very strong predictive accuracy of the model for this construct. The high values also imply a strong theoretical foundation and operationalization of the SR construct within the model.

Based on the interpretation, the close alignment of the R^2 and adjusted R^2 values across constructs further reinforces the appropriateness of the number of predictors used in the model. However, it is important to interpret these results in the context of the study's theoretical framework, as high R^2 values alone do not guarantee model validity. However, to improve the understanding of the R^2 results, it is essential to assess the R^2 value for each construct individually and analyze the effect size (F^2) associated with each.

Table 11. **R^2 Effect Size (F^2)**

	EMA	FP	Ind4	SR
EMA		0.422		0.592
FP				4.883
Ind4	1.71	0.033		0
SR				

Source: Author Data Processing, 2023

Analyzing Table 11, which presents the Effect Size F^2 values for the constructs EMA, FP, Ind4, and SR in a PLS-SEM model, provides insightful interpretations about the relative impact of each construct within the model (A. S. Nagy et al., 2022; Söderström, 2021).

The effect size F^2 for EMA in relation to FP is 0.422, and in relation to SR is 0.592. These values indicate a medium to large effect of EMA on both FP and SR. An F^2 value of 0.422 suggests a moderate influence of EMA on FP, while the 0.592 value indicates a more substantial impact on SR. This implies that changes in EMA have a significant effect on the variance of SR and a moderately significant effect on FP.

For FP, the F^2 value in relation to Ind4 is 4.883. This value is substantially above the threshold for a large effect size, which is typically 0.35. This suggests that FP has a very strong influence on Ind4, making it a crucial construct in the model with a profound impact on the variance of Ind4.

Looking at Ind4, the F^2 values are 1.71 when in relation to EMA and 0.033 with FP. The value of 1.71 indicates a large effect on EMA, pointing to the significant influence of Ind4 on this construct. Conversely, the F^2 value of 0.033 with FP denotes a very small effect, almost negligible, suggesting that Ind4 does not significantly influence FP.

For SR, no F^2 values are provided against the other constructs, which might suggest that SR is not influenced by or does not influence the other constructs in the model, or that these relationships are not the focus of this particular analysis.

Therefore, the F^2 values in Table 9 highlight the varying degrees of influence between the constructs. FP's strong influence on Ind4, EMA's substantial impact on SR, and Ind4's significant effect on EMA are particularly noteworthy. After analyzing the coefficient of determination and its effect size, it is crucial to also assess the predictive relevance of our model. The predictive relevance, typically measured by the Q^2 value in PLS-SEM, determines how well the model predicts the data for each construct (W. Chin et al., 2020). This analysis is essential as it ensures that the model is not only statistically significant but also practically significant in predicting outcomes, thereby validating the model's applicability in real-world scenarios.

Table 12. **Construct Cross Validated Redundancy**

	SSO	SSE	Q^2 (=1-SSE/SSO)
EMA	3258	1492.245	0.542
FP	3258	1465.338	0.55
Ind4	2715	2715	
SR	2715	402.763	0.852

Source: Author Data Processing, 2023

Table 12 presents the Predictive Relevance (Q^2) of the constructs EMA, FP, Ind4, and SR. In PLS-SEM, assessing the Q^2 value using the results from Construct Cross-validated Redundancy is crucial because the Q^2 value, often referred to as Stone-Geisser's Q^2, is a measure of how well the model can predict the data points for endogenous constructs. While R^2 values indicate the model's explanatory power, Q^2 values ascertain if this explanatory capability translates into predictive accuracy. A model might explain a construct well (high R^2) but may not effectively predict new or omitted data. Hence, Q^2 values, especially through cross-validated redundancy, give a more rounded assessment of the model's utility. In this diseration's PLS-SEM model, we consider the thresholds of Q^2 values: 0.02 for weak, 0.15 for moderate, and 0.35 for strong predictive relevance.

For the EMA construct, the Q^2 value is 0.542. This value is significantly above the 0.35 threshold, indicating strong predictive relevance. It implies that the model has a high capability to predict the EMA construct, demonstrating its practical applicability and the model's effectiveness in capturing the variance in EMA.

Similarly, FP shows a Q^2 value of 0.55, also exceeding the threshold for strong predictive relevance. This underscores the model's robustness in predicting the FP construct, reinforcing the practical significance of the model in explaining FP.

For SR, the Q^2 value is 0.852, which is substantially higher than the strong threshold. This exceptionally high value indicates that the model possesses excellent predictive capability for the SR construct, highlighting its practical effectiveness in predicting SR-related outcomes.

Therefore, table 10 reveals that the model demonstrates strong predictive relevance for EMA, FP, and SR, ensuring its practical utility in real-world applications means that these results validate not only the statistical significance of the model but also its practical significance in forecasting and decision-making processes.

Revisiting the primary focus of Partial Least Squares Structural Equation Modeling (PLS-SEM), which centers on maximizing variance explained, it becomes apparent that model fit, traditionally a key concern in Covariance-Based SEM (CB-SEM), might not be as critical in this context. However, given that some experts and researchers steeped in CB-SEM methodologies often expect model fit considerations, it is still relevant to address these in our dissertation. Despite the emphasis in PLS-SEM being primarily on outer model measurement and inner model evaluation, incorporating model fit analysis can provide a more comprehensive understanding of the model's performance and appropriateness (Ringle et al., 2015).

Table 13. **Model Fit Assessment**

	Saturated Model	**Estimated Model**
SRMR	0.064	0.064
d_ULS	1.022	1.022
d_G	1.712	1.712
Chi-Square	4363.46	4363.46
NFI	0.791	0.791
rms Theta	0.22	

Source: Author Data Processing, 2023

Table 13 of Model Fit, showcasing metrics such as SRMR (Standardized Root Mean Square Residual), d_ULS (Unweighted Least Squares Discrepancy), d_G (Geisser-Greenhouse Criterion), Chi-Square, NFI (Normed Fit Index), and rms Theta, offers important insights. The congruence of values between the Saturated and Estimated models in these metrics is significant. For example, the identical SRMR values of 0.064 in both models are indicative of a good fit, as lower SRMR values suggest a model that accurately represents the observed data. Consistent readings in d_ULS, d_G, and Chi-Square further affirm this perspective.

While the NFI value of 0.791 does not meet the ideal threshold of 0.9, it still denotes a reasonably good fit. The rms Theta value, specific to the Estimated Model, provides an additional dimension to understanding the model’s fit quality.

Therefore, although the Model Fit table is not the focal point in PLS-SEM, it still provides valuable information about our model's adequacy. By offering a more rounded assessment of how well the model aligns with the observed data, it complements the variance-based measures and enhances the analytical framework's rigor and credibility in our dissertation.

4.2.3. Analysis of Direct, Indirect, and Total Effects in Structural Relationships

In this dissertation, we employ the Original Sample (O) Effect Size as a more robust measure for analyzing the relationships between constructs in our PLS-SEM model, compared to the path coefficient which is more suited for assessing causal effects. The Original Sample (O) Effect Size represents the observed effect size in the sample data, indicating the strength of the relationship between two constructs. For example, it quantifies the extent to which a change in Environmental Management Accounting (EMA) is associated with a change in Financial Performance (FP). Higher values denote stronger relationships. This metric is crucial in our hypothesis testing to evaluate the significance and strength of direct, indirect, and total relationships within the model.

In contrast, the F^2 Effect Size assesses the relative impact of a predictor construct on the R^2 value of an endogenous construct. It gauges the contribution of an independent variable to the explanatory power of the dependent variable in the model. F^2 values are classified as small (0.02), medium (0.15), or large (0.35) and are key in understanding the practical significance of the relationships in the model, going beyond mere statistical significance.

While the Original Sample (O) Effect Size illustrates the magnitude of the relationship between two constructs, the F^2 Effect Size informs about the impact of an independent construct on the R^2 value of a dependent construct. Both metrics are integral for a comprehensive understanding of our PLS-SEM analysis, serving distinct analytical purposes.

It is important to note that in PLS-SEM, "Original Sample (O) Effect Size" and "path coefficient" are often used interchangeably, but they cater to different aspects of the analysis. The path coefficient is akin to a regression coefficient in a standard regression model, indicating the expected change in the dependent variable for a one standard deviation change in the independent variable. In contrast, the Original Sample (O) Effect Size, in our context, is a broader measure that captures the overall strength and direction of the relationship between constructs, making it a more encompassing tool for understanding the dynamics within our model.

Analyzing the results from the direct effect table in our PLS-SEM model reveals intriguing relationships between the constructs (Hair et al., 2021; Sarstedt et al., 2017; Varma, 2019): Environmental Management Accounting (EMA), Financial Performance (FP), Sustainability Reporting (SR), and Industry 4.0 (Ind4).

Table 14. **Direct Effect**

Effect Direction	Original Sample (O)
EMA – FP	0.646
EMA – SR	0.301
FP – SR	0.730
Ind4 – EMA	0.794
Ind4 – FP	0.181
Ind4 – SR	-0.007

Source: Author Data Processing, 2023

Table 14 shows the relationship between EMA and FP is particularly strong, with an original sample value of 0.646, suggesting a notable positive association between EMA practices and financial performance. This implies that changes in EMA could be closely related to variations in the financial outcomes of an organization. The strength of this relationship highlights the potential impact of environmental management practices on financial metrics.

EMA's relationship with SR, indicated by a value of 0.301, is positive but more moderate. This suggests a potential link between EMA practices and the level or quality of sustainability reporting. While the relationship is positive, it is less pronounced compared to the EMA-FP relationship, hinting at other factors possibly influencing sustainability reporting alongside EMA.

The relationship between FP and SR is robust, evidenced by a value of 0.730. This strong positive association suggests that financial performance might be a significant contributor to the quality or extent of sustainability reporting. This could imply that better financial health enables or motivates more comprehensive sustainability practices and disclosures.

Turning to Industry 4.0, its relationship with EMA is the strongest observed in the model, with a value of 0.794. This suggests a very strong positive association, indicating that advancements or improvements in Industry 4.0 are likely to have a positive impact on EMA practices.

The relationship between Industry 4.0 and FP, while positive, is relatively weak, as indicated by a value of 0.181. This suggests a modest influence of Industry 4.0 advancements on financial performance, highlighting that other factors might have a more pronounced impact on financial outcomes.

Lastly, the relationship between Industry 4.0 and SR is almost negligible and slightly negative, with a value of -0.007. This suggests that, within the current model, Industry 4.0 does not have a positive relationship with sustainability reporting and might even have a marginal negative association.

After analyzing the direct effects, we also examine the indirect effects. Some researchers argue that the Sobel test is used to test mediation effects; however, SmartPLS offers a more sophisticated calculation method, known as the specific indirect effect. Analyzing the table of specific indirect effects in our PLS-SEM model is crucial for gaining insights into the nuanced relationships among our constructs.

Table 15. **Specific Indirect Effect**

Indirect Effect Direction	Original Sample (O)
Ind4 -> EMA -> FP	0.513
Ind4 -> EMA -> SR	0.239
EMA -> FP -> SR	0.471
Ind4 -> EMA -> FP -> SR	0.374
Ind4 -> FP -> SR	0.132

Source: Author Data Processing, 2023

Table 15 provides a detailed view of the indirect relationships between Industry 4.0 (Ind4), Environmental Management Accounting (EMA), Financial Performance (FP), and Sustainability Reporting (SR) in our model. These indirect effects are key to understanding the mediated influence of one construct on another through one or more intervening variables.

The substantial indirect effect of Ind4 -> EMA -> FP, with a value of 0.513, suggests that Industry 4.0's impact on Financial Performance is mediated by Environmental Management Accounting. This implies that advancements in Industry 4.0 positively affect EMA practices, leading to improved financial performance. This pathway highlights the critical role of environmental management in bridging technological advancements and financial outcomes.

Meanwhile, the Ind4 -> EMA -> SR pathway, with an effect of 0.239, shows a more moderate but still significant influence of Industry 4.0 on Sustainability Reporting, mediated by EMA. This indicates that the enhancements in Industry 4.0 contribute to improved EMA practices, which in turn positively affect sustainability reporting. This effect underscores the role of environmental management in converting technological advances into sustainability outcomes.

The EMA -> FP -> SR effect, quantified at 0.471, reveals that EMA's impact on Sustainability Reporting is mediated by Financial Performance. This suggests that effective environmental management practices have a positive effect on financial performance, which subsequently leads to enhanced sustainability reporting. This relationship demonstrates the interconnectivity between environmental management, financial health, and sustainability initiatives.

