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The Effect of Technological Innovation on Sustainability and Industry 4.0 Implementation: An Empirical Analysis of Indonesian Small and Medium-Sized Businesses

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Abstract

Small and medium-sized businesses, or SMEs, are the foundation of the majority of economies in the world. Small and medium-sized enterprises (SMEs) will find it extremely difficult to improve their performance and hard to meet their sustainability objectives in the absence of qualified technological innovation. Hence, Industry 4.0 (I4.0), the next technology frontier, should be embraced by small firms. This study's primary goal is to comprehend the connection between sustainability objectives and the adoption of Industry 4.0 (I-4.0) technologies. It also examines how innovative features facilitate the adoption of I-4.0 by small enterprises. In order to address the research inquiries and scrutinize the intricate data, AMOS software was used to conduct a structural equation model in this study. The findings showed that the adoption of I-4.0 and sustainability objectives are positively and significantly impacted by the features of technological innovation. With the exception of observability, effective I-4.0 implementation mediates the relationship between innovation traits and sustainability goals. According to the research's conclusions, SMEs should create an effective I-4.0, put it into practice, and cultivate innovative traits in order to meet sustainable objectives.

Pengaruh Inovasi Teknologi terhadap Keberlanjutan dan Implementasi Industri 4.0: Analisis Empiris terhadap Usaha Kecil dan Menengah di Indonesia

Abstrak

Usaha kecil dan menengah, atau UKM, adalah fondasi dari mayoritas ekonomi di dunia. Usaha kecil dan menengah (UKM) akan merasa sangat sulit untuk meningkatkan kinerja mereka dan sulit untuk memenuhi tujuan keberlanjutan mereka tanpa adanya inovasi teknologi yang mumpuni. Oleh karena itu, Industri 4.0 (I-4.0), yang merupakan batas teknologi berikutnya, harus diadopsi oleh perusahaan-perusahaan kecil. Tujuan utama dari penelitian ini adalah untuk memahami hubungan antara tujuan keberlanjutan dan adopsi teknologi Industri 4.0. Studi ini juga meneliti bagaimana fitur-fitur inovatif memfasilitasi adopsi I4.0 oleh perusahaan kecil. Untuk menjawab pertanyaan penelitian dan meneliti data yang rumit, perangkat lunak AMOS digunakan untuk melakukan model persamaan struktural dalam penelitian ini. Temuan menunjukkan bahwa adopsi I-4.0 dan tujuan keberlanjutan dipengaruhi secara positif dan signifikan oleh fitur-fitur inovasi teknologi. Dengan pengecualian pada observabilitas, implementasi I-4.0 yang efektif memediasi hubungan antara sifat-sifat inovasi dan tujuan keberlanjutan. Berdasarkan kesimpulan penelitian, UKM harus menciptakan I-4.0 yang efektif, mempraktikkannya, dan mengembangkan sifat-sifat inovatif untuk memenuhi tujuan keberlanjutan.

INTRODUCTION

Since the beginning of the first industrial revolution, technology and innovation have been crucial for enhancing the performance and sustainability of businesses. Sustainable manufacturing methods are beneficial because they minimize waste in both the input and output. Because they are major players in the global economy, businesses have a significant role to play in promoting sustainability and highlighting its significance. Businesses can gain a competitive edge by pursuing sustainability goals, and the triple bottom line (TBL) social justice, ecological integrity, and financial profitability can be used to measure this. Additionally, it gives businesses a cachet for sustainability that they can employ for marketing purposes and to influence consumer choices. It's not only about protecting the environment; environmental research conducted in advance of the attainment of sustainability goals can impart to businesses new skills that increase efficiency or make them more desirable. That is still a top priority, though, since business executives are starting to realize that if natural resource depletion continues uncontrolled, it will eventually result in financial losses. Visible environmental repercussions encourage SMEs to operate sustainable, ecologically friendly enterprises by increasing their ecological consciousness. Many of these SMEs understand that operating sustainably will benefit them in many ways, including cost savings, regulatory satisfaction, and customer satisfaction. demonstrated that the performance of SMEs is positively impacted by the environment and its components. However, animosity toward sustainability regulations and costs may increase if small businesses feel oppressed by larger corporations or if they believe that there are no development prospects in the market because of fierce competition.

Numerous industries can make use of Industry 4.0 technologies. But rather than being restricted to big businesses, these new technologies need to reach small and medium-sized enterprises (SMEs) in order to realize their full potential. The foundation of the majority of economies in the globe are SMEs. SMEs have a tonne of amazing prospects in Industry 4.0. Nonetheless, small businesses always have a number of obstacles to overcome since they lack the resources and capital necessary to do research and development (R&D). A number of European Union (EU) nations have implemented policies that encourage innovation in order to address this issue. These nations think that this R&D will result in the development of digital technologies that will not only make businesses stronger, more competitive, and more adaptable (by enabling, for instance, the provision of more customized goods and services), but also more socially and environmentally conscientious.

While practitioners and scholars have differing definitions of Industry 4.0, smart production through digital methods is widely accepted as its essence. Widespread adoption suggests that I4.0 is being well received by enterprises. The research and consultancy firm Gartner predicts that I4.0 will become increasingly important in the future. They have also identified nine key I4.0 pillars. The technologies under question are "Cloud, Cyber-security, Big Data Analytics, Industrial Internet, Horizontal / Vertical Integration, Augmented Reality, Simulation, and Advanced Manufacturing."

