JABA
Journal of Applied Business Administration
https://jurnal.polibatam.ac.id/index.php/JABA

Accelerative Capacity of Keyresources Industry 4.0 in Metropolitan Culinary Micro-Small Sector and Green Business Sustainability Impact

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Article Information

Article History:
Received : August 2023
Accepted : September 2023
Published : September 2023

Keywords:
Industry 4.0, Culinary MSMEs, Circular Economy, Sustainable Business, Technology Adoption

Abstract

Indonesia's MSME sector is torn between economic growth and environmental damage. Industrial Revolution 4.0 encourages MSMEs, including in the culinary sector, to integrate business and social values with the principle of circularity. This study analyzes the influence of Industry 4.0 key resources on Culinary MSMEs in Jakarta on the circular economy and sustainable business. A quantitative approach was used by surveying Culinary MSME owners in Jakarta, taking 82 samples by random sampling. The data were analyzed using structural equation modeling-partial least square (SEM-PLS). The analysis results show that the key resources of Industry 4.0, such as production system management, HR leadership, environmentally friendly business operations, and information technology, significantly affect the adoption of Industry 4.0 and the establishment of Sustainable Culinary Production Systems. The adoption of Industry 4.0 also impacts circular economy capabilities and sustainable business. Similarly, Sustainable Culinary Production Systems contribute to circular economy capabilities and sustainable business.

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ISSN 2548-9909

Introduction

The industrial revolution 4.0 has changed the business paradigm, consumer behavior, and various sectors such as computers, telecommunications, and health services. The development of industrial technologies such as supercomputers, intelligent robots, cloud computing, and AI marks the entry into the 21st century and the emergence of the industrial revolution 4.0. The industrial revolution 4.0 brings the potential for employment to increase to 2.1 million jobs by 2025 but also threatens to eliminate 1-1.5 billion jobs in the 2015-2025 period due to automation (Bashar Fakhri et al., 2021). Despite concerns about replacing human workers with robots, new AI-enabled jobs will also emerge, and humans and AI will work together to improve productivity and efficiency (Bankins & Formosa, 2023). In the industrial era 4.0, industrial human resources in Indonesia need to experience a transformation of skills towards information technology because applying this system can create more specific job opportunities and require high competence.

Micro, Small, and Medium Enterprises (MSMEs) dominate 99.9% of the business industry in Indonesia and are closely related to the era of the industrial revolution 4.0 (Harini, Pranitasari, Said, & Endri, 2023). The government aims to make MSMEs heroes in the revival of the national economy in 2023. Minister of Tourism and Creative Economy/Head of the Tourism and Creative Economy Agency (Menparekraf/Kabaparekraf) Sandiaga Salahuddin Uno stated that MSMEs in 2023 will become heroes in the national economy by opening business opportunities and new jobs, targeting 4.4 million new and quality jobs in 2024 (Rimadias, 2023). The contribution of MSMEs to Indonesia's gross domestic product (GDP) has almost reached 61% and absorbed as much as 97% of the workforce (Muna, Ardani, & Putri, 2022).

MSMEs in the era of the industrial revolution 4.0 have an important role in creating jobs, entrepreneurship, and increasing state income (Somohano-Rodríguez, Madrid-Guijarro, & López-Fernández, 2020). However, MSMEs face several challenges that must be overcome, such as lack of time and financial resources, difficulty adapting to market needs, and low levels of competence in marketing which impact low market share in the online market. One of MSMEs' most difficult challenges is implementing a business-oriented marketing system, which relies on big data analysis (Turkyilmaz, Dikhanbayeva, Suleiman, Shaikholla, & Shehab, 2020).

The culinary sector is part of the Micro, Small, and Medium Enterprises (MSMEs) sector which is experiencing rapid growth and showing strong resilience during the COVID-19 pandemic crisis. Indonesia's food and beverage industry increased by 2.54 percent from 2020 to 2021, reaching a total of Rp775.1 trillion. The Central Statistics Agency (BPS) reported that the Gross Domestic Product (GDP) of the national food and beverage industry reached Rp1.12 quadrillion in 2021, which contributed 38.05 percent of the non-oil and gas processing industry or 6.61 percent of the total national GDP, which reached Rp16.97 trillion (Qodriah, Darsono, Riani, & Anantanyu, 2021). The Ministry of Industry noted that in 2022, the restaurant industry sector experienced growth of 3.68 percent, increasing from the previous year's growth of only 2.95 percent (Simangunsong, 2022). Meanwhile, the Ministry of Tourism and Creative Economy of the Republic of Indonesia noted that the culinary sector is the largest subsector contributing to the creative economy's Gross Domestic Product (GDP). In 2020, the culinary subsector contributed around 41 percent of the total GDP of the creative economy, reaching Rp455.44 trillion of the total GDP of the creative economy of Rp1,134 trillion. Thus, the MSME culinary sector has a vital role in the Indonesian economy and has managed to survive and grow amid the challenges of the COVID-19 pandemic (Az'har & Nawawi, 2022).