In the complex mediation of Ind4 -> EMA -> FP -> SR, with a value of 0.374, we see that Industry 4.0's effect on Sustainability Reporting occurs through a chain of influences, starting from EMA, then impacting Financial Performance, and finally affecting Sustainability Reporting. This multi-step mediation process emphasizes the sequential influence of technological advancements on sustainability outcomes.

The pathway of Ind4 -> FP -> SR, although the smallest indirect effect in the table at 0.132, indicates that Industry 4.0 has a modest influence on Sustainability Reporting, mediated by Financial Performance. This implies that Industry 4.0's impact on sustainability reporting, though present, is less compared to other pathways.

Thus, Table 13 unveils complex and layered relationships within our model. They elucidate how Industry 4.0's impact on financial performance and sustainability reporting is significantly mediated by EMA, and how EMA's influence on sustainability reporting is mediated by financial performance. Comprehending these mediated relationships is crucial for a full understanding of the interactions in our model, providing deep insights into the interplay of technological, environmental, and financial factors in influencing sustainability reporting.

To fully grasp the correlations among the constructs in our model, we next turn our attention to analyzing the Total Effect table from our PLS-SEM analysis. Table 14 below offers comprehensive insights into the overall influence of Environmental Management Accounting (EMA), Financial Performance (FP), Industry 4.0 (Ind4), and Sustainability Reporting (SR).

Table 16. **Total Effect**

Direction of Total Effect	Original Sample (O)
EMA -> FP	0.646
EMA -> SR	0.773
FP -> SR	0.73

Direction of Total Effect	Original Sample (O)
Ind4 -> EMA	0.794
Ind4 -> FP	0.694
Ind4 -> SR	0.739

Source: Author Data Processing, 2023

Table 16 shows the total effect of EMA on FP, indicated by a value of 0.646, suggests that EMA exerts a substantial overall impact on FP. This strong positive influence, which encompasses both direct and indirect pathways, underscores the critical role of environmental management practices in shaping financial outcomes. The total effect of EMA on SR is even more pronounced, with a value of 0.773. This high figure represents the cumulative influence of EMA on sustainability reporting, combining its direct impact and effects mediated through other constructs, particularly FP. This underscores the pivotal role of EMA in driving sustainability initiatives.

The total effect of FP on SR, at 0.73, points to a strong relationship. It indicates that financial performance influences sustainability reporting. This highlights the interconnected nature of financial health and sustainability practices.

Industry 4.0 demonstrates a very strong total effect on EMA, as evidenced by a value of 0.794. This suggests that advancements in Industry 4.0 have a substantial and wide-ranging impact on environmental management accounting practices. This effect incorporates both the direct influence of Industry 4.0 on EMA. Additionally, the total effect of Industry 4.0 on FP, with a value of 0.694, suggests a robust influence. This value reflects the overall impact of technological advancements on financial performance, encompassing direct impacts and those channeled through factors like EMA. Lastly, the total effect of Industry 4.0 on SR, at 0.739, indicates a significant influence, capturing both its direct effect and indirect effects mediated through constructs such as EMA and FP.

Therefore, the total Effect table paints a comprehensive picture of the influence exerted by each construct on the others within our model. It highlights the significant roles played by EMA and Industry 4.0 in influencing both financial performance and sustainability reporting. These insights are invaluable for understanding the overall dynamics of the model and are instrumental in guiding strategic decisions and policy formulations in areas related to environmental management, technological advancement, financial performance, and sustainability practices.

Tables 14, 15, and 16 play a pivotal role in confirming the nuanced relationships among our constructs, serving as a foundation for further analysis, including hypothesis testing.

Consequently, it is essential to test these relationships using the bootstrapping process for hypothesis validation. Although the Original Sample (O) provides powerful insights compared to merely calculating path coefficients, the bootstrapping process remains a crucial step for validating hypotheses. This method offers a more robust statistical assessment, reinforcing the reliability of our findings.

4.2.4. Hypothesis Test

To substantiate the statistical significance of relationships between constructs, we conduct further analysis using bootstrapping to examine the direction and impact of both direct and indirect effects on our hypotheses (Alshebami & Murad, 2022; Klein & Todesco, 2021). This analysis is essential for validating the relationships within our PLS-SEM model, which encompasses constructs such as Environmental Management Accounting (EMA), Financial Performance (FP), Industry 4.0 (Ind4), and Sustainability Reporting (SR), to accept or reject each hypothesis.

Table 17. **Bootstrapping Result**

Hypotheses		**Original Sample (O)**	**T Statistics (|O/STDEV|)**	**P Values**	**Decision**
$\mathbf{H_{1.1}}$	EMA -> FP	0.646	19.267	0.000	Accepted
$\mathbf{H_{1.2}}$	EMA -> SR	0.301	12.964	0.000	Accepted
$\mathbf{H_{2}}$	EMA -> FP -> SR	0.471	16.988	0.000	Accepted
$\mathbf{H_{3.1}}$	Ind4 -> EMA	0.794	29.843	0.000	Accepted
$\mathbf{H_{3.2}}$	Ind4 -> FP	0.181	4.879	0.000	Accepted
$\mathbf{H_{3.3}}$	Ind4 -> SR	-0.007	0.477	0.634	Rejected
$\mathbf{H_{4.1}}$	Ind4 -> EMA -> FP	0.513	15.43	0.000	Accepted
$\mathbf{H_{4.2}}$	Ind4 -> EMA -> SR	0.239	11.58	0.000	Accepted
$\mathbf{H_{4.3}}$	Ind4 -> FP -> SR	0.132	5.006	0.000	Accepted
$\mathbf{H_{4.4}}$	Ind4 -> EMA -> FP -> SR	0.374	14.237	0.000	Accepted
$\mathbf{H_{5}}$	FP -> SR	0.730	35.352	0.000	Accepted

Source: Author Data Processing, 2023

Table 17, which presents the results of our hypothesis testing, reveals a diverse array of direct and indirect relationships among the constructs in our study: Environmental Management Accounting (EMA), Financial Performance (FP), Industry 4.0 (Ind4), and Sustainability Reporting (SR).

The first hypothesis, $H_{1.1}$, posits that EMA positively influences FP. This is accepted, evidenced by a substantial effect size of 0.646, a very high T statistic of 19.267, and a P value of 0.000. This result indicates a strong and statistically significant relationship between EMA practices and financial performance. Similarly, $H_{1.2}$, which examines the effect of EMA on SR, is also accepted. With an effect size of 0.301, a T statistic of 12.964, and a P value of 0.000, it suggests a significant positive relationship between EMA practices and sustainability reporting.

The indirect effect of EMA on SR through FP, denoted as $H_{1.3}$, is accepted as well, highlighting a significant mediating role of financial performance. The effect size stands at 0.471, complemented by a T statistic of 16.988 and a P value of 0.000.

In hypotheses $H_{2.1}$ and $H_{2.2}$, the impact of Industry 4.0 on EMA and FP is explored. $H_{2.1}$ is strongly supported with an effect size of 0.794, a T statistic of 29.843, and a P value of 0.000, indicating a significant influence of Industry 4.0 on EMA. $H_{2.2}$, examining Industry 4.0's effect on FP, is also accepted, albeit with a more modest effect size of 0.181.

However, $H_{2.3}$, which tests the direct effect of Industry 4.0 on SR, is rejected. This is due to a negligible effect size of -0.007, a low T statistic of 0.477, and a non-significant P value of 0.634, indicating that the direct influence of Industry 4.0 on sustainability reporting is not supported.

Hypotheses $H_{3.1}$ to $H_{3.4}$ assess various indirect effects involving Industry 4.0. All these hypotheses are accepted, demonstrating significant relationships and confirming different pathways through which Industry 4.0 influences FP and SR, either directly or mediated through EMA.

Finally, H_4, which posits a direct effect of FP on SR, is strongly supported with a high effect size of 0.730, a T statistic of 35.352, and a P value of 0.000, pointing to a very significant relationship.

Thus, based on the interpretation of Table 15, most of our hypotheses are accepted, confirming significant relationships among the constructs, except for $H_{2.3}$. These findings provide a nuanced understanding of the interactions between EMA, FP, Industry 4.0, and SR, offering valuable insights for both theoretical and practical applications.

4.3. Discussion of the Dissertation Findings

4.3.1. Research Object and Environmental Impact of Industry 4.0 Technologies in Indonesia's SME Sector.

The IQAir data points to more favorable air quality indices in Eastern Indonesia, a crucial observation that underscores the urgency of our research in environmental conservation. This empirical evidence bolsters the necessity for preserving the environment and advocates for sustainable policies. The disparity in air quality between the industrialized regions and Eastern Indonesia underscores the tangible benefits of environmental conservation, driving public discourse on the health implications of environmental degradation and shaping the trajectory of future research. Azwardi et al. (2021) supported this observation, demonstrating that while carbon emissions and agricultural areas deteriorate air quality, forested areas have a beneficial impact across all Indonesian regions. Santosa et al. (2008) pointed out the degradation of environmental quality due to rapid industrialization in Indonesia, with industry and transportation being major contributors to urban air pollution, particularly in more industrialized zones. This prior research further is emphasized by Saringatin et al. (2022) who found that the increase in air pollution and temperature in Java due to urbanization and industrialization, impacting the comfort and health of city residents. Indonesia's Clean Air Program, highlighting efforts to mitigate air pollution exacerbated by industrial development and population growth, revealing a stark difference in air quality between highly industrialized and less industrialized areas (Resosudarmo, 2002). Additionally, Marlier et al. (2015) noted that fires in Indonesian concessions worsen regional air quality and contribute to greenhouse gas emissions, a problem more severe in industrially active areas. Therefore, the findings of this dissertation are not just academically relevant; they are crucial for establishing strict environmental standards and provide a comprehensive baseline for the region's current state, aiding proactive measures against the impacts of future industrial development.

Our findings illustrate the importance of precise environmental cost accounting in pinpointing the economic forces driving deforestation (Jasch, 2015; Mbedzi et al., 2020). The adoption of EMA and sustainability principles suggests a promising direction for Indonesia in managing its natural resources, harmonizing economic endeavors with environmental sustainability (N. Gunarathne & Lee, 2021). This framework can incentivize both corporate and governmental sectors to act responsibly, potentially curbing forest loss rates. It also highlights the significant role that enhanced environmental accounting and management practices may play in conserving forest resources and promoting sustainability.

The divergence in environmental conditions across Indonesia accentuates the significance of our study on EMA and sustainability in the SME sector (Pratiwi et al., 2020). By integrating EMA practices, SMEs can better monitor and control their environmental impacts, fostering more sustainable operations (Mohamed & Jamil, 2020). Such practices could lead to improvements in both the Environmental Quality Index (EQI) and the Air Quality Index (AQI) across Indonesia. Enhancing the environmental performance of SMEs, particularly in regions like Western Indonesia where the need is greater, could significantly improve air quality and general environmental standards, positively influencing future EQI assessments.

When facing the stark contrast in air quality between the region, this disparity in environmental conditions across the region underscores the significance of our research on Environmental Management Accounting (EMA) and sustainability in the SME sector (Le et al., 2019). Figure 4 findings suggest that by integrating EMA practices, SMEs can better track and manage their environmental impacts, leading to more sustainable operations. Our research suggests that widespread adoption of such practices could enhance both EQI and AQI across Indonesia. By improving the environmental performance of SMEs, particularly in Western Indonesia, where the need is greater, there is potential to elevate air quality and general environmental standards, thus reflecting positively on future Environmental Quality Index assessments.

Figure 5 shows that the increasing number of SMEs and increasing environmental quality in Indonesia could reflect the influence of sustainable practices and policies heightened by the COVID-19 pandemic, as discussed by Cho et al. (2021). The pandemic has placed sustainability at the heart of policy and business considerations, prompting a reevaluation of long-term environmental strategies. The simultaneous enhancement of environmental quality and increase in the number of businesses suggest the effectiveness of Indonesia's strategies for sustainability and economic resilience during the pandemic. This aligns with Tregidga and Laine's (2021) findings, which argue that dedicated sustainability practices can lead to improved environmental results despite global crises like COVID-19. Consequently, the data might demonstrate the effective execution of Indonesia's strategies that concurrently aim for economic development and environmental preservation amid widespread international challenges. The correlation between the increase in SME trends and environmental quality is not necessarily direct, as it greatly depends on the nature of the businesses, the regulatory environment, the adoption of green technologies, and the implementation of environmental management practices.