Scientists are researching how Industry 4.0 might lead to enhanced sustainability and how it can be adopted more because states and corporations are becoming more interested in becoming ecologically sustainable. Ref is to optimize resource utilization, minimize waste, and enhance workplace safety and comfort. TBL can assist businesses in achieving this because it refocuses the emphasis from maximizing profits at all costs including destroying the environment to maximizing profits while promoting sustainability. Despite the widespread acceptance of the technologies' benefits, there have been few research on the effects of Industry 4.0 technologies on SMEs due to disagreements over a few key areas.

Any nation must overcome the challenge of adopting such technologies. Even more so for up-and-coming ones. These technologies are difficult for firms to develop or embrace since so many emerging economies are still rentier nations. Aside from security and political unpredictability, factors including a nation's digital, educational, and economic infrastructure frequently prevent emerging economies from using cutting-edge technologies.

The processes by which nations can adopt Industry 4.0 technologies are not immediately evident, despite the well-known benefits of smart technology for enterprises and economies. This is because there is a lack of established theoretical understanding and few instructions in the literature. To date, research on the relationship between Industry 4.0 technology and sustainability has primarily been exploratory in nature. The fact that researchers and practitioners haven't always agreed on what defines Industry 4.0 technology is one of the issues. Determining the precise nature of a technology makes it challenging to assess its influence on company.

Numerous technologies that enhance performance and efficiency, such as those that produce energy from renewable sources and save energy, have been shown to have positive environmental effects. They also provide fresh information. This information can help develop new environmental policies, steer businesses in new directions, increase company flexibility, and enable more efficient use of people and other resources.

The purpose of this article is to partially close the knowledge gap about the connection between sustainability objectives and Industry 4.0 technologies. Its primary goal is to determine whether Industry 4.0 technologies can improve how businesses manage their social, environmental, and financial resources.

The amount of research on the connection between sustainability and Industry 4.0 technology has grown recently. Nevertheless, certain results indicate that sustainability should include social aspects in addition to environmental ones, and it is suggested that future studies look into this gap. This study fills that knowledge gap by providing a more comprehensive grasp of sustainability.

With reference to the backdrop mentioned above, this study investigates three primary research questions: (1) How can the innovative features of Industry 4.0 technologies support TBL sustainability and the efficient application of those same technologies? (2) How much does TBL sustainability change when Industry 4.0 is implemented successfully? and (3) Does the relationship between TBL sustainability and these new technologies' innovative qualities get mediated by the successful use of Industry 4.0?

The format of this document is as follows. A basic introduction is presented first, then a survey of the literature about the connection between sustainability and Industry 4.0 technology. Next, the study's methodology is described. A hypothesis test and a discussion of the findings are then included, along with an explanation of the implications for researchers and practitioners. The study's findings and a few suggestions for potential further research will be offered at the end.

LITERATUR REVIEW

An outline of Industry 4.0

Industry 4.0's inception dates back to the Hannover Fair in 2011. When the German government backed it in 2013, it became an official strategic plan for the manufacturing industry. Industry 4.0 technologies aim to: customize and connect manufactured goods to the internet; simplify product and part tracking; automate and increase the flexibility of production chains; establish communication between products, parts, and machines as the norm; enable human-machine interaction (HMI); enable Internet of Things (IoT)-enabled products to make factories smarter; and enhance business models by adding value to the production chains.

Foundation Theory

Industry 4.0 technologies, which function through a diffusion and implementation mechanism that sees the innovations adopted in other countries, including developing ones, were developed in some of the world's most technologically advanced nations, such as Germany. Reaching new economies, however, is usually a more gradual process. When comparing, for instance, the implementation rates in Germany and Indonesia, one can see the stark differences right away. These variations in implementation rates may result from a variety of causes, as well as multiple obstacles. The degree of rivalry in the adopters' and suppliers' industries can have a significant impact. This implies that, in part because various countries have varied demands, emerging nations may value Industry

4.0 technologies differently than developed nations.

The spread of technologies has piqued the curiosity of academics throughout the last fifty years. Nine theories have been proposed to explain the variations in diffusion: the Unified Theory of Acceptance and Use of Technology (UTAUT), the Technology Environment Organization Framework (TOE), the Theory of Planned Behavior (TPB), the Motivation Model (MM), the Diffusion of Innovations (DOI), the Technology Acceptance Model (TAM), and Social Cognitive Theory (SCT). The DOI idea is the one that is most widely recognized out of all of these.

The sociologist developed the DOI theory. It is mostly dependent on the characteristics of Industry 4.0 technology and the opinions of current and prospective users. However, an individual may not have the same sophisticated perspective on such technologies as a firm or organization. As to the DOI theory, successful technology adoption in an organization depends on providing accurate and comprehensible information to all its members. According to the organization diffusion of innovation (ODI) theory, those who are employed by an organization have a different perspective on the implementation process than do those who are not. Within organizations, people typically have set roles within rigorous communication rules and hierarchical hierarchies. Reference so emphasizes that people in organizations tend to think more based on their roles than on their own personal convictions.