However, there is a challenge that culinary MSMEs are the fastest-generating sector and can beat large-scale sectors. This condition can endanger business operations, surrounding communities, and the macro-environmental resilience of the country. Verboven &; Vanherck (2016) stated that more than 75% of the Culinary MSME sector could not run a sustainable business (Verboven & Vanherck, 2016). The Jakarta Metropolitan Area recorded to produce around 3.08 million tons of waste generation. Of these, the largest type of waste is food waste, with a proportion reaching 27.8% (Raharjo, 2019). This condition can occur because, citing data from the Central Statistics Agency (BPS) summarized by Goodstats in June 2022, 11,223 culinary businesses spread throughout Indonesia in 2020. DKI Jakarta is ranked first in the province with the highest number of culinary businesses in Indonesia, with 159 businesses in 2020 (Pujiastuti, 2023). This achievement is

much higher than other provinces, up to almost four times compared to West Java which is in 2nd position with 1,414 businesses in 2020. This is also compared to the fact that Indonesia, the number two country producing plastic waste that ends up in the ocean, is also number two in the combination of food loss and food waste (Waluyo & Kharisma, 2023). With this fact, MSMEs must start running a business by considering the triple bottom line concept (profit, planet, and people).

The circular economy concept is one option for combining environmental sustainability and business operations for resource use and consumption control. The working definition of a circular economy is an industrial system designed to restore or resurrect. It replaces the view that something will end in recovery, switching to the use of renewable energy, eliminating the use of hazardous chemicals that hinder reuse, and seeks to reduce waste through improved design of materials, products, systems, and business models (Klein, Nier, & Tamásy, 2022). In essence, the circular economy and Industry 4.0 are very closely related. Circular economy and Industry 4.0 are two interrelated concepts that can positively impact environmental sustainability and industrial progress. Kurnia et al. (2022) in their study stated that between the circular economy and Industry 4.0 lies in how digital technology and artificial intelligence can increase efficiency in the production process and support circular economy principles (Kurniawan, Dzarfan Othman, Hwang, & Gikas, 2022). Several studies found the role of key resources brought in the business concept of industry 4.0, such as the integration of advanced technology (IoT, Artificial Intelligence, Big Data, Could Computing), psychological-based HR management collaboration, integrated production systems can create business efficiency (Bag, Yadav, Dhamija, & Kataria, 2021; Hung & Chen, 2023; Safar, Sopko, Bednar, & Poklemba, 2018). Sommer (2015), in a case study of German manufacturing companies, shows that adopting Industry 4.0 acceleration internal management systems, such as technology readiness, organizational readiness, and human resource readiness, can encourage MSMEs to achieve business sustainability (Sommer, 2015). Meanwhile, Soomro et al. (2021), in IoT adoption research for Malaysian instant food factories, found the potential for the integration of minimized wasted production materials to increase energy savings and positive effects on the environment (Soomro, Hizam-Hanafiah, Abdullah, Ali, & Jusoh, 2021).

Research Method

This study uses quantitative methods that can explain the causal analysis between the variables studied with data conducted on Micro, Small, and Medium Enterprises (MSMEs) in the culinary sector in the Jakarta metropolitan area. The Jakarta metropolitan area is the entire administrative city. At the same time, the Thousand Islands Regency is not included in the research coverage area.

The population using 103 entrepreneurs in the culinary sector in Jakarta City who have been registered in the MSME association assisted by the DKI Jakarta Provincial Small and Medium Enterprises Cooperative Trade Industry as of July 2023.

In this study, the selection of respondents used probability sampling with a random sampling method, considering that each member of the population has the same opportunity to be involved in the research sample. Next, determine the number of samples using the Slovin formula (Mukherjee, 2019).

$$n = \frac{N}{1 + Nd^2} = \frac{103}{1 + (103)(0{,}05)^2} = 81{,}90$$

n= sample size, N= population, d= precision value.