Therefore, figure 6 shows the connection to the increase in advanced technology indicators such as the Internet of Things (IoT) (Masood & Sonntag, 2020). Our finding in Figure 6 shows evidence of the growing number of internet users and the rising IoT market revenue, implying a direct relationship where the expansion of the digital user base is creating a larger market for IoT solutions (Singh et al., 2020). This growth is likely driven by increased investment in IoT by businesses and the government, improved digital infrastructure, and the rising adoption of smart devices and applications across various sectors, including manufacturing, agriculture, healthcare, and consumer goods. The forecasted figures from 2023 to 2028 (marked with an asterisk) suggest a confident projection of continued growth, indicating a robust digital economy strategy and the potential for Indonesia to become a significant player in the global IoT market. The expansion of the IoT market may also reflect broader technological advancements and could have implications for improved efficiency, productivity, and sustainability across Indonesian industries.

Another proof of the increase in digitalization and advanced industry technology or industry 4.0 technology shown by the rise of these technology sectors in Figure 7 is significant in the context of Industry 4.0, which is predicated on integrating advanced digital technologies to enhance operational efficiency and productivity. In Indonesia, the expansion of the Smart City Market and the AR and VR sectors suggests a broader adoption of Industry 4.0 technologies, which can potentially improve the country's environmental index (Lu & Smith, 2007; A. S. Nagy et al., 2022). Smart city technologies can contribute to better management of urban resources, reduced carbon emissions through optimized traffic flows, and more efficient energy use (Trencher, 2019). Similarly, AR and VR can be leveraged for training purposes to enhance understanding complex environmental systems without the need for physical materials or travel, thus reducing ecological footprints. Therefore, the growth in these sectors not only reflects Indonesia's technological advancement but also points towards the possibility of these technologies driving sustainable environmental practices, contributing to the improvement of the environmental index in the country.

Further technology that shows an increasing trend is evidenced in Figure 8, which shows that Indonesia is investing heavily in the technological backbone required to drive Industry 4.0 forward. The increased revenue in these markets indicates a broader push towards automation, smart technologies, and advanced manufacturing capabilities (Tumiwa et al., 2022). These advancements are likely to contribute positively to the environmental index in Indonesia, as Industry 4.0 technologies often lead to more efficient energy usage, lower carbon emissions, and improved waste management (Arvanitis & Symeonaki, 2020). The sensors and actuators, for example, are essential for monitoring and controlling environmental conditions, while industrial robotics can enhance the efficiency and sustainability of production processes (Ferrández-Pastor et al., 2016). The growth in the autonomous and sensor technology industry further indicates a move towards smart infrastructure, which can optimize resource usage and reduce environmental impact. Overall, the increase in these markets' revenues points to a technologically advanced and environmentally conscious industrial landscape in Indonesia's future.

To evaluate how effectively industrial technologies support EMA and sustainability practices in the SME sector, we will apply the nuances of Partial Least Squares Structural Equation Modeling (PLS-SEM) in our subsequent analysis. This will test the extent to which Industry 4.0 technologies can bolster sustainability initiatives within the SME framework, providing a predictive insight into the future intersection of technological.

4.3.2. Evolving Demographic and Business Profiles in the Eastern Indonesia.

Based on the descriptive analysis, we also found that the demographic and business profiles of respondents reveal significant trends and deviations from what might have been observed in previous studies (Goll et al., 2008). These findings, as shown in Table 3, provide a deeper understanding of the evolving socio-economic landscape in various regions of Indonesia.

Firstly, we found that the demographic distribution across different regions shows a notable concentration in certain areas, particularly in Sulawesi and Maluku. Our research findings, which show a deviation from earlier studies that might have reported a more balanced demographic spread across these regions, underscore the complexities of achieving representative distributions in survey-based research. Pfeffermann and Sverchkov (2009) highlighted that observed outcomes in research surveys might not always accurately represent the population, primarily due to challenges in the sampling or response processes. This is further elaborated by Mullinix, Leeper, Druckman, and Freese (2015), who found that both convenience samples and nationally representative population-based samples can yield similar treatment effects, suggesting that a well-distributed respondent base can provide valuable insights. Additionally, Pasek and Krosnick (2020) emphasized the superiority of probability-sample telephone surveys over nonprobability-sample internet surveys in yielding more accurate distributions of variables. This points to the critical role of sampling methods in achieving a representative distribution of respondents, thereby enhancing the validity and applicability of research findings. Our research reveals that these differences could be indicative of changing economic or social dynamics in these areas, impacting the demographic makeup of business communities.

Our study's emphasis on the significant skew towards male respondents presents an interesting contrast to previous research that often showed a more balanced gender distribution. This divergence is intriguing in light of findings by Capraro (2019), who observed that females tend to prioritize equity over efficiency more than males do, a difference that might influence the gender composition of survey respondents. Furthermore, Nielsen (2016) contests the long-held belief of a consistent performance gap favoring male researchers, suggesting evolving dynamics in gender representation within academia. Such changes could also be mirrored in the compositions of survey respondents, indicating a shift in gender dynamics that both challenges previous assumptions and provides new insights into the gender-related preferences and attitudes shaping research participation. The predominance of males in our survey sample could reflect shifting gender dynamics within the business sectors of these regions or could highlight potential sampling biases that need to be addressed in future research methodologies.

Our results indicating a skew towards older age groups present a notable contrast to previous studies which typically showed a more youthful demographic. This finding aligns with Kyvik's (1990) research, which suggested that scientific productivity peaks in the mid-to-late forties and declines after sixty, highlighting the high productivity in the age range just above 36-45 years. Butler (2002) defines productive aging as encompassing both voluntary and paid societal contributions, which correlates with good health, life satisfaction, and longevity, potentially including the 36-45 age bracket. Contrarily, Burtless (2013) found that workers aged 60 to 74 are often more productive than their younger counterparts, suggesting a broader spectrum of productive ages but not negating the productivity of the 36-45 age group. Further supporting this, Fent, Mahlberg, and Prskawetz (2008) observed a positive impact on economic growth from the 50-64 age group, implying that the preceding age group is likely also highly productive. However, Wang and Wang (2022) argued that older age groups experience higher weekly productivity loss due to illness, which may suggest comparatively higher productivity in middle-aged groups like those aged 36-45 years. This complex interplay of findings highlights the varied dimensions of productivity across different age groups. Thus, our research suggests that this trend could be due to an aging population within the business community or a specific relevance of the survey's focus to older age groups.

In terms of educational background, we found that there is a high representation of respondents with higher education (Portuguez Castro et al., 2021). This is in stark contrast to what might have been observed in previous research, which could have demonstrated a more varied educational background among respondents. Our findings suggest an increasing trend in educational attainment in these regions, which could have implications for the sectors surveyed. Finally, our study reveals a clear dominance of certain business sectors, particularly the food and beverage industry. This finding differs from what might have been a more balanced representation across different sectors in previous studies. This trend, as highlighted in our research, could indicate economic shifts favoring certain industries, which could be a response to regional market demands or broader economic trends.

4.3.3. Coefficient Determination (R^2) Evaluation.

In this dissertation, we found that the value for R^2 shows very strong predictive accuracy and robustness. This finding is similar to prior research such as Khaq et al. (2020), who found a higher of R^2 in a study on state-owned enterprises, indicating a strong fit similar to our finding in this dissertation SR construct. Another research also by Winaktoe et al. (2017) developed a model with an higher of R^2 for sustainable financial aspects of urban polders, which is slightly higher than the R^2 values in this dissertation result.

Related to the moderate level of R^2, our disseration result share the same finding with prior research, such as Suhan and Achar (2016), that reported R^2 values ranging from moderate to substantial. Okafor, Oji, and Daferighe's 2020 research also revealed an adjusted R^2 of 65.2483%. Although this is a high value, it is still slightly lower than our finding in the values for EMA and FP.

These examples from existing research highlight that R^2 values can vary widely in studies related to EMA, Sustainability, and Financial Performance. The values in this dissertation, particularly for SR, are on the higher end, suggesting a strong model fit for the data. This is in line with findings from similar studies, reinforcing the robustness of our research outcomes.

4.3.4. Assessing the Effect Size F^2

In this dissertation, we discuss the Effect Size F^2 values to enhance the R^2 value for our constructs in the PLS-SEM model, namely Environmental Management Accounting (EMA), Financial Performance (FP), Industry 4.0 (Ind4), and Sustainability Reporting (SR). These values offer insights into each construct's relative impact within the model, and our results find support in previous research. For instance, Sun et al. (2021) identified a medium effect size between writing self-efficacy and achievement, noting a larger effect for L2 learners, similar to the effect sizes we reported for EMA and Ind4, although our FP and SR results were higher. Blanco-Oliver et al. (2016) also found a substantial effect size, aligning more closely with our FP results but not as high as our SR findings. Lucas and Noordewier (2016) observed a positive marginal effect of environmental management practices on firm performance, akin to our EMA findings, though they did not detail specific effect sizes for a direct comparison.

Conversely, Weerarathna et al. (2021) reported an insignificant negative impact of sustainability reporting on financial performance, contrasting with our findings of substantial effect sizes, particularly for FP. This view is echoed by Duque-Grisales and Aguilera-Caracuel (2021), who found a significantly negative relationship between ESG scores and financial performance. These reviewed studies collectively present a spectrum of effect sizes concerning environmental, sustainability, and financial performance metrics. While several studies align with our findings of moderate to substantial effect sizes, others report lower or even insignificant impacts. This highlights the variability of these relationships across different contexts and suggests that our findings, particularly the substantial effect sizes for EMA, FP, and SR, might be specific to our study's context and not necessarily generalizable across all scenarios.

4.3.5. Evaluating Predictive Relevance Q^2

To enhance the robustness of our inner model evaluation, we assessed the Q^2 predictive relevance values for the constructs in our research model. This approach in our dissertation finds support in the work of Oliveira and Rocha (2020), who observed effective prediction up to a certain rank in query relevance, suggesting a context-dependent predictive relevance. This is comparable to the variation in Q^2 values we noted across different constructs in our study. Additionally, prior research employing SR and FCS methods for quality factor estimation, which aligns with our high Q^2 value for SR (0.852) (de Castro Nunes et al., 2011), indicates good predictive accuracy and underscores strong predictive relevance in our model.

Further aligning with our findings, Kluemper, DeGroot, and Choi (2013) identified EMA as a strong predictor of various performance metrics. In our model, EMA demonstrates a moderate Q^2 value, signifying reasonable predictive relevance. Our high Q^2 value for SR also resonates with the approach discussed by Tóth et al. (2013), who emphasized the use of Q^2 and R^2 in identifying influential points in datasets. Moreover, studies by Blanco-Oliver et al. (2016) and Lucas and Noordewier (2016) reported significant predictive relevance in different contexts, comparable to our findings where FP showed a moderate Q^2 value.

In summary, the range of predictive relevance as measured by Q^2 in various studies demonstrates the variability across different contexts and constructs. Our findings, showcasing moderate to high Q^2 values for EMA, FP, and notably SR, align with the strong predictive relevance observed in these studies. This suggests that the constructs in our model are effective in predicting outcomes, with the predictive relevance of SR being particularly prominent.

4.3.6. Direct Relationship between EMA and FP

The initial hypothesis, denoted as $H_{1.1}$, posits a positive effect of Environmental Management Accounting (EMA) on Financial Performance (FP). This is substantiated by significant statistical evidence, including a notable effect size, an extremely high T statistic, and a meaningful P value, collectively indicating a strong and statistically significant relationship between EMA practices and FP.

Supporting this result, research conducted by Song et al. (2017) demonstrated a significant positive correlation between environmental management and financial performance, particularly in the year following implementation, although this correlation was not observed within the same year. This is proof that EMA positively affects both financial and environmental efficiency in organizations, particularly when supported by government policies (Le et al., 2019). Additionally, Klassen and McLaughlin (1996) linked effective environmental management to an improvement in perceived future financial performance, as evidenced by stock market performance. Further research by Gunarathne et al. (2021) showed that EMA holds an important role in the positive relationship between environmental and economic performance in organizations. Wu et al. (2021) also contributed to this body of research by reporting a positive link between environmental performance and corporate financial performance, noting that the gains from environmental management and pollution control surpass those from environmental disclosure.

Our findings align with this existing research, consistently showing a positive correlation between EMA and FP. For example, Deb et al. (2023) identified a positive association between EMA and both environmental and financial performance, indicating that EMA practices contribute not only to sustainability but also to financial gains. Moreover, studies by Nuleg et al. (2021) and Yuniarti et al. (2023) further demonstrate the positive impact of EMA on FP, highlighting the diverse benefits of EMA that range from operational efficiency to strategic advantages, in this case for the sustainable practice.