In small and medium-sized enterprises (SMEs), the focus of this study, the authority to decide on technology is often held by a small group of influential people, as the founders of the company are typically the ones who drive all operations. This is referred to as authoritarian innovation on occasion. As the reference notes, a key component of the DOI model is persuading business executives of the advantages of technology. The perceived qualities of innovation relative advantage, compatibility, complexity, trialability, and observability must be carefully considered in order to achieve this. The idea of path dependency states that current technical advantages and knowledge bases serve as the cornerstone for future technological advancements. This study's hypothesis is that SMEs could be persuaded to adopt new technologies and obtain a competitive edge by revealing the relative benefits of innovation, their compatibility, as well as their complexity, trialability, and observability.

It is impossible for firms to achieve their sustainability goals without using new technologies. The COVID-19 pandemic serves as proof that achieving these aims is becoming more and more crucial. Research on the subject of information management from an I4.0 perspective shows that SMEs can definitely benefit from I4.0 in achieving their sustainability objectives. SMEs are impacted by technologies and underlying variables in both positive and bad ways, though, because of the price, complexity, and skill associated with their deployment. Created a technology-for-sustainability-adoption model based on Polish SMEs to aid in the better understanding of the dynamics by academics and industry players.

Implementing Industry 4.0

According to the reference, there are more specialized areas in I4.0 implementation that need to be investigated, and the researchers have provided an implementation framework. This technical innovation creates fundamental capabilities for attaining sustainability, particularly for SMEs, and forms intelligent manufacturing. It also successfully initiates action. While some industries adopted technology at a rapid pace, others had great difficulty implementing new ideas. The significant financial outlay required to integrate new technology serves as a barrier to SME adoption. In addition to technological difficulties, organizations and society have issues. Efficiency in industrial production has increased dramatically as technology has advanced, particularly with industrial 4.0, which is supported by nine technologies.

Technology for Industry 4.0 and Triple Bottom-Line Sustainability

As previously mentioned, research is limited; nonetheless, based on available empirical data, Industry 4.0 technologies have the potential to increase productivity by enhancing working methods through creative and efficient approaches. These adjustments could save energy, cut emissions, and prevent environmental pollution. Making structural adjustments to businesses is how these gains in efficiency and production are realized. Though there is a clear correlation between Industry 4.0 technology and improved environmental protection, there isn't much empirical data to support this claim. In actuality, scientists, researchers, and practitioners are not entirely in agreement as of now that Industry 4.0 will result in increased environmental sustainability. Even though some technologies, like 3D printing, have shown to improve manufacturing, their relative novelty raises questions about their environmental credentials. For this reason, it is suggested that, in order to increase certainty regarding the advantages of these technologies, a model based on the TBL should be used. Using such a model has the benefit of simplifying the measurement of technological contributions to the environment and society. Regardless of the industry a company operates in or its size, their own research concludes that Industry 4.0 technologies are beneficial for each of these goals. Reference also came to similar conclusions regarding the advantages of Industry 4.0 and its contribution to environmental sustainability. Reference-based research also came to positive conclusions regarding Industry 4.0's contributions to sustainability in the environment, especially in the areas of energy and resources. They did, however, caution that additional research is required to evaluate the findings.

According to sources, complete digitalization can assist businesses in utilizing these tactics more successfully since it offers accurate and up-to-date environmental information. A review of the prior research by means of citation examined various approaches to tackling the problem of sustainability and Industry 4.0. It considered resources about waste and its consequences on the environment, including statistical data, exploratory investigations, expert interviews, and other materials. According to this assessment of the literature, there are still a lot of obstacles to overcome before Industry 4.0 technologies can fully be implemented, and more research is necessary to determine both the good and bad effects they will have on sustainability. Scientists and practitioners would benefit from new research that clarifies how Industry 4.0 technologies might improve TBL sustainability and help accomplish the Sustainable Development Goals (SDGs) of the United Nations.

HYPOTHESIS DEVELOPMENT

Creation of Relative Advantage Hypotheses

The term "relative advantage" describes the benefit that comes from utilizing modern technology in comparison to earlier ones. What the user wants to enhance determines what innovation is sought after. Clear-cut benefits such as increased sales (strategic effectiveness) and cost savings (operational effectiveness) increase the likelihood of innovation adoption. Industry 4.0 technologies have so far proved that they can greatly improve processes and practices, thus they have a good probability of being implemented. Given that relative advantage has been shown to be crucial to the spread of technology, further research on this idea is needed in the context of Industry 4.0.

References were used to identify the disruptions brought about by 4.0 technologies with regard to environmental sustainability. Industry 4.0 technologies like Big Data, cloud computing, and the Internet of Things (IoT) can help reduce pollution, greenhouse gas emissions, and climate change while enhancing waste management, water treatment, and more environmentally friendly supply chains.