Based on the confidence level of 95%, it is known that d = 5%. The results showed that the sample was n= 81.90 or rounded to 82. The sample of this study is the owners of MSMEs in the culinary sector in the Jakarta Metropolitan Area. The owner is assumed to be a representative of MSMEs because he is seen as the person who knows the content of the statement in the questionnaire best.

The questionnaire instrument was developed based on the results of a literature review related to this study. Table 1 contains the operationalization of the proposed variables.

Tabel 1: Definisi Operasional Variabel

Variable	Operational definition	Indicator	Source
Production System Management	Arrangements, methods, and processes used in producing goods or services in an industrial environment that has adopted the concept of Industry 4.0. full of flexibility	Production System Flexibility	(Dombrowski, Crespo, & Zahn, 2010; Haseeb, Hussain, Ślusarczyk, & Jermsittiparsert, 2019; Ingaldi & Ulewicz, 2019; Javaid, Haleem, Singh, & Suman, 2021; Mahmood, Lanz, Toivonen, & Otto, 2018; Somohano - Rodríguez et al., 2020; Vrchota, Řehoř, Maříková, & Pech, 2020)
		Work Area Layout Flexibility	
		Product and Process Traceability	
		Production Quality Control System	
		Teamwork in Production (Project Management Variable Transfer)	
		Psychological protection of the work environment (Moving Project Management Variables)	
		Supply Chain Relations (Collaborative Cooperation Variable Transfer)	
Human Resources Leadership	The workforce involved in the operation and transformation of industries that have adopted the concept of Industry 4.0.	Training and Capacity Building	(Bongomin, Nganyi, Abswaidi, Hitiyise, & Tumusiime, 2020; Haseeb et al., 2019; Javaid et al., 2021; Jermsittiparsert, 2020; Mukhuty, Upadhyay, & Rothwell, 2022; Sima, Gheorghe, Subić, & Nancu, 2020; Somohano-Rodríguez et al., 2020)
		Employee Empowerment	
		Readiness for Organizational Change	
		Management System Innovation and Long Term Investment (Leadership Management Variable Transfer)	
		Organizational Governance (Leadership Management Variable Transfer)	
Green Business Operations	Sustainable and environmentally friendly business practices that integrate environmentally friendly design principles into business operations.	Sustainable Friendly Logistic Resources (Transfer of Variable Green Logistic Management)	(Hseeb et al., 2019; Javaid et al., 2021; Somohano-Rodríguez et al., 2020)
		Sustainable Product Design and Production	
		Management of End of Life Resources	
		Eco-Friendly Product Design	
		Management of Suboptimal and Remaining Products	
Information Technology Management	Use and application of sophisticated information technology to support digital transformation and increase efficiency in the production process and industrial operations 4.0	Information Technology Resources	(Frank, Dalenogare, & Ayala, 2019; Haseeb et al., 2019; Javaid et al., 2021; Somohano-Rodríguez et al., 2020)
		Production Floor Robotics Knowledge	
		MSME Big Data Capability (Big Data Variable Transfer)	
Industry Adoption 4.0	Application of digital technologies such as the Internet of Things (IoT), big data analytics, artificial intelligence (AI), and integrated automation in production and business processes to increase efficiency, productivity, and quality and provide added value to the company.	Digitization of Business Transactions	(Frank et al., 2019)
		Application of Smart Technology for Raw Material Processing	
		Sophisticated Machines in the Creation of Product Brands	
		Integrated Supply Chain System	
		Integrated Management System	
Sustainable Culinary Production System	The process or flow of food and beverage production by maintaining sustainable environmental, social, and economic health by considering the product life cycle from raw materials to disposal, minimizing the use of limited natural resources, and ensuring the availability of sufficient and quality food along the supply chain.	Natural Energy Use	(Gunarathne, Lee, & Hitigala Kaluarachchilage, 2021)
		Environmentally Friendly Production Technology	
		Environmental Regulations in the Production Process	
		Environmentally Friendly Logistics and Waste Management	
Circular Economy Capability	The ability of an economic unit to apply the concept of circularity in the production, distribution, and consumption processes to create a sustainable circular economy by involving the implementation of strategies such as the use of recycled	Consumption Efficiency of raw materials and energy	(Zeng, Chen, Xiao, & Zhou, 2017)
		The efficiency of Supporting Logistics (Packaging, Cleaning Equipment, etc.)	
		Suboptimal Raw Material Management	