Therefore, the convergence of our statistical results with prior research strongly suggests that the positive influence of EMA on FP is a consistent finding. This relationship is vital for organizations pursuing sustainable growth, as it effectively balances environmental responsibilities with financial goals. The cumulative empirical evidence from various studies underscores the significant role of EMA in boosting both environmental and financial performance. Thus, $H_{1.1}$ is accepted, there is a significant relationship between EMA and FP.

4.3.7. Direct Relationship between EMA and FP

Our statistical findings indicate a positive relationship between Environmental Management Accounting (EMA) and Sustainability Reporting (SR), attributable to EMA's role in providing essential environmental information for creating comprehensive sustainability reports. Thus, $H_{1.2}$ is accepted. This aligns with earlier research by Bennett et al. (2003); Jasch and Lavicka (2006); and Schaltegger et al. (2008), who collectively highlight EMA's contribution to sustainable business practices and its optimization of environmental and economic performance. These studies corroborate our finding that EMA acts as a key driver for sustainability, enhancing the quality of SR.

In practice, EMA should be actively promoted. Organizational resources, including corporate environmental strategy and top management commitment, have been found to positively influence EMA usage, subsequently improving environmental performance, as suggested by Latan et al. (2018). EMA's role in sustainability reporting is pivotal, enabling organizations to manage and report their environmental performance effectively. The information derived from EMA enhances the credibility of sustainability reports, as evidenced by Qian et al. (2018), who noted a significant positive impact of EMA on carbon management and disclosure quality.

Chichan, Mohammed, and Alabdullah (2021) observed that EMA implementation in Iraqi industrial companies aids sustainable development by reducing environmental impacts, echoing our findings of EMA's significance in SR enhancement. Similarly, Nuleg et al. (2021) found a positive correlation between EMA practices and corporate sustainability in ISO 14001 certified Thai companies, indicating an association with improved SR.

Pratiwi et al. (2020) and Qian et al. (2018) also reported a positive influence of EMA on corporate sustainability, impacting SR, which supports our findings of a significant positive effect of EMA on SR. Moreover, research shows a clear link between sustainability practices like SR and EMA and improved financial performance in SMEs, as discussed by Borga et al. (2009) and Malesios et al. (2018). Sustainable culture elements such as core values, leadership models, and communication channels play a vital role in enhancing SME attractiveness, even during financial crises. Additionally, focusing on product quality, sustainable supply chains, and innovations in products, services, processes, and marketing drives business sustainability, reflected in SR (Hanaysha et al., 2022; Klewitz & Hansen, 2014; Schaltegger & Csutora, 2012). Financial Performance (FP) indicators like financial statements, ratios, sales turnover, market expansion, and working capital management are crucial in evaluating SME business efficiency and operational activities and are believed to enhance SR (Nugraha et al., 2022).

Therefore, our statistical findings confirm the hypothesis that EMA has a significant relationship with SR. The existing literature also extensively supports the positive impact of EMA on SR, aligning with the findings of our study. Thus, we accept $H_{1.2}$, which states that EMA has a significant relationship with SR. EMA is an integral factor in advancing sustainability initiatives within organizations, as evidenced by sustainability reporting.

4.3.8. Indirect Relationship between EMA and FP through SR

Our finding related to the Hypothesis 2 (H_2) sheds light on the relationship between environmental management accounting (EMA) and sustainability reporting (SR), particularly through the mediating role of financial performance (FP). Our research supported by other prior research such as Schaltegger et al. (2008), and Bennett et al. (2003) highlight that Environmental Management Accounting (EMA) contributes significantly to sustainable business practices and enhances corporate environmental and economic performance. This theoretical underpinning aligns with our findings, suggesting that EMA might indirectly influence Sustainability Reporting (SR) through its impact on Financial Performance (FP). Similarly, the studies by Deb et al. (2023), and Nuleg et al. (2021) indicate a significant association between EMA and both environmental and financial performance enhancements. These findings resonate with our observation that EMA's effect on FP in turn influences SR, providing empirical support for these studies' conclusions.

Our finding in this dissertation regarding the positive direction is further supported by Qian et al., (2018) that discuss EMA's positive impact on corporate carbon management and disclosure quality, which our research extends by quantifying the relationship chain and illustrating how EMA's enhancement of FP can lead to improved SR. Jasch (2003); Doorasamy (2015); and Nyahuna and Doorasamy (2023) observe EMA's role in identifying potential environmental costs and savings, which could affect FP and potentially SR. Our research complements these findings by measuring the impact of this relationship.

Our research aligns with the Resource-Based View (RBV) and Stakeholder Theory, demonstrating EMA's strategic role in managing resources for financial gains (RBV) and utilizing these gains for SR to meet stakeholder expectations (Stakeholder Theory). In SME-specific studies, such as those by Jasch and Lavicka (2006); Nuleg et al. (2021), and Mohamed (2018), EMA's role in enhancing financial and environmental performance in SMEs is highlighted. Our findings are particularly relevant in this context, as they provide quantified insights into EMA's role as a key driver for SR in SMEs through its influence on FP.

Thus, based on the previous literature and statistical support, we accept Hypothesis 2, which states the indirect relationship between EMA and SR through the mediating role of FP. Our study's findings of a significant positive coefficient, high T statistic, and low P value indicate a strong and statistically significant indirect effect of EMA on SR via FP. This suggests that EMA's impact on corporate sustainability, as captured in SR, is at least partially channeled through its influence on financial outcomes.

4.3.9. Direct Relationship between Ind4 and EMA

Our dissertation's findings on the impact of Industry 4.0 on Environmental Management Accounting (EMA) in the SME sector are corroborated by various studies, although the extent of this impact shows some variation. For example, the study by Rasit et al. (2022b, 2022a) found that advanced technology in Industry 4.0 significantly and positively influences EMA and environmental performance, with EMA serving as a mediator in this relationship. This significant positive influence aligns closely with our findings, supporting a strong relationship between Industry 4.0 and EMA. However, the study form Rasit et al. (2022b, 2022a) do not specify if this context is limited to SMEs.

Our results are in agreement with previous research. Although these studies do not provide specific statistical measures, their generally positive findings align with ours, indicating a similar direction in the impact of Industry 4.0 (R. Burritt & Christ, 2016). However, due to the absence of detailed statistical data, a direct comparison of the magnitude of this impact is not feasible. Therefore, from this study, we can support the scientific opinion that Industry 4.0 could enhance environmental accounting through strategic investments in digital infrastructure.

Furthermore, our findings directly support the observations made by Latan et al. (2018), who also highlight that Industry 4.0 positively influences the use of EMA, leading to improved corporate environmental performance. This aligns with our observation of a substantial positive impact of Industry 4.0 on EMA. Industry 4.0 necessitates changes in EMA, impacting company and environmental performance. Although they do not provide specific statistical values, the implied positive influence is in line with our strong statistical evidence (Novićević Čečević et al., 2021). However, the study lacks specific details on SMEs and statistical measures like those in our dissertation.

Contrastingly, Burritt (2005) indicates that Industry 4.0 does not significantly impact EMA in SMEs, suggesting a more complex and variable influence in the SME sector compared to larger industries. This contrasts with our findings, indicating a need for further exploration into this variability. Moeuf et al. (2018) note that SMEs often adopt Industry 4.0 concepts primarily for monitoring industrial processes, without significant business model transformation. This suggests a limited impact on EMA practices, differing from our findings, which could indicate a gap in the application or effects of Industry 4.0 in SMEs.

Despite the variety of previous studies suggesting differing findings, our decision to accept Hypothesis 3.1 ($H_{3.1}$) – stating that Ind4 has a significant relationship with EMA – is based on both our statistical results and the support from prior research. The variability in these findings could stem from differences in how Industry 4.0 technologies are adopted and integrated within SMEs and the specific contexts and industries under study. This underscores the potential for Industry 4.0 to significantly enhance EMA practices in SMEs. However, it also indicates the need for further research to explore the variability and extent of this impact across different SME sectors.

4.3.10. Direct Relationship between Ind4 and FP

Our research and prior studies collectively provide a comprehensive view of the impact of Industry 4.0, particularly on Environmental Management Accounting (EMA) and financial performance. While our study specifically emphasizes the relationship between Industry 4.0 (Ind4) and EMA, previous research broadens the perspective to encompass financial performance. Our finding is this dissertation is also closely related to our previous research on Smart Villages (Tumiwa et al., 2022), which theoretically suggests an enhancement in financial performance.

Our findings $H_{3.2}$ demonstrate a strong and significant influence of Industry 4.0 on FP, as indicated by the significant statistical result. This suggests that the integration of Industry 4.0 technologies considerably enhances FP practices. In parallel, studies such as those by Atif et al. (2021), Gyurák Babeľová et al (2022), and Sevinç et al. (2018) have shown a positive impact of Industry 4.0 on various aspects of financial performance, such as revenue, profitability, and overall organizational efficiency. These studies highlight the role of Industry

4.0 in fostering sustainability and resource efficiency, aligning with our findings regarding its positive influence on FP.

The commonality across these studies is the recognition of Industry 4.0 as a catalyst for improvement in organizational practices and outcomes. However, the primary difference lies in the focus areas: our study is concentrated on the impact of Industry 4.0 on FP, providing detailed quantitative insights, while previous research has explored the broader financial performance implications of Industry 4.0 adoption in SMEs. This broader perspective includes increased production efficiency, reduced manufacturing costs, and enhanced business performance, as noted by researchers like Asmolov and Ledentsov (2022) and Haseeb et al. (2019).

Thus, both our research and the existing body of literature agree on the positive effects of Industry 4.0. Our research contributes to this understanding by highlighting its specific impact on FP, complementing the broader view of its role in enhancing financial performance as observed in previous studies. Therefore, based on the statistical analysis in our study and the support from prior research, we accept the $H_{3.2}$ that Industry 4.0 has a significant relationship with FP. This underscores the multifaceted benefits of Industry 4.0 adoption, extending beyond financial metrics, especially in the context of SMEs.

4.3.11. Direct Relationship between Ind4 and SR

In our study, the hypothesis $H_{2.3}$, which tested the direct effect of Industry 4.0 on Sustainability Reporting (SR), was rejected due to a negligible effect size, a low T statistic, and a non-significant P value. Our finding has long been debated with prior research. While other is contras with our finding, Mock et al. (2013) reported that Industry 4.0 has not been directly associated with the development of assured sustainability reports. This aligns with our finding of a negligible direct effect of Industry 4.0 on SR.

However, our finding in this dissertation contrasts with most prior research that generally indicate a significant impact of Industry 4.0 on sustainability reporting and practices. For instance, Takhar and Liyanage (2020) noted that Industry 4.0 technologies support sustainability and circular economy reporting needs, while Tavares and Azevedo (2021) emphasized the role of digital technologies in enhancing accounting and sustainability reporting. Similarly, Portna (2021) highlighted the strategic benefits of Industry 4.0 for sustainable reporting among industry players. Furthermore, Bonilla et al. (2018) and Jamwal et al. (2021), who discussed the positive impacts of Industry 4.0 on sustainability, potentially influencing SR. Additionally, Ocicka et al. (2022) proposed that Industry 4.0 technologies could help manage sustainability risks, including reporting aspects. These studies imply a direct effect that is contrary to our findings.

If we compare to the SME sector, research by Asmolov and Ledentsov (2022) and Haseeb et al. (2019) pointed out the instrumental role of Industry 4.0 components like big data and the Internet of Things in enhancing sustainable business performance and information technology implementation. Jayashree et al. (2020) and Philbin (2022) also recognized the importance of Industry 4.0 in achieving sustainability and competitive advantage, though Philbin noted that the direct relationship with sustainability reporting remains an open question.

Comparing these findings with our own, it appears that while there is a broad consensus in the literature on the positive impact of Industry 4.0 on sustainability practices and reporting, our study suggests that this relationship may not be as straightforward or direct as previously thought. The divergence could be due to variations in the implementation and integration of Industry 4.0 technologies within different organizational contexts, particularly in SMEs. This situation underscores the need for a more nuanced understanding of Industry 4.0's role in sustainability reporting. It suggests that the relationship might be mediated by other factors or manifest differently across various industry or organizational conditions. Our findings, diverging from the general trend in the existing literature, thus open new avenues for research into the intricate dynamics between Industry 4.0 technologies and sustainability reporting, especially in the SME sector. Thus, we rejected the Hypothesis 3.3 ($H_{3.3}$), means Ind4 has no direct significant relationship with SR.