When using radio-frequency identification (RFID) technologies, Chinese businesses discovered that relative advantage had a marginally beneficial effect. In the meantime, an analysis of big data innovations by reference discovered that the adoption of big data by various businesses was significantly influenced by the technology's capacity to foster creativity, competitiveness, productivity, customer value, and optimal business solutions. This is excellent news for environmental sustainability since, as the referenced empirical study demonstrates, Big Data is a powerful indicator of increased social and environmental protection. Big Data has several benefits for sustainability because it may completely change how firms run and react to circumstances. Cloud computing, like big data, has the potential to save costs, increase performance, and offer crucial backup choices. In light of all of this, this article suggests that relative advantage is a key element that can influence businesses to embrace Industry 4.0 technologies, as they do so when the advantages of a technology clearly exceed any drawbacks. Industry 4.0 is well-positioned for adoption by several businesses and sectors of all sizes due to its associations with increased customization, flexibility, and resource efficiency.

H1a: The successful use of I4.0 and relative advantage are significantly positively correlated.

H1b: Relative advantage and TBL sustainability have a strong positive association.

H1c: The relationship between TBL sustainability and relative advantage is mediated by effective I4.0 implementation.

Theories and the Rise of Complexity

The more difficult a technology is to utilize, the more sophisticated it is thought to be. They have a lower chance of being adopted the more sophisticated they are. The complexity of Industry 4.0 technologies often prevents SMEs from adopting them due to a lack of technical competence. The amount of various elements and diverse relationships are typically used to quantify complexity. Cyber-physical systems consist of a variety of diverse, specialized devices that can adapt to their surroundings and function in a flexible manner. They accomplish this with the use of programs that combine various business activities and innovations, as well as data analysis. However, a set of protocols and communication standards that facilitate integration across business processes should ideally exist for such a system to perform well. Getting software and hardware to work together seamlessly can be especially difficult. Users frequently experience confusion and uncertainty while dealing with complicated technologies. This may have a detrimental impact on the choice to use new technologies. Research from the past has shown a significant relationship between functionality and the choice to use new technology. People's opinions on technology are typically influenced by how complex they think it is. For instance, many find it difficult to comprehend and trust blockchain technology since they believe it to be complicated, until it is incorporated into simpler systems. Concerns regarding the speed of the block chain's transaction methods have been highlighted. Additionally, the fact that blockchain technology is still developing and poses security risks may hamper its adoption [106]. Users get distrustful of a system more and more when they believe they have little control over the way it works. Companies will be less inclined to accept new technology if they believe it to be highly complex and incompatible with their current processes and technologies.

H2a: There is a significant positive relationship between complexity and effective implementation of I4.0.

H2b: There exists a noteworthy affirmative correlation between TBL sustainability and complexity.

H2c: Complexity and TBL sustainability are related, however the relationship is mediated by effective I4.0 implementation.

Theories for the Growth of Compatibility

The degree to which a new technology aligns with current organizational structures, protocols, policies, and values determines how likely it is to be accepted. When new technologies are integrated with the existing technological infrastructure and work procedures, it is the best scenario. For SMEs, it's critical that changes align with business culture to prevent employee resistance. Since e-businesses are technological by nature, they have an advantage, but they still need to identify methods that work with their company. The adoption of Industry 4.0 technologies can be seriously hampered by antiquated work procedures and production techniques. A serious risk of implementation failure exists in the absence of appropriate compatibility. Many studies have raised the question of compatibility's significance.

This study's conclusion is that SMEs will find it difficult to adopt and grasp sophisticated technologies if they have unfavorable attitudes toward them. However, Industry 4.0's technologies will have a higher chance of success in SMEs if they are compatible with the technology that businesses now employ. A study found that the likelihood of sophisticated technology being adopted increased with the degree of perceived structure compatibility. Referred to empirical research, the findings about Indonesian manufacturing SMEs were identical. According to the study, compatibility has a favorable effect and encourages staff members to start using new technologies. Businesses are more likely to adopt a new value development strategy when the new procedures mesh well with the current system.

An empirical investigation on the application of additive manufacturing (AM) technology in the manufacturing of industrial parts was conducted. They discovered, like the other studies, that the adoption of AM technology depends on its ability to work with older infrastructure, procedures, and systems. Reference and the study by reference both supported the positive correlation between compatibility and the adoption of new technologies. Reference also noted that Industry 4.0 technologies have the potential to introduce alternative socio-economic models into societies that adopt them widely, changing the course of nations and bringing them closer to their natural surroundings. "Green" or "clean" technologies are those that bring nature and humankind into harmony. By improving upon current procedures, software, and methods, they aid in the attainment of sustainability objectives and lessen environmental damage. These concepts form the basis of the next indicator.

H3a: The successful application of I4.0 and compatibility are significantly positively correlated.

H3b: There is a strong correlation between TBL sustainability and compatibility.

H3c: Compatibility and TBL sustainability are related, although the relationship is mediated by effective I-4.0 implementation.

Development of Trialability Hypotheses

Trialability is the feeling that a technology offers an opportunity for users to try it out before committing to a full-scale adoption. Trialability is a crucial component of new technology since it eases adopters' concerns. Trialability is crucial for SMEs since their innovation budgets are typically constrained, and they need to know right away if a new technology would be beneficial. Because trialability accelerates the benefits of technology, it may be the most significant predictor of adoptability. The implementation process will accelerate if advantages can be realized more quickly. Trials are beneficial because they reassure prospective users and demonstrate that a technology is simpler than it may initially appear. Trials also allow for the resolution of problems that could prevent a business from implementing a technology.