Variable	Operational definition	Indicator	Source
	raw materials, more efficient use of resources, product designs that can be recycled, and utilization of waste as production inputs, thereby reducing the need for new resources and reducing waste discharged into the environment.	Integrated Waste Management is Economical	
Sustainable Business Capability	The ability of an organization or business to integrate sustainability principles into all of its operations and business decisions includes efforts to reduce the negative impact of business on the environment and society, as well as increase the positive value generated through sustainable product and service development, responsible supply chain management, and adopting ethical and transparent business practices.	Positive Business Reviews	(Zeng et al., 2017)
		Availability of Eco-Friendly Culinary Products	
		Stakeholder Audited Business Performance	
		Internal Business Environment Policy	
		Cooperation and Problem Solving Based on Triple Bottom Line (TBL)	
		Increase in Revenue and Number of Subscribers	
		Tax Obligations	

The proposed variables are related in the hypothesis line forming the research model in Figure 1.

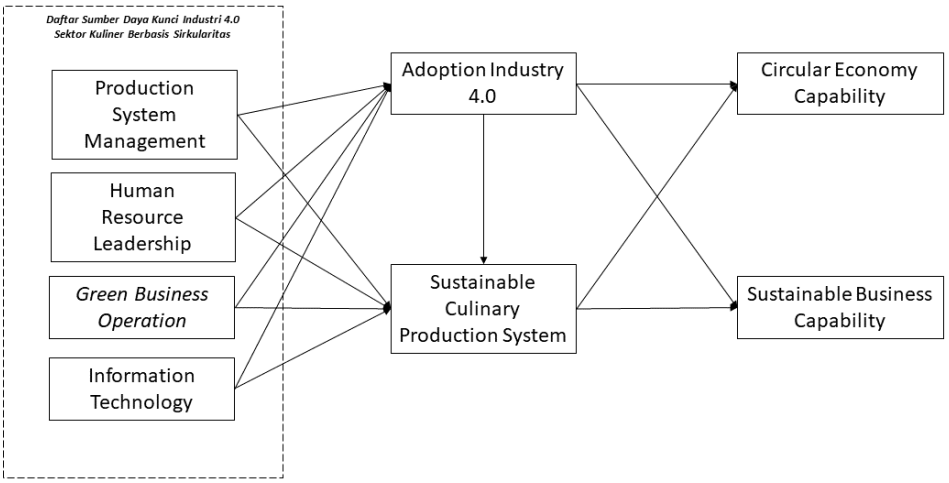

Figure 1. Research Model

Data collection techniques are carried out distributing questionnaires directly by the research team by becoming enumerators and visiting Culinary MSMEs for a full one month. In addition, some samples conducted surveys and direct observations. In addition to surveys, other data collection techniques used are field observation and interviews. Both were conducted to collect supporting data in this study. It aims to determine empirical phenomena in building the framework and background of this research. Causal analysis is used to see influence relationships and hypothesis testing using the Structural Equation Model (SEM). Data processing in this study uses the Partial Least Square (PLS) method because all variables are latent variables and are measured by indicators, even if there is multicollinearity between these variables (Becker, Cheah, Gholamzade, Ringle, & Sarstedt, 2023). A partial Least Square is used to confirm the proposed hypothesis.

Data analysis is carried out in two steps: descriptive analysis and causal analysis. In descriptive analysis, this research uses outer, inner, and hypothesis testing or structural models using SmartPLS version 3. Second, the results of the descriptive analysis are interpreted based on empirical theories and phenomena. The research model is reflective of indicators. We consider that SmartPLS 3.3.3 was developed based on more accurate modeling

and bootstrapping pathways for predicting research hypothesis models and recommended SEM modeling methodologists (Hair Jr., Matthews, Matthews, & Sarstedt, 2017).