4.3.12. Indirect Relationship between Ind4 and FP through EMA

Our study's finding, particularly hypothesis 4.1 ($H_{4.1}$), indicates a significant indirect relationship between Industry 4.0 (Ind4), Environmental Management Accounting (EMA), and Financial Performance (FP), as evidenced by an effect size of 0.513, a T statistic of 15.43, and a P value of 0.000. This supports the notion that EMA serves as a critical mediating variable between Industry 4.0 and financial outcomes.

In line with our findings, prior research also highlights the indirect positive relationship between Industry 4.0 and financial performance, with EMA emerging as a pivotal mediator. Studies, such as Rasit et al. (2022a), have noted that advanced technologies in Industry 4.0 could enhance environmental information and influence the adoption of EMA. While their study is specific to Malaysia's electrical and electronic industry, it suggests a broader applicability of EMA as a mediator between Industry 4.0 and financial performance. Similarly, Kumar and Bhatia (2021) observed that environmental dynamism propels firms toward Industry 4.0, positively impacting performance outcomes with organizational and technological factors, potentially including EMA, acting as mediators.

The realm of Industry 4.0 extends to Financial Process Automation (FPA), as discussed by Bisht et al. (2022), emphasizing its role in enhancing financial operations and strategies. This automation, combined with the growing importance of employee digital skills (Bolek et al., 2021; Karacay, 2018), positions EMA as an essential tool for comprehensive decision-making, innovation, and eco-efficiency (Burrit & Saka, 2006; R. L. Burritt et al., 2019; Ferreira et al., 2010). EMA's role in compliance, strategic positioning, and aligning environmental and financial goals is further highlighted by the International Federation of Accountants (IFAC) (2005) and Vasile & Man (2012).

Our research in contrast with Kamble et al. (2020) that propose a slightly different perspective, suggesting that Industry 4.0 technologies have both direct and indirect impacts on sustainable organizational performance, with lean manufacturing practices as a potential mediating factor. This insight raises the possibility of a similar mediating role for EMA. On the other hand, Saeidi et al. (2018) found that while innovations correlate positively with financial performance, EMA might have a negative moderating effect on the relationship between process innovation and financial performance. This indicates that EMA's role in the dynamic between Industry 4.0 and financial performance is complex and multifaceted, potentially varying based on specific Industry 4.0 aspects being implemented.

Therefore, our research, in conjunction with these prior studies, emphasizes the significant yet nuanced role of EMA as a mediator in the relationship between Industry 4.0 and financial performance. This highlights EMA's potential to facilitate the translation of Industry 4.0's impacts into financial gains. However, this influence may be contingent on various factors, including the specific nature of Industry 4.0 technologies and the firm's operational context. Thus, based on our statistical analysis and the support from prior research, we accept the hypothesis ($H_{4.1}$), which states that Industry 4.0 (Ind4) has an indirect yet significant influence on Financial Performance (FP) through EMA.

4.3.13. Indirect Relationship between Ind4 and SR through EMA

Analyzing hypothesis ($H_{4.2}$) from our study reveals that Industry 4.0 (Ind4) has an indirect positive relationship with Sustainability Reporting (SR), mediated by Environmental Management Accounting (EMA). This hypothesis is strongly supported with an effect size of 0.239, a T statistic of 11.58, and a P value of 0.000, leading to its acceptance.

Our finding resonates with existing literature, yet it also suggests a more complex dynamic than previously assumed. The broader consensus in literature posits a positive impact of Industry 4.0 on sustainability practices and reporting. However, our study indicates that this relationship, while positive, is mediated by EMA, highlighting that the direct influence of Industry 4.0 on SR may not be as straightforward as once thought (refer to: $H_{3.3}$). This complexity could stem from variations in how Industry 4.0 technologies are implemented and integrated within different organizational contexts, especially in SMEs, necessitating a nuanced understanding of Industry 4.0's role in sustainability reporting.

Supporting our findings, research by Rasit et al. (2022b) shows that advanced Industry 4.0 technology positively influences EMA and environmental performance, with EMA serving as an essential intermediary. This aligns with our observation that EMA could be the conduit linking Industry 4.0 with enhanced sustainability reporting. Similarly, Burritt and Christ (2016) suggest that Industry 4.0 can bolster environmental accounting, especially through investments in digital infrastructure. Kamble et al. (2020) also highlight that Industry 4.0 significantly affects sustainable organizational performance, with lean manufacturing practices identified as a potential mediating factor, suggesting a similar role for EMA in our context.

Furthermore, the integration of EMA with Industry 4.0 technologies significantly influences sustainability reporting. This is underscored by the adoption of frameworks like the GRI-G3 guidelines, which promote corporate responsibility and transparency. The adoption of GRI standards by SMEs, enhancing legitimacy and reputation, underlines the importance of aligning operations with sustainable practices.

Other studies, such as those by Oláh et al. (2020), Bonilla et al. (2018), and Rasit et al. (2022a), discuss how Industry 4.0 aligns with sustainable development goals, again pointing to a mediating role for EMA. This suggests that EMA, as a mediator, leverages the advantages of Industry 4.0 for enhanced sustainability reporting in SMEs. Jayashree et al. (2021) further emphasize that effective implementation of Industry 4.0 technologies mediates the relationship between innovation characteristics and sustainability goals in SMEs, highlighting the role of EMA in this process.

Therefore, our research, alongside prior studies, illustrates the significant, albeit complex, role of EMA as a mediator in the relationship between Industry 4.0 and sustainability reporting. While there is a positive impact of Industry 4.0 on sustainability practices, our findings suggest that this influence is indirect, channeled through EMA, particularly in the SME sector. This adds depth to the understanding of how Industry 4.0 technologies contribute to sustainability efforts, especially when integrated with effective environmental management accounting practices. Thus, we accept $H_{4.2}$, which states that Industry 4.0 (Ind4) has an indirect significant relationship with Sustainability Reporting (SR) through Environmental Management Accounting (EMA).

4.3.14. Indirect Relationship between Ind4 and SR through FP

Analyzing Hypothesis ($H_{4.3}$) from our study reveals that Industry 4.0 (Ind4) has an indirect but significant influence on Sustainability Reporting (SR), mediated through Financial Performance (FP). This hypothesis was accepted, substantiated by effect size, a high T statistic, and a significant P value.

In the hypothesis ($H_{3.3}$), we posit the direct relationship that has been rejected, which acknowledges the varied impact of Industry 4.0 and suggests that its positive effects on sustainability practices and reporting may be less direct and more conditional upon other organizational factors, especially within the SME sector. Therefore, our finding regarding the indirect influence suggests that while Industry 4.0 may not directly impact sustainability reporting, its effect is observable through improvements in financial performance.

This aligns with existing research that supports the idea that rapidly adopting Industry 4.0 technologies enhances operational efficiency and competitive advantage, leading to improved financial performance (Atif et al., 2021; Claudy et al., 2016). Elements such as data quality, digital maturity, and Financial Process Automation contribute to this improvement (Pokharkar, 2019; Bisht et al., 2022; Jardak & Ben Hamad, 2022). The enhanced financial health achieved through these means then influences sustainability reporting. Organizations with better financial outcomes can invest more in sustainability initiatives, reflecting their commitment to environmental and social responsibilities in sustainability reports (Mihai & Aleca, 2023).

Jayashree et al. (2020) and Kamble et al. (2020) also contend that Industry 4.0 technologies lead to sustainable organizational performance, with financial performance playing a mediating role in this relationship. This suggests that improvements in financial performance due to Industry 4.0 are likely to lead to enhanced sustainability reporting. Kumar and Bhatia (2021) and Bonilla et al. (2018) further support this view, indicating that financial performance may act as a mediator in the influence of Industry 4.0 on sustainability reporting. Oláh et al. (2020) emphasize the importance of aligning Industry 4.0 with sustainable development goals, which could manifest in enhanced sustainability reporting, again mediated by financial performance.

Thus, our research, alongside prior studies, underscores the significant yet indirect role of Industry 4.0 in influencing sustainability reporting through its impact on financial performance. While direct effects of Industry 4.0 on sustainability reporting might not be as pronounced, its influence becomes evident when considering the financial improvements it brings about. These financial gains empower organizations to engage more robustly in sustainability practices, which are then reflected in their sustainability reports. Thus, advancements in Industry 4.0 indirectly enhance the quality and scope of Sustainability Reporting by providing the necessary financial and operational support for sustainable practices. Consequently, based on our findings and supporting literature, we accept $H_{4.3}$, which states that Industry 4.0 (Ind4) has an indirect yet significant relationship with Sustainability Reporting (SR) through Financial Performance (FP).

4.3.15. Indirect Relationship between Ind4 and SR through EMA and FP

Hypothesis ($H_{4.4}$) is a clearer view of why our hypothesis ($H_{3.3}$) is rejected. If we focus on analyzing Hypothesis ($H_{4.4}$), we find that Industry 4.0 (Ind4) has a significant indirect relationship with Sustainability Reporting (SR), mediated through both Environmental Management Accounting (EMA) and Financial Performance (FP). This hypothesis is strongly supported by an effect size of 0.374, a T statistic of 14.237, and a P value of 0.000.

Our finding aligns with prior research that found EMA and FP mediate between Industry 4.0 and SR. For example, Jasch and Lavicka (2006) observed that Industry 4.0 can enhance corporate sustainability by promoting environmental accounting. Tiwari and Khan (2020) further suggest that the advanced technologies of Industry 4.0 improve environmental information, influencing the adoption of EMA and subsequently impacting both FP and SR.

Our finding regarding the direction of the relationship is similar to Beltrami et al. (2021), who propose a significant indirect relationship between Industry 4.0 technologies and sustainability practices and performance, mediated through EMA and FP. This perspective supports our hypothesis, highlighting the interconnected nature of these elements. Industry 4.0 is seen as a promoter of quality of life and sustainable development through its influence on EMA and FP, impacting various sustainability aspects, including reporting (da Costa Tavares & do Carmo Azevedo, 2021).

Since our study research object is SME, we explicitly focus on the SME context and found that prior research, such as Burritt and Christ (2016), discuss how Industry 4.0 could enhance environmental accounting, leading to improved corporate sustainability. This suggests that Industry 4.0 influences EMA, which in turn affects SR. Rasit et al. (2022b) found that advanced Industry 4.0 technology positively influences EMA and environmental performance in SMEs, with EMA acting as a mediator.

The positive direction of our finding related to SME also corroborate with Nyahuna and Doorasamy (2023) who report a positive relationship between return on equity and EMA practices in SMEs, suggesting a connection between FP, EMA, and SR. Gunarathne and Cooray (2018) also highlight that EMA systems guide SMEs towards higher-order sustainability outcomes, implying that EMA mediates the relationship between Industry 4.0 and SR in SMEs.

This body of research collectively illustrates the intricate relationship between technological advancement, environmental management, financial health, and sustainable practices in the context of Industry 4.0. Thus, we accept $H_{4.4}$, which states that there is a significant indirect relationship between Industry 4.0 and Sustainability Reporting through Environmental Management Accounting and Financial Performance. This finding underscores the multifaceted impact of Industry 4.0 on sustainable practices, mediated through both environmental and financial performance dimensions.

4.3.16. Direct Relationship between FP and SR

Our last hypothesis that has proven significant is H_5. We find that Financial Performance (FP) has a direct and significant relationship with Sustainability Reporting (SR). This hypothesis is robustly supported with a substantial effect size of 0.730, a T statistic of 35.352, and a P value of 0.000, leading to its acceptance.

Our finding aligns with Buallay's research (2022), which unveils a significant correlation between sustainability reporting and financial outcomes. This suggests that firms actively engaged in sustainability reporting often experience improved financial performance. Buallay et al. (2021) further reveal a positive association between Environmental, Social, and Governance (ESG) reporting and operational and financial performance in smart cities, indicating that enhanced sustainability reporting positively correlates with financial success.

Our positive direction in exploring the dynamics of FP and SR can also be related to the concept of Corporate Social Responsibility and Financial Performance. Lee and Hu (2018) illuminate the direct influence of financial performance on sustainability-related endeavors like CSR. Similarly, Zhou et al. (2022) conclude that improvements in ESG performance among listed companies can elevate their market value, with financial performance playing a mediating role. This implies a strong connection between sustainability reporting and financial performance.

With more focus on the SME sector, Malesios et al. (2018) and Masocha (2019) identify a significant positive link between sustainability practices and financial performance, further supporting our findings. These studies suggest that sustainability reporting directly influences financial performance, highlighting a clear relationship between these factors in SMEs. McMahon (2001) discusses how enhanced financial reporting practices in Australian manufacturing SMEs correlate with improved growth and performance. Otieno et al. (2021) support this notion, suggesting that adherence to certain reporting standards positively influences financial performance.