Research demonstrates unequivocally that a technology's chances of being adopted are significantly increased when it is available for trial. According to a reference study, trialability had a significant impact on cloud technology adoption in micro, small, and medium-sized businesses. A study cited in the reference similarly discovered a strong correlation between technology implementation and trialability. After researching the primary drivers of Big Data technology adoption in businesses, the reference found that trialability ranked highly. But in a related study about 3D printing in American manufacturing, reference discovered further contradictory findings regarding the impacts of DOI and recommended further investigation to validate its efficacy. Given all the benefits that trialability appears to have, BDA service providers ought should provide a trial version of their products in order to encourage small and medium-sized businesses to adopt them more frequently.

H4a: The successful application of I4.0 and trialability are significantly positively correlated.

H4b: Trialability and TBL sustainability are substantially positively correlated.

H4c: Trialabilty and TBL sustainability are related, and this link is mediated by effective I4.0 implementation.

Development of Observability Hypotheses

The degree to which the outcomes of an innovation are apparent to outsiders is referred to as observability. "The process by which companies observe the success factor of other firms that have already adopted that technology" is the definition of observability given by reference. To date, research has yielded conflicting results about the extent to which observability influences technological adoption rates. Observability, according to those who have researched the matter, is a significant implementation aspect. This is supported in part by reference, who conducted an empirical investigation into the matter and discovered a strong correlation between observability and the application of technology. The study conducted by Reference revealed a noteworthy correlation with the use of BDA in supermarkets. The relationship has been criticized for being weak and is still contentious. The following hypotheses are put forth because observability does appear to have some beneficial benefits, even though this study will continue to be aware of this controversy:

H5a: The successful application of I4.0 and observability are significantly positively correlated.

H5b: The TBL sustainability and observability have a strong positive correlation.

H5c: A successful use of I4.0 mediates the connection between TBL sustainability and observability.

Developing an Effective I4.0 and TBL Sustainability Implementation Hypothesis

For SMEs, the high implementation costs of I4.0 serve as a barrier to investment. Aside from the technological difficulties in execution, there are worries about how successfully society and organizations can interact with Industry 4.0. It is obvious that both technological and human factors must be taken into consideration for implementation to be successful. Organizations must integrate I4.0 technologies in a vertical, horizontal, and end-to-end manner. Through the integration of many hierarchical systems inside an organization, vertical integration increases the flexibility, agility, and efficiency of a reconfigured production system. The smooth cooperation of value networks throughout the value chain between businesses and organizations is known as horizontal integration. In the value chain, end-to-end engineering enables unique innovations. More adaptability, quicker lead times, and more effective market reach are the outcomes of fully integrating all these factors. Environmentally friendly technology are being employed in many industries to reduce costs and increase revenue.

H6: TBL sustainability and successful I4.0 implementation are significantly correlated.