Results and Discussion

Respondent Characteristics

This study managed to get 103 respondents with a selected sample of 82 respondents. This dataset contains interesting information about the characteristics of the group of respondents. First of all, regarding gender, it can be seen that women's participation is much more dominant, with 71%. In comparison, men only account for 29% of the total population of respondents. Regarding the age range, the age group of 41-50 years is the largest group, with 27% of the total respondents, followed by the age group of 51-60 years, with 23%. There is also a fairly even distribution in other age groups, such as 20-30 years (13%), 31-40 years (21%), and age groups over 60 years (16%). Moving to demographic locations, respondents are scattered in various areas of Jakarta. East Jakarta became the respondents' largest place to live, with 29% of the total. Meanwhile, West Jakarta and South Jakarta contributed 22% and 20%, respectively. The rest is divided between Central Jakarta (18%) and North Jakarta (11%). Respondents' recent education also reflects diverse backgrounds. Around 34% of respondents have a Bachelor/Diploma education background, followed by Senior High School (26%) and Junior High School (19%). In contrast, lower levels of education, such as Primary School (9%), and higher levels of education, such as Master/Doctorate (12%), are also present in smaller proportions. Regarding business type, the beverage sector has the largest portion, with 45% of respondents engaged in this field. They are followed by snacks with 32% and main xourses with 23%. When sorted by business category, most respondents fall into the micro category (77%), while the rest fall into the small category (23%). Finally, talking about the business's age, most respondents have a business that has been operating for 1-2 years (55%). Some are more established, with businesses that have been running for 3-4 years (15%) and businesses that have existed for more than five years (30%).

Research Validity-Reliability Testing

Data analysis techniques use the SEM-PLS analysis method. The SEM-PLS path analysis model consists of structural, internal, and measurement models or external models(Becker et al., 2023).

The measurement model analysis process is carried out to test the validity and reliability of the study. Validity testing is carried out by paying attention to the output of outer loadings on each indicator supported by the Average Variant Extracted value. Furthermore, the reliability value is seen in the Composite Reliability (CR) output supported by the Cronbach Alpha (CA) value (Rigdon, Sarstedt, & Ringle, 2017).

In Table 3, it was found that the variable was declared valid because the outer loadings value showed a number above 0.7, supported by Average Variance Extracted (AVE), indicating a number above 0.5. Then the Cronbach Alpha value on each variable shows a number above 0.7 or reliable. The composite reliability value of all variables is declared reliable because the overall value shows a number above 0.7, meaning the test is still declared reliable.

Table 2: Research Validity-Reliability Test Results

Variable *Indicator*	Outer Loadings	AVE	CR	CA
Production System Management				
MSP1	0.718	0.508	0.861	0.808
MSP2	0.752			
MSP3	0.786			
MSP4	0.934			
MSP5	0.861			
MSP6	0.773			
Human Resources Leadership				
KSDM1	0.871	0.687	0.916	0.884
KSDM2	0.900			
KSDM3	0.759			
KSDM4	0.707			
KSDM5	0.812			
Green Business Operation				
GBO1	0.771	0.570	0.887	0.846
GBO2	0.888			
GBO3	0.825			
GBO4	0.794			
GBO5	0.916			
GBO6	0.746			
Information Technology				
TIK1	0.761	0.577	0.845	0.755
TIK2	0.875			
TIK3	0.790			
TIK4	0.803			
Adoption Industry 4.0				

Indus_4.0_1	0.846	0.621	0.867	0.797
Indus_4.0_2	0.780			
Indus_4.0_3	0.729			
Indus_4.0_4	0.827			
Sustainable Culinary Production				
SPKB1	0.700	0.563	0.920	0.901
SPKB2	0.748			
SPKB3	0.865			
SPKB4	0.929			
SPKB5	0.757			
SPKB6	0.891			
SPKB7	0.792			
SPKB8	0.820			
SPKB9	0.953			
Circular Economy Capability				
KES1	0.733	0.538	0.874	0.828
KES2	0.799			
KES3	0.922			
KES4	0.800			
KES5	0.703			
KES6	0.857			
Sustainable Business Capability				
KBB1	0.939	0.549	0.916	0.895
KBB2	0.837			
KBB3	0.741			
KBB4	0.767			
KBB5	0.995			
KBB6	0.932			
KBB7	0.863			
KBB8	0.950			
KBB9	0.844			

After all indicators and variables are declared valid and reliable, the next step is that we will see the influence between one latent variable and another latent variable, both exogenous and endogenous, and its significance by looking at the value of the coefficient of determination (R2) and T-Statistics (Kock, 2018).

R-Square is used to explain the effect of exogenous variables on endogenous variables and whether they have a substantive influence. The R-Square value grouping has three categories: 0.75 including strong, 0.50 including medium and 0.25 including weak(Sarstedt, Radomir