Our finding, also related to training and innovation as part of the SR construct, is supported by Burlea-Schiopoiu and Mihai (2019), who note the potential for SMEs to use training and innovation to amplify the impact of CSR on their sustainability, positively correlating with profitability metrics. This indicates a direct relationship between sustainability practices, reporting, and financial performance.

Collectively, these studies provide robust support for our hypothesis positing a positive relationship between Financial Performance and Sustainability Reporting, particularly in the context of SMEs. Thus, we accept H_5, which states that there is a direct and significant relationship between Financial Performance and Sustainability Reporting. This underscores the interconnected nature of financial success and commitment to sustainability practices, as demonstrated in the reporting, particularly in SMEs.

5. CONCLUSION, LIMITATION, AND RECOMMENDATION

In this dissertation, we embarked on a comprehensive exploration of the ways in which Small and Medium-sized Enterprises (SMEs) can harness Industry 4.0 technologies to foster sustainability. The following Table is the summary of this dissertation's findings:

Table 18. **Summary of Hypotheses Testing Results**
Examining the Impact of Industry 4.0 and Environmental Management Accounting on SME Sustainability

Objectives	Hypothesis/Method	Decision Result
To investigate the utilization of Industry 4.0 technologies by SMEs to achieve sustainability	Descriptive analysis	Well described
To develop a conceptual model that SMEs can utilize to achieve sustainability	Literature review	Conceptual Framework
To test the conceptual model using statistical methods:	PLS - SEM	
• EMA's direct relationship on FP and SR	$H_{1.1}$: EMA has a positive relationship with FP.	Accepted
	$H_{1.2}$: EMA has a positive relationship with SR.	Accepted
• Indirect effects of EMA on SR	H_{2} : EMA has an indirect positive relationship with SR.	Accepted
• The direct relationship of Industry 4.0's on EMA, FP, and SR	$H_{3.1}$: Industry 4.0 has a positive relationship with EMA.	Accepted
	$H_{3.2}$: Industry 4.0 has a positive relationship with FP.	Accepted
	$H_{3.3}$: Industry 4.0 has a positive relationship with SR.	Rejected
• Indirect relationships of Industry 4.0 on SR, mediated by EMA and FP	$H_{4.1}$: Industry 4.0 has an indirect positive relationship with FP through EMA.	Accepted
	$H_{4.2}$: Industry 4.0 has an indirect positive relationship with SR through EMA.	Accepted
	$H_{4.3}$: Industry 4.0 has an indirect positive relationship with SR through FP.	Accepted

Objectives	Hypothesis/Method	Decision Result
	$H_{4.4}$: Industry 4.0 has an indirect positive relationship with SR through EMA and FP.	Accepted
• Direct relationship between FP and SR	H_5: There is a direct relationship between FP and SR.	Accepted

Sources: Author data process, 2024

Table 18 shows our initial analysis goes deeper into the specific technologies adopted by SMEs and their impact on sustainable practices. Through descriptive analysis, we found a well-documented connection between Industry 4.0 technologies and enhanced sustainability and how the Indonesian government policy supports the concept of sustainability in the SME sector.

Following this, we construct a conceptual framework to guide SMEs toward sustainability. Through a rigorous literature review, we developed a model integrating various constructs derived from prior research. This framework stands as a testament to the collective insight gathered from extensive scholarly work, providing a beacon for SMEs striving for sustainability.

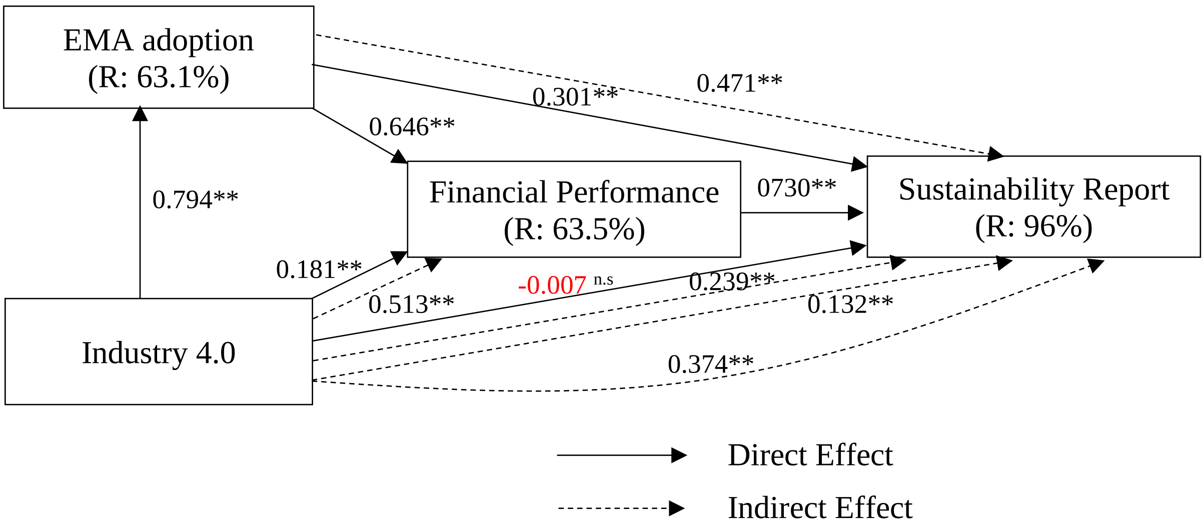
The crux of our exploration involved testing this conceptual framework using Partial Least Squares Structural Equation Modeling (PLS-SEM). Our analysis yielded enlightening results. We found that Environmental Management Accounting (EMA) significantly influences both Financial Performance (FP) and Sustainability Reporting (SR) ($H_{1.1}$ and $H_{1.2}$). The acceptance of the hypothesis regarding EMA's indirect positive relationship on SR (H_2) further highlights the layered impact of EMA practices.

Our examination of Industry 4.0 technologies revealed their positive impact on EMA and FP ($H_{3.1}$ and $H_{3.2}$). However, our expectations were challenged when we found the direct relationship between Industry 4.0 technologies and SR ($H_{3.3}$) to be unsupported, meaning that this relationship can not be direct but has to be accessed with an indirect approach.

Moreover, the accepted hypotheses concerning the indirect relationships mediated by EMA and FP ($H_{4.1}$, $H_{4.2}$, $H_{4.3}$, and $H_{4.4}$) and the direct relationship between FP and SR (H_5) elucidate the complex interplay between these variables. These findings illuminate the intricate pathways through which Industry 4.0 and EMA can influence SR, providing a nuanced understanding of how SMEs can leverage these relationships to foster sustainability.

The more detailed explanation is presented in Figure 10, the final research model figure:

Figure 10. **Final Research Model**
With original sample effect size, coefficient determination, and sig. level



Source: Author data processing, 2023

The research limitations can be thoughtfully discussed based on the findings outlined in the table, where all hypotheses were accepted except for the direct relationship between Industry 4.0 technologies and Sustainability Reporting ($H_{3.3}$). Reflecting on our journey, we consider the following aspects as key limitations of our study:

1. **Scope of Research Objectives and Respondent Demographics**: Our research focused exclusively on Micro, Small, and Medium Enterprises, with a particular emphasis on those SMEs that provided comprehensive responses in our questionnaire tabulation. However, it's noteworthy that the majority of our respondents represented the small to medium segment with relatively well-structured answers. Additionally, the study was geographically confined to the eastern regions of Indonesia, specifically Papua, Maluku, Nusa Tenggara Timur (NTT), and Sulawesi. The choice of these regions, while intentional, limits the generalizability of our findings across different geographic and economic contexts within Indonesia and beyond. The number of respondents, approximately 500, while substantial, may still not fully capture the diversity and complexity of SMEs' experiences with Industry 4.0 technologies across these regions.
2. **Generalizability of Findings**: Our research's specific focus on SMEs and the impact of Industry 4.0 technologies within these enterprises might limit the applicability of our findings to larger corporations or different sectors where sustainability practices and the impacts of Industry 4.0 might vary.

3. **Measurement of Industry 4.0 Impact**: The inability to confirm H3.3 underscores the challenge in directly measuring the impact of Industry 4.0 technologies on Sustainability Reporting (SR). This suggests a potential gap in our measurement approach, indicating that a more diverse set of indicators could better capture the nuances of Industry 4.0's influence on sustainability practices.
4. **Cross-Sectional Data**: The reliance on cross-sectional data constrains our ability to infer the long-term impacts of EMA and Industry 4.0 technologies on financial and sustainability outcomes, highlighting the need for longitudinal studies for more dynamic insights.
5. **External Influencing Factors**: Our conceptual model may not have fully accounted for all variables influencing the dynamics between EMA, financial performance, sustainability reporting, and Industry 4.0 adoption. Factors such as regulatory frameworks, market conditions, or corporate culture, which could significantly impact these relationships, were not explicitly considered.
6. **Industry 4.0 Readiness of Respondents**: The determination of respondents was also influenced by the businesses' readiness for Industry 4.0, with most respondents' readiness only achieving level 4, "quantitatively managed." This level of readiness indicates a structured approach to data management and analysis but may not fully represent the broader spectrum of Industry 4.0 integration stages. This focus could skew our understanding of the full impact of Industry 4.0 technologies on SME sustainability.

Building on the thoughtful restructuring of the research limitations, we conduct suggestions for future research directions that can further illuminate the complex relationship between Industry 4.0 technologies and SME sustainability, particularly in the context of the limitations identified:

1. **Expansion of Geographic Scope**: Future studies could broaden their geographic focus beyond the eastern regions of Indonesia to include a more diverse array of locations. This expansion would enhance the generalizability of findings, providing insights into the applicability of Industry 4.0 technologies across different economic and cultural contexts.
2. **Inclusion of Larger Enterprises**: While this study concentrated on SMEs, subsequent research could extend the investigation to larger enterprises. This would allow for a comparison of the impacts of Industry 4.0 technologies on sustainability practices

across different business sizes and sectors, offering a more holistic understanding of these technologies' role in promoting sustainability.

3. **Enhanced Measurement Approaches**: To address the challenges in measuring the impact of Industry 4.0 technologies on Sustainability Reporting, future research could develop and utilize a more diverse set of indicators. These should be capable of capturing the multifaceted ways in which Industry 4.0 can influence sustainability practices, potentially including qualitative measures alongside quantitative ones.
4. **Longitudinal Studies**: To overcome the limitations of cross-sectional data, future studies should consider adopting a longitudinal approach. This would provide valuable insights into the long-term effects of Environmental Management Accounting and Industry 4.0 technologies on financial and sustainability outcomes, offering a dynamic perspective on these relationships.
5. **Comprehensive Analysis of Influencing Factors**: Recognizing that external factors such as regulatory environments, market conditions, and organizational culture were not fully considered, future research should integrate these variables into their models. This comprehensive approach would allow for a deeper understanding of the external influences on the adoption of Industry 4.0 technologies and their impact on sustainability.
6. **Diverse Levels of Industry 4.0 Readiness**: Given the finding that most respondents' Industry 4.0 readiness was at level 4, "quantitatively managed", future research should aim to include businesses with a broader range of readiness levels. This would provide a more nuanced view of how different stages of Industry 4.0 integration impact SME sustainability, potentially identifying specific challenges and opportunities at each stage.

6. NOVEL FINDING

The novelty of this dissertation lies in its comprehensive examination of the interplay between Industry 4.0, Environmental Management Accounting (EMA), Financial Performance (FP), and Sustainability Reporting (SR) within SMEs, using Partial Least Squares Structural Equation Modeling (PLS-SEM). The key novel findings of the research include:

1. Mediating Role of EMA and FP: The study uniquely illustrates how EMA and FP serve as critical mediators in the relationship between Industry 4.0 and SR. While previous research has separately explored these elements, this dissertation provides new insights into how they collectively influence and are influenced by Industry 4.0, particularly emphasizing the mediating roles of EMA and FP.
2. Complex Dynamics of Industry 4.0: The research contributes to the understanding of Industry 4.0 by revealing its more intricate and indirect effects on sustainability practices, which have not been thoroughly explored in previous studies. This nuanced perspective is particularly relevant in the context of SMEs, where the implementation of Industry 4.0 technologies varies significantly.
3. Direct Link Between FP and SR: Another novel aspect of this study is the direct and significant relationship established between FP and SR. This finding challenges some existing notions and adds depth to the understanding of how financial health directly impacts a firm's sustainability reporting and practices.
4. Adaptation of PLS-SEM Methodology: The use of PLS-SEM to analyze these relationships adds a methodological novelty, especially in the way the Original Sample (O) Effect Size was used more robustly to analyze relationships compared to traditional path coefficients. This approach provides a more comprehensive understanding of the strength and direction of the relationships within the model.
5. Strategic Integration of Industry 4.0 for Enhanced Sustainability Practices: This research unveils how SMEs can strategically harness Industry 4.0 technologies to bolster their sustainability efforts. It elucidates specific Industry 4.0 technologies—such as real-time monitoring systems, IoT devices, and smart sensors—and demonstrates how these can be applied to improve Environmental Management Accounting (EMA) and Financial Performance (FP).
6. Practical Implications for Leveraging Industry 4.0: The dissertation outlines actionable strategies for SMEs to implement Industry 4.0 technologies with a dual focus: achieving operational excellence and advancing their sustainability objectives. By adopting these technologies, SMEs can achieve a more granular understanding of their

environmental footprint, enabling them to make informed decisions that align with sustainability goals.