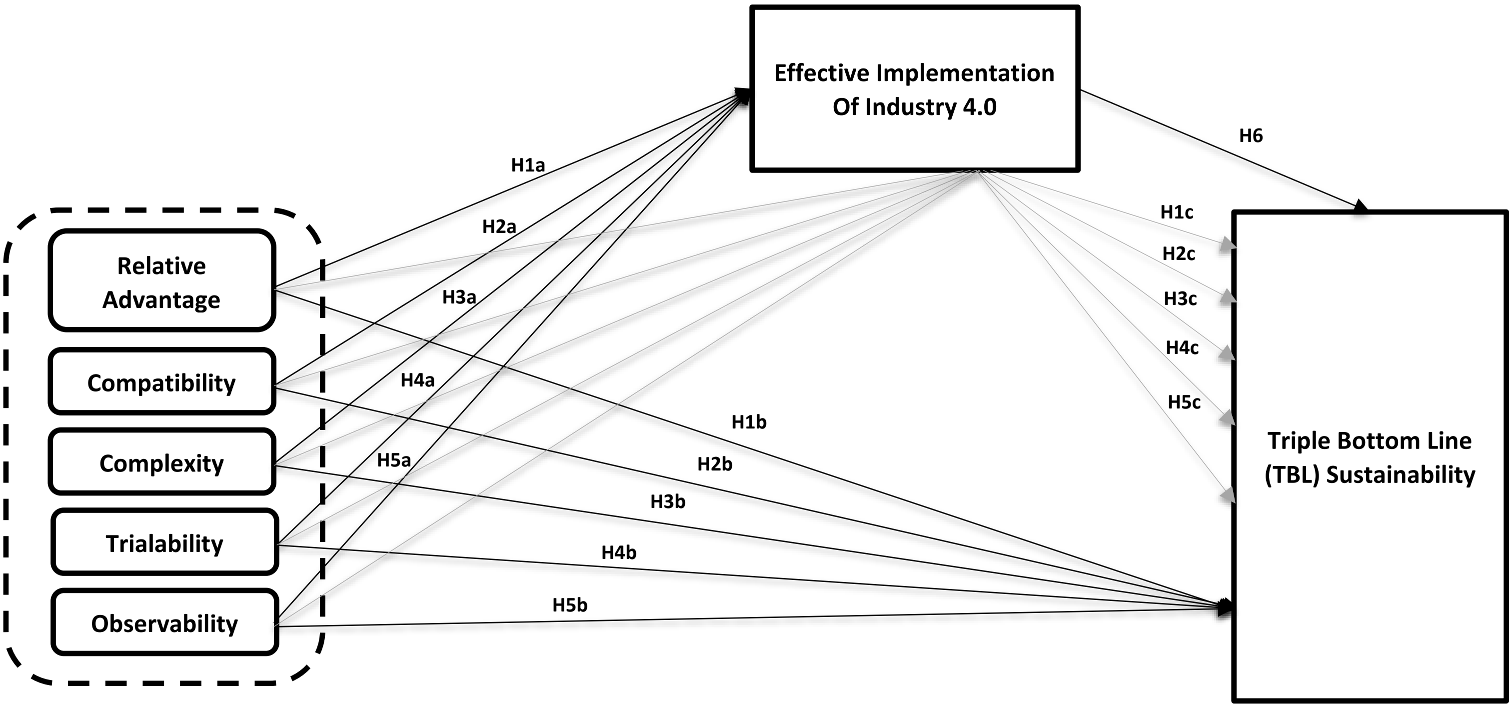

Figure 1. Conceptual Framework

MATERIALS AND METHOD

The purpose of this study is to quantify how innovation qualities affect Industry 4.0 and TBL sustainability implementation. Innovation variables' diffusion. The purpose of this study is to quantify how innovation qualities affect Industry 4.0 and TBL sustainability implementation. This study makes use of the diffusion of innovation factors as they are presented in the framework. According to the paradigm utilized in this study, the research (Figure 1) demonstrates how the innovative features of Industry 4.0 technologies help SMEs achieve TBL sustainability through efficient use of Industry 4.0. Figure 1 of the research demonstrates how the innovative features of Industry 4.0 technologies help SMEs achieve Triple Bottom Line sustainability through efficient Industry 4.0 adoption.

Population and Sampling

Using a cross-sectional methodology, the authors collected quantitative data from Indonesian SMEs that had registered by filling out a questionnaire. The SMEs listed in the Indonesian SME Business Directory SME Corp. made up the study's population. Higher-level managers who were more conversant with their organizational practices and the adoption of Industry 4.0 made up the study's respondents.

Reference suggested an acceptable sample size of 200 as a minimum and 400 as a maximum for Structural Equation Modelling (SEM) research. The sample size was determined by the authors using G-Power version 3.1. To test the model with six predictors, the study needed 255 samples, based on a power of 0.80 and a smaller effects size of 0.055. To mitigate potential issues arising from a limited sample size, the authors opted to gather data from over 300 small and medium-sized enterprises (SMEs) in Indonesia. The study used a straightforward random sampling technique to find possible study participants. The managers of the SMEs received 1100 questionnaires from the authors, who also made personal visits, phone calls, and emails to the responders. 409 questionnaires were received in response, however 13 of them were incomplete, therefore those were not included in the study. For the purposes of the final data analysis, 396 replies were used.

Measurement

Because the measuring items on the questionnaire were drawn from previously published material, the study's questionnaire was valid and dependable. In this study, the 5-point Likert scale where 1 represents strongly disagree and 5 represents strongly agree was used to facilitate decision-making. Because the measuring items on the questionnaire were drawn from previously published research, the study's questionnaire was valid and dependable. To make choice selection as simple as feasible for the respondents, a 5-point Likert scale was used in this study, with 1 denoting strongly disagree and 5 strongly agree.

Methods of Analysis

Studies that aim to comprehend the data structure in high dimensions should use multivariate analytics. When analyzing data with numerous variables, the multivariate analysis method is employed since it is believed that these variables are connected to one another. Multivariate analysis can be divided into three categories: dependency, interdependence, and structural models. One method that attempts to analyze the link between dependent and independent variables at the same time is structural modeling.

A measurement model and a structural model are the two main components of a comprehensive SEM model. The purpose of measurement models is to validate a component or dimension using empirical indicators. Models pertaining to the relationship's structure that establishes or clarifies the causation between variables are known as structural models. A comprehensive model necessitates the following steps: (a) creating theory-based models; (b) creating flowcharts to demonstrate causality; (c) turning flowcharts into a set of structural equations and measurement model specifications; (d) choosing input matrices and estimation methods for the constructed model; (e) evaluating identification problems; (f) evaluating the model and determining its goodness of fit; and (g) interpreting and modifying the model.

A model's correctness is evaluated using a variety of goodness of fit criteria, the majority of which are handled automatically by the AMOS program. In order to fully evaluate the model, two things must be done: (a) assess the sample size; and (b) assess the normalcy and linearity assumptions. The process of estimating SEM using Maximum Likelihood involves calculating the critical ratio, which has a value range of

2.58. (c) Additionally, data with unique characteristics that deviate significantly from other observations and appear as extreme values for univariate or multivariate outliers are evaluated. The z-score value with a threshold in the range of 3.00 is used to evaluate univariate outliers, while the Mahalonobis distance can be used to evaluate multivariate outliers. Other methods of evaluating multivariate outliers include: (d) assessing the assumptions made about multicollinearity and singularity; (e) assessing the goodness of fit criteria with a cut-off value; and (f) analyzing direct, indirect, and total effects. The three legitimate requirements unidimensionality (factor loading 0.50), discriminant validity (correlation 0.30), and internal reliability (Cronbach alpha 0.70) must all be satisfied in order to analyze the SEM path structure.