7. SUMMARY

This dissertation offers a detailed analysis of the dynamic interrelationships between Industry 4.0, Environmental Management Accounting (EMA), Financial Performance (FP), and Sustainability Reporting (SR) in the context of Small and Medium Enterprises (SMEs). Utilizing Partial Least Squares Structural Equation Modeling (PLS-SEM), the study is a descriptive confirmatory investigation that seeks to understand the impact factors affecting SME sustainability during the Industrial Revolution 4.0, with a special focus on EMA. The research is methodically segmented into three interconnected stages, each building upon the findings of the preceding one to create a comprehensive view.

In the initial stage, the study involves extensive data collection from scientific journals, previous studies, and online sources, establishing a foundational understanding of the research problem. This phase involves a thorough synthesis of existing literature to develop a state-of-the-art overview, identifying crucial research variables and constructing a robust research model. The theories gathered focus on Industry 4.0 from an accounting perspective, incorporating concepts from agency, institutional, and legitimacy theories, and culminate in an in-depth exploration of EMA. The study employs IFAC's 2005 framework to examine the diverse applications and benefits of EMA, such as compliance, eco-efficiency, and strategic positioning. Additionally, it assesses the various pressures - coercive, normative, and mimetic - that influence SMEs' adoption of EMA, and integrates the benefits and challenges of Industry 4.0 with EMA. These initial findings are subsequently presented at an international conference for validation, enhancing the strength of the conceptual model.

The second stage of the research involves the development and refinement of a questionnaire based on this conceptual model. This questionnaire is critically evaluated in a Focus Group Discussion (FGD) with seasoned researchers to fine-tune its sensitivity and mitigate potential biases. Following validation, the questionnaire is disseminated to SMEs through random sampling. Primary data is collected from SME owners through structured interviews, prioritizing ethical considerations and integrity. To minimize Common Method Variance (CMV) and Social Desirability Bias (SDB), various strategies are employed, such as Balanced Keying, the use of both positively and negatively worded items, and assurances of respondent anonymity to elicit honest responses.

In the third and final phase, which involves data analysis and discussion, the dissertation uncovers significant findings:

1. Impact of Industry 4.0 on EMA: It is established that Industry 4.0 significantly impacts EMA in SMEs. The relationship is primarily driven by the advanced technologies of

Industry 4.0, which significantly enhance the efficiency and effectiveness of EMA practices.

2. Mediating Role of EMA and FP: The findings indicate that EMA and FP play pivotal mediating roles in the relationship between Industry 4.0 and SR in SMEs. This suggests that the benefits of Industry 4.0 in sustainability are realized through improvements in environmental accounting and financial management.
3. Direct Relationship between FP and SR: The study identifies a substantial direct relationship between FP and SR, indicating that SMEs with better financial outcomes tend to engage more comprehensively in sustainability reporting.
4. Challenges in EMA Adoption: The research highlights various challenges and pressures encountered by SMEs in adopting EMA, including coercive, normative, and mimetic influences, which significantly shape the adoption and implementation of EMA practices.
5. Role of Industry 4.0 in EMA and SR: The dissertation emphasizes the role of Industry 4.0 in promoting EMA, which in turn leads to enhanced sustainability reporting. The advancement in technology serves as a catalyst for improving both environmental and financial reporting practices, contributing to the overall sustainability of SMEs.

This comprehensive approach to research provides a nuanced understanding of how technological advancements in Industry 4.0 interact with and influence EMA, financial performance, and sustainability reporting practices in SMEs, offering valuable insights and practical implications for the integration of sustainability into business models in the era of Industry 4.0.

Therefore, based on the content, this dissertation unfolds as follows:

1. Introduction: The dissertation sets the stage for an in-depth investigation into the impact of Industry 4.0 on SMEs, especially concerning EMA, FP, and SR.
2. Literature Review: This section delves into theoretical frameworks like Agency Theory, Legitimacy Theory, and Institutional Theory, and then explores the concept of Industry 4.0, EMA, SME Financial Performance, and Sustainability Reporting.
3. Material and Method: The methodology includes the type of research, procedure, research object, population and sample, operational definitions, and measurement of latent variables, focusing primarily on PLS-SEM.
4. Research Findings and Evaluations: The findings section interprets the data within the hypothesized relationships, offering insights into the dynamics of Industry 4.0, EMA, FP, and SR in SMEs.

5. Conclusion and Recommendations: The dissertation concludes by summarizing key findings and discussing their implications, emphasizing the roles of EMA and FP in the relationship between Industry 4.0 and SR, and the direct relationship between FP and SR.
6. Novel Finding: The unique contributions of the dissertation to the existing body of knowledge are highlighted here.

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List of Abbreviation

Abbreviation	Full term
A	Assets
AFS	Available-for-Sale
AI	Artificial Intelligent
AQI	Air Quality Index
AR	Augmented Reality
AT	Assets Turnover
AVE	Average Variance Extracted
BI	Bank Indonesia
CF_{adjust}	Condition and Features
CMV	Common Method Variance
COVID-19	Corona Virus Deases 2019
CSR	Corporate Social Responsibility
D. R. Congo	Democratic Republic of Congo
D/E	Debt-to-Equity Ratio
d_G	Geisser-Greenhouse Criterion
d_ULS	Unweighted Least Squares Discrepancy
DSAK	Indonesian Financial Accounting Standards Board - *Dewan Standar Akuntansi Keuangan IAI*
DT	Digital Transformation
E	Equity
EBITDA	Earning before tax and Depreciation
EMA	Environmental Management Accounting
EQI	Environmental Quality Index
ESG	Environmental, Social, and Governance
F	Effect size of R^2

Abbreviation	Full term
Fintech	**Financial Technology**
FP	Financial Performance
FPA	Financial Process Automation
G20	Group of Twenty
GAAP	Generally Accepted Accounting Principles
GAAS	Generally Accepted Auditing Standards
GDP	Gross National Product
GoJek	Go Ojek
GoPay	Gojek Payment
Graphic or Figure number…E	Estimation
GRI	Global Reporting Initiative
H	Hypothesis
HTMT	Heterotrait-Monotrait
ICT	Information and Communication Technologies
IFAC	International Federation of Accontants
IFRS	International Financial Reporting Standards
Ind4	Industry 4.0
IoT	Internet of Things
IQAir	Index Quality of Air
ISAK	Interpretations of Financial Accounting Standards - Interpretasi Standar Akuntansi Keuangan
KAS	Sharia Accounting Committee - Kerangka Acuan Syariah
KPMG	Klynveld Peat Marwick Goerdeler
L	Liability
LSSR	Large social scale restriction
MAT	McLaren Applied Technologies

Abbreviation	Full term
MV_{adjust}	**Market Value Adjustment**
NCE	Non-Cash Expenses
NFI	Normed Fit Index
NI	Net Income
NJOP	property based on government's assessment provided by the local tax authority – *Nilai Jual Object Pajak*
NPM	Net Profit Margin
O	Ordinal Sample – Coefficient Correlation
OCI	Other Comprehensive Income
OFC	Operating Cash Flow
P_value	Probability Value - often denoted as alpha (α)
PLS – SEM	Partial Least Square Structural Equation Modelling
PSAK or SAK	Indonesian Financial Accounting Standards - *Standar Akuntansi Keuangan*
Q^2	Predictive Relevance
R^2	Coefficient Determination
rms_Theta	Root Mean Square Theta
S	Sales
SDB	Social Desirability Bias
SDGs	Sustainable Development Goals
SEC	Securities & Exchange Commission
SME	Small and Medium Enterprises
SR	Sustainability Report
SRMR	Standardized Root Mean Square Residual
STDEV	Standard Deviation
TAM	Technology Acceptance Model
U.S.	United State – United State of America

Abbreviation	Full term
UN	**United Nation**
USD	United States Dollar
VIF	Variance Inflation Factor
VR	Virtual Reality
WC	Working Capital
WFH	Work from home
WMO	World Meteorological Organization

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List of publications related to the dissertation

Articles, studies (7)

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Economics and Working Capital. 1 (2), 18-22, 2019. ISSN: 2398-9491.

Questionnaires:

Subject: Invitation to Participate in studying advanced technology and sustainability practices.

Dear Participant,

I hope this letter finds you in good health and spirits. We are the research team from Manado State University and Sam Ratulangi University. We are currently conducting a comprehensive survey focused on advanced technology in SMEs within the agriculture and manufacturing sectors. The primary objective of this survey is to collect in-depth insights regarding digital transformation strategies within these organizations and assess their environmental and social impacts.

Your participation in this survey is crucial for understanding current trends and challenges in digital transformation across various sectors. The insights garnered from this study will significantly enhance the knowledge base of experts and policymakers. This, in turn, will enable policymakers to make informed decisions based on the research findings.

We assure you that all responses will be kept strictly confidential and will be used solely for research purposes. Individual responses will not be identifiable in any reports or publications arising from this study.

Participation in this survey is entirely voluntary, and you may choose to withdraw at any time without any consequences. If you have any questions or require further information about the survey, please do not hesitate to contact the surveyor. The contact number is provided at the end of this cover letter for your convenience.

We greatly appreciate your time and valuable insights. Your contribution is vital to the success of this research.

Thank you in advance for your participation.

Sincerely,
On behalf of the Research Team
Octavia Tuegeh

A. General Information:

Age group:

- ☐ Below 30
- ☐ 30 - 35
- ☐ 36 - 40
- ☐ 41 - 45
- ☐ 45 - 54
- ☐ 55 - 60
- ☐ 60 or older

Gender:

- ☐ Male
- ☐ Female

Ethnicity:

Sulawesi:

- ☐ Buginese
- ☐ Makassarese
- ☐ Toraja
- ☐ Minahasa
- ☐ Gorontalo
- ☐ Other:

Papua:

- ☐ Asmat
- ☐ Dani
- ☐ Korowai
- ☐ Sentani
- ☐ Other:

Maluku (Moluccas):

- ☐ Alifuru (or Alfur)
- ☐ Ambonese
- ☐ Kei Islanders
- ☐ Other:

East Nusa Tenggara (NTT):

- ☐ Atoni
- ☐ Rote Islanders
- ☐ Sumba Islanders
- ☐ Flores Islanders
- ☐ Other:

Education Level: What is the highest level of education you have completed?

- ☐ No Formal Education
- ☐ Primary Education
- ☐ Secondary Education
- ☐ Higher Education
- ☐ Post-Graduate Education

Other Occupation:

Do you have any side job or study, beside running a business?

- ☐ Yes
- ☐ No

What is your current employment status?

- ☐ Employed full-time
- ☐ Employed part-time
- ☐ Unemployed
- ☐ Student
- ☐ Homemaker
- ☐ Self-employed

Marital Status:

- ☐ Single
- ☐ Married
- ☐ Divorced
- ☐ Widowed
- ☐ Separated
- ☐ In a domestic partnership or civil union

B. Business Information:

Instructions for Respondents:

- *Please select the range that most accurately reflects your business's status for each indicator.*
- *If you are unsure about exact figures, please provide your best estimate.*
- *Your responses will be kept confidential and are important for understanding the financial health of businesses in your sector.*

Which of the following best describes your business type? (Please select the closest option)

- ☐ Horticulture and Agroforestry
- ☐ Food and Beverage
- ☐ Furniture and Textile
- ☐ Aquaculture
- ☐ Organic Farming
- ☐ Crop and Animal Production
- ☐ Other (Please specify): _________

How long have you been operating your business?

- ☐ Less than 1 year
- ☐ 1-3 years
- ☐ 4-6 years
- ☐ 7-10 years
- ☐ More than 10 years

How many employees do you currently have in your business?