RESULT

The target population for this study was SMEs in Indonesia, and the organization served as the unit of analysis. The questionnaire focused on I4.0 practices within this group. Managers having a minimum of three years' experience implementing Industry 4.0 were the respondents. The Federation of Indonesian Manufacturing and SME Corporation provided the list.

Researchers must appropriately handle the generated model's incapacity to yield high-quality estimates while doing multivariate analyses using SEM. As a result, each parameter estimate cannot be performed without first evaluating the model. When estimating dusing Maximum Likelihood Estimation, the SEM model requires that the normality assumptions be met. This may be done by looking at the crucial ratio from the output AMOS program's results of the normality evaluation. However, prior to doing so, it is necessary to confirm that each construct's dependability and factor loading both satisfy the specifications. The loading factor value is obtained by the estimate of Standardized Regression Weights. The split-half Cronbach's Alpha approach was utilized to conduct the liability test in this instance.

Twelve of the parameters do not match the 0.50 minimum loading factor requirement. The metrics for increased sales and revenue and the created bespoke items were invalid for determining the relative advantage construct. Indicators did not follow a normal distribution either. The technical support and training parameters weren't routinely distributed or valid. The respondents find little value in competitors' efforts to adopt smart technologies and take advantage of Industry 4.0 to outperform domestic rivals. They didn't care that technology was increasing product quality or creating variety; instead, they thought it would just make their jobs easier. Consequently, these indicators were unable to quantify the constructions and, as a result, could not be applied to the subsequent stages. This study kept the third and fourth sustainability variable parameters although many of the other parameters were invalid. If there are many study samples far more than what is required this can still be accepted. Furthermore, both parameters' critical values satisfied the criterion, indicating that they are both feasible to maintain and regularly distributed.

The number of parameters that will be compared with the goodness of fit cut-off value is the last step in testing the SEM model employed in the investigation. While some tests yield negligible results, others yield positive outcomes, according to the chi square and GFI tests. As a result, the model is suitable for the following stages, which involve forecasting the direct and indirect effects of independent variables (such as trialability, complexity, relative advantage, and observability) on the dependent variable (sustainability) through the use of Industry 4.0 as mediating variables.

The researchers made modifications to the model because the created model still had a big residual. It is possible to make modifications with a solid theoretical foundation. The estimated model needs to be changed if the standardised residual covariances matrix has a value outside of the ring 2.58 and probability less than 0.05. Researchers also take note of the strongest theoretical foundation and the high value of the modification indices. The chi square value will drop when the coefficient is estimated, and the model will perform better. the optimal calculated value after several modifications.

The estimation summary has a definite advantage that has a favorable and major impact on the successful implementation of I4.0. The desire of SMEs to adopt I4.0 increases by 13% (Hypothesis H1a) and the environmental performance by 30% (Hypothesis H1b) due to the relative benefits of using innovative information technology. These results are consistent with the reference studies [91,96,97]. The respondents acknowledged the ease of understanding of smart technology and expressed support for the introduction of Industry 4.0.

The majority of SMEs have systems that are sufficiently structured to integrate smart technologies. Because its staff members possess the requisite expertise and comprehension of smart technologies, they don't require extensive training and have no trouble implementing them. Businesses can also implement industry 4.0 with the help of technical support. Hypothesis H2a states that the perception of low complexity leads to a large rise in industry 4.0 implementation of 28%, while Hypothesis H2b states that it boosts environmental or sustainabilty achievement by 11%.

The goal of this study is to determine whether the system is compatible with the technological environment of SMEs. If the organization's system is compatible with smart technology, they will readily embrace Industry 4.0. However, the corporation will be less likely to embrace industry 4.0 if it needs to make several adjustments, such as integrating software. SMEs were questioned about industry 4.0 adoption intentions and smart technology compatibility in this study. SMEs were more interested in embracing Industry

4.0 (Hypotehsis H3a) when their systems were more interoperable, which in turn made it easier for them to meet their sustainability goals (Hypothesis H3b).

SMEs have limited resources, so it's critical that they get the chance to test out new technologies before implementing them. By doing this, they are able to identify the new technology's performance benefits and resolve any potential implementation issues. Because this procedure addresses problems before an expensive roll-out, it facilitates implementation and reduces costs. They won't think twice about adopting the technology if, after using it, they perceive its advantages. The estimation findings make this clear. Trialability has a 26% significant impact on I4.0 implementation (Hypothesis H4a). Because smart technologies make it simple to learn from mistakes, they give operators more control over operational tasks. The sustainability objectives will be met if SMEs believe they can lower production waste and error rates. This results in a 55% high positive and substantial influence of trialability on sustainability (Hypothesis H4b).

SMEs must assess their company's performance by contrasting it with that of their rivals. They may quickly see their competitors' business performance by implementing Industry 4.0. Despite being extremely small only 1% the effect is significant (Hypothesis H5a). Intelligent technology can simplify the task of keeping an eye on company activities and analyzing client requests and grievances. These procedures don't require a lot of resources to complete. As a result, observability benefits sustainability goals and appears to increase them by 16% once I4.0 is implemented (Hypothesis H5b).