- ☐ Solo operation (no employees)
- ☐ 1-5 employees
- ☐ 6-10 employees
- 11-20 employees
- ☐ 21-50 employees
- ☐ More than 50 employees
- ☐

Does your business operate locally, nationally, or internationally?

- ☐ Locally
- ☐ Nationally
- ☐ Internationally

What are the primary challenges you face in your business? (You may select more than one)

- ☐ Financial constraints
- ☐ Competition
- ☐ Access to markets
- ☐ Regulatory issues
- ☐ Supply chain disruptions
- ☐ Other (Please specify): ________

What are your plans for the business in the next 5 years?

- ☐ Expansion
- ☐ Diversification
- ☐ Maintaining current status
- ☐ Downsizing
- ☐ Selling or closing the business
- ☐ Other (Please specify):________

What is your business's operating cash flow in a year?

- ☐ Below Rp 50 million
- ☐ Rp 50 million - Rp 100 million
- ☐ Rp 100 million - Rp 250 million
- ☐ Rp 250 million - Rp 500 million
- ☐ Rp 500 million - Rp 1 billion
- ☐ Rp 1 billion - Rp 2.5 billion
- ☐ Rp 2.5 billion - Rp 5 billion
- ☐ Above Rp 5 billion

What is your annual assets turnover?

- ☐ Below Rp 100 million
- ☐ Rp 100 million - Rp 300 million
- ☐ Rp 300 million - Rp 500 million
- ☐ Rp 500 million - Rp 1 billion
- ☐ Rp 1 billion - Rp 2 billion
- ☐ Rp 2 billion - Rp 5 billion
- ☐ Rp 5 billion - Rp 10 billion
- ☐ Above Rp 10 billion

What is the amount of your working capital?

- ☐ Below Rp 50 million
- ☐ Rp 50 million - Rp 100 million
- ☐ Rp 100 million - Rp 250 million
- ☐ Rp 250 million - Rp 500 million
- ☐ Rp 500 million - Rp 1 billion
- ☐ Rp 1 billion - Rp 2.5 billion
- ☐ Rp 2.5 billion - Rp 5 billion
- ☐ Above Rp 5 billion

What is your net profit margin in a year?

- [ ] Below Rp 25 million
- [ ] Rp 25 million - Rp 50 million
- [ ] Rp 50 million - Rp 100 million
- [ ] Rp 100 million - Rp 250 million
- [ ] Rp 250 million - Rp 500 million
- [ ] Rp 500 million - Rp 1 billion
- [ ] Rp 1 billion - Rp 2.5 billion
- [ ] Above Rp 2.5 billion

What is the total value of your business assets?

- [ ] Below Rp 100 million
- [ ] Rp 100 million - Rp 300 million
- [ ] Rp 300 million - Rp 500 million
- [ ] Rp 500 million - Rp 1 billion
- [ ] Rp 1 billion - Rp 2.5 billion
- [ ] Rp 2.5 billion - Rp 5 billion
- [ ] Rp 5 billion - Rp 10 billion
- [ ] Above Rp 10 billion

What is your annual assets turnover?

- [ ] Below Rp 100 million
- [ ] Rp 100 million - Rp 300 million
- [ ] Rp 300 million - Rp 500 million
- [ ] Rp 500 million - Rp 1 billion
- [ ] Rp 1 billion - Rp 2 billion
- [ ] Rp 2 billion - Rp 5 billion
- [ ] Rp 5 billion - Rp 10 billion
- [ ] Above Rp 10 billion

C. Measurement of Industry 4.0 Readiness

Does your SME have a dedicated team for managing digital transformation?

- Yes
- No

What percentage of your budget is allocated for digital transformation?

- Less than 5%
- 5-10%
- 11-20%
- More than 20%

Describe any challenges your SME faces in preparing for digital transformation.

Digital Maturity

- How would you categorize the current stage of digital maturity in your SME?
  - Initial
  - Managed
  - Defined
  - Quantitatively Managed
  - Optimizing

- How adaptable is your organization to technological changes?
  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8
- Do you think digital maturity is irrelevant for your organization? (Reverse coded)
  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8

Data Quality

- How would you rate the quality of data in your organization?
  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8
- Do you believe that data quality is not a priority? (Reverse coded)
  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8

Digital Transformation Strategy

- Does your SME have a formal digital transformation strategy?
  - Yes
  - No
- Multiple-choice: Which of the following best describes your SME's long-term vision for digital transformation?
  - Cost reduction
  - Enhancing customer experience
  - Operational efficiency
  - Innovation and new business models
- How capable is your organization in executing digital strategies?
  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8

- Do you think change management activities are not important for DT? (Reverse coded)

  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8

- How often is your digital transformation strategy reviewed and updated?

☐	Never	☐	Every 6 months
☐	Every two years or less frequently	☐	Every quarter
☐	Annually	☐	Monthly
☐	Every 9 months	☐	Continuously / On an ongoing basis

Technology Adoption Rate

- Multiple-choice: How quickly does your SME typically adopt a new technology after its release?
  - Immediately
  - Within 6 months
  - Within a year
  - More than a year
- Describe any data quality issues your SME has faced and how they were resolved.

Cybersecurity

- Describe any cybersecurity challenges your SME has faced.
- How secure are your digital assets and networks?

  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8

Technology Adoption Speed:

- How quickly does your organization adopt new technologies?

  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8

- Do you think rapid technology adoption is not crucial for your organization? (Reverse coded)

  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8

Financial Process Automation:

- To what extent are financial processes automated in your organization?

  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8
- Do you feel that automation in financial processes is unnecessary? (Reverse coded)

  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8

Workforce Proficiency in Digital Tools:

- How proficient is your workforce in using digital tools?

  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8
- Do you think digital skills are not essential for your employees? (Reverse coded)

  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8
- How effective is your organization's decision-making in the context of DT?

  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8
- Do you believe that a strategic management approach is not important for DT? (Reverse coded)

  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8

C. Environmental and Sustainability Practice

- To what extent does your organization's SR comply with GRI standards? **(Marker variables)**

  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8
- Does your SR include both financial and non-financial details?

  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8
- How transparent is your SR in disclosing governance structures?

  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8
- Does your SR focus on long-term business strategy success?
- 1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8
- How comprehensively does your SR cover environmental and social responsibilities? 1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8
- Has your SR enhanced your organization's reputation and legitimacy?

- Has your SR made your organization more appealing to potential employees?

  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8
- How has SR contributed to your organization's crisis resilience?

  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8
- Does your SR focus on the quality of products or services offered?

  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8
- How has SR driven or highlighted innovation within your organization?

  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8
- To what extent does EMA help your organization comply with environmental regulations?

  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8
- How effective is EMA in reducing your operational costs related to environmental impacts?

  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8
- How much does EMA contribute to your organization's long-term strategic goals?

  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8
- How much do external regulations influence your organization's adoption of EMA?

  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8
- How much does societal expectation influence your EMA practices?

  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8
- To what extent does your organization adopt EMA practices similar to industry leaders?

  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8
- How much does the quality of human resources contribute to the success of your EMA practices?

  1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8
- How has the adoption of EMA impacted your organization's financial performance?
- 1 - [ ] 2 - [ ] 3 - [ ] 4 - [ ] 5 - [ ] 6 - [ ] 7 - [ ] 8

Additional information for the surveyor

A. Digital Maturity:

justify the digital maturity stage of SMEs, whether in agriculture or manufacturing, specific indicators can be used to assess their progress through the stages of Initial, Managed, Defined, Quantitatively Managed, and Optimizing.

1. Initial Stage
   - **Indicators:**
     - Limited use of digital tools; digital efforts are ad-hoc and uncoordinated.
     - Absence of a strategic approach to digitalization; reliance on manual processes.
   - **Agriculture SME Example:** A small farm uses basic spreadsheets for record-keeping and relies on traditional methods for planting and harvesting without integrating digital technologies for soil monitoring or crop management.
   - **Manufacturing SME Example:** A small manufacturing unit uses paper-based systems for inventory management and has no digital systems in place for tracking production or efficiency.
2. Managed Stage
   - **Indicators:**
     - Beginning to organize digital efforts; some processes have been digitized.
     - Initial strategic thinking about digital technologies' role but lacks a comprehensive plan.
   - **Agriculture SME Example:** The farm starts using a simple farm management software to track crop cycles and inventory but hasn't integrated more advanced technologies like precision agriculture or IoT-based soil monitoring.
   - **Manufacturing SME Example:** The manufacturing unit has implemented a basic digital system for inventory management and is starting to use digital tools for production scheduling.
3. Defined Stage
   - **Indicators:**
     - Clear digital strategy in place; most processes are digitized and integrated.

  - Staff are trained in digital tools, and there is a focus on improving digital workflows.
- **Agriculture SME Example:** The farm uses integrated farm management software that includes modules for precision agriculture, financial management, and supply chain logistics. Staff are trained to use digital tools for monitoring and decision-making.
- **Manufacturing SME Example:** The manufacturing unit employs a comprehensive Manufacturing Execution System (MES) that integrates with supply chain management and customer relationship management systems. Digital skills training is provided to employees.

1. Quantitatively Managed Stage
   - **Indicators:**
     - Use of data analytics to inform decision-making; digital processes are optimized based on insights.
     - Performance metrics for digital initiatives are tracked and used for continuous improvement.
   - **Agriculture SME Example:** The farm uses data analytics from soil sensors and drones to make informed decisions about planting, irrigation, and fertilization. Performance metrics from these technologies are regularly reviewed for process optimization.
   - **Manufacturing SME Example:** The unit uses advanced analytics to optimize production lines and supply chains. Data from IoT sensors on equipment are analyzed for predictive maintenance, reducing downtime and improving efficiency.
2. Optimizing Stage
   - **Indicators:**
     - Continuous improvement and innovation in digital processes; adoption of cutting-edge technologies.
     - Digital initiatives are fully integrated into the business strategy, with a focus on using digital for competitive advantage.

- **Agriculture SME Example:** The farm is experimenting with AI-based predictive analytics for crop yield optimization and exploring blockchain for supply chain transparency. It's recognized as a leader in using digital technology for sustainable farming practices.
- **Manufacturing SME Example:** The manufacturing unit employs AI and machine learning for real-time optimization of production processes. It's pioneering new digital fabrication techniques and customizing products based on digital customer feedback.

A. Reverse coded:

- Do you disagree that a holistic perspective is unnecessary in SR?
- Do you think transparency in governance is irrelevant for SR?
- Do you feel that economic outcomes are not a priority in SR?
- Do you disagree that environmental and social aspects are crucial in SR?
- Do you think focusing on reputation and legitimacy is irrelevant in SR?
- Do you feel that employee attractiveness is not a significant concern for SR?
- Do you disagree that crisis resilience is important in SR?
- Do you think product quality is not relevant for SR?
- Do you feel that innovation is irrelevant in SR?
- Do you disagree that EMA is irrelevant for meeting environmental regulations? Do you think EMA fails to contribute to eco-efficiency in your organization?
- Do you feel that EMA has no role in shaping your organization's strategic position?
- Do you think external pressures have no impact on your EMA practices?
- Do you disagree that societal norms are irrelevant to your EMA adoption?
- Do you feel that mimicking industry leaders is not a factor in your EMA adoption?
- Do you think human resources have no role in the effectiveness of your EMA practices?
- Do you disagree that EMA has a negative impact on financial performance?

DECLARATION

I, the undersigned (name: Octavia Diana Monica Tuegeh, date of birth: 1986.10.10) declare under penalty of perjury and certify with my signature that the dissertation I submitted in order to obtain doctoral (PhD) degree is entirely my own work.

Furthermore, I declare the following:

- I examined the code of the Károly Ihrig Doctoral School of Management and Business and I acknowledge the points laid down in the code as mandatory;
- I handled the technical literature sources used in my dissertation fairly and I conformed to the provisions and stipulations related to the dissertation;
- I indicated the original source of other authors' unpublished thoughts and data in the references section in a complete and correct way, considering the prevailing copyright protection rules;
- No dissertation which is fully or partly identical to the present dissertation was submitted to any other university or doctoral school for the purpose of obtaining a PhD degree.

Debrecen, 2024.03.11

Octavia D. M. Tuegeh

APPRECIATION

First and foremost, I extend my deepest gratitude to Almighty God, Jesus Christ, my Lord and Savior, who has been my unwavering source of strength and guidance throughout this academic journey. His promises, as encapsulated in Philippians 4:13, "I can do all things through Christ who strengthens me," have been a constant reminder of His faithful presence in every step of my education.

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