Using I4.0 implementation as a mediating variable, this study also examines the indirect effects of relative benefit, complexity, compatibility, trialability, and observability on sustainability goals. This study demonstrates that the use of I4.0 mediates the effect of trialability (H4c) by 27.7%, observability (H5c) by 10.2%, complexity (H2c) by 29%, and relative advantage (H1c) by 14.3% on sustainability goals using the results of standardized indirect effects. I4.0 implementation, however, is unable to completely mitigate the impact of compatibility on sustainability objectives (H3c).

DISCUSSION

The triple bottom line, sometimes referred to as sustainability goals, comprises social equality, ecological integrity, and financial profitability. These metrics are crucial for small and medium-sized businesses (SMEs), which are frequently inefficient and ineffective in operating their businesses. Achieving sustainability goals involves not just increasing environmental performance but also enhancing skills to provide more effective and efficient customer service. SMEs need possess innovation traits including relative advantage, complexity, compatibility, trialability, and observability to successfully apply I4.0 in order to meet their sustainability goals. These traits make SMEs more eager to adopt Industry 4.0 and enhance their environmental performance. Thus, the purpose of this study is to examine how innovation attributes impact I4.0 implementation.

The hypothesis test's findings indicate that relative advantage had a major influence on how well I4.0 was implemented. It has been noted that Chinese businesses who implemented RFID technology without a comparative advantage were unable to improve their performance. The majority of respondents think that implementing I4.0 lowers costs, makes better use of resources, and improves monitoring systems, all of which boost sales and revenue. Businesses grow more nimble and are able to create specialized goods. Additionally, this study discovered that applying I4.0 improves sustainability performance by 58%. As mentioned by reference, many SMEs think that the advantages of investing in technology will exceed the drawbacks, despite the fact that it is a rather large expenditure.

Smart technology adoption is less likely when it is complicated to use. Respondents to this study were questioned if SMEs had sufficient infrastructure systems, if staff members had the necessary skills, and if smart technology is simple to comprehend and use. The impression of smart technology's simplicity has a major beneficial impact on I4.0 deployment and sustainability performance.

Technology compatibility with current IT systems is another major concern for SMEs looking to implement Industry 4.0. Intelligent technology ought to mesh well with the current organizational values and staff mindset. According to this study and others, businesses are more likely to adopt a new value creation strategy when the new procedures work well with the existing systems. Accordingly, compatibility-related findings pointed to a major influence on I4.0's successful deployment. Despite having a 21% lower impact on sustainability goals, this research produced the same findings as the reference. I4.0 technologies have the power to harmonize with their environment.

Since trialability significantly raises the I4.0 implementation rate, it is a crucial characteristic for developing technologies. The findings of this study are consistent with earlier research. Trialability lessens the reluctance of SMEs to technology adoption. Furthermore, as trialability lowers the chance of human error while utilizing smart technology, it can enhance sustainability performance.

IMPLICATIONS OF THE STUDY

In order to achieve the sustainable development goals, it is important to have an attitude toward Industry 4.0 acceptance and implementation aim, as indicated by Roger's diffusion of innovation model in the research. Thus, CEOs, owners, and managers of SMEs should take note of numerous important implications of this study. As a result, the study's conclusions may not only apply to SMEs in Indonesia but also to businesses that operate in other developed and rising nations. Initially, the research suggests that the innovative features of Industry 4.0 technologies are crucial for the implementation of Industry 4.0 in the pursuit of sustainable development objectives. The relative benefits of Industry 4.0 to meet customer requirements in sustainable ways, such as cost reduction, enhanced energy efficiency, sales and revenue proficiency, should therefore motivate SMEs managers to do everything in their power to foster innovation in technology: introduce Industry 4.0 technologies that are more flexible and compatible for quick adoption; lessen the challenges associated with Industry 4.0 technologies and make them simple for employees to learn and use. SMEs have the ability to observe and pursue a sustainable project with their prospective clientele.

CONCLUSIONS

The effective implementation of Industry 4.0 has been measured using the technology of innovation theory. There haven't been many studies done in this area, so this one will provide additional information to businesses using the idea. The meditation impact of successfully using I4.0 was overlooked in earlier research, and this study has rectified this. Additionally, this study contributes by creating a model that has undergone hypothetical testing. It will be important research for small and medium-sized enterprises in Indonesia. This study has also attempted to quantify the effects of I4.0 on TBL sustainability. This study has demonstrated the beneficial effects of technological advancements on the successful execution of Industry 4.0 initiatives and sustainability objectives. The relationship between technological innovation and sustainability objectives is mediated by I4.0 implementation. But there isn't much of an indirect relationship between observability and sustainability. The results of this study indicate that the association between these two variables is somewhat supported by the implementation of I4.0. The pandemic's time limits presented significant difficulties. Another drawback is that the degree of employee awareness of sustainability is the sole social element taken into account. For later research, the optimal respondent count ought to be increased. Other industries can be the subject of studies. Further research can be conducted in other nations to compare how I4.0 is being implemented.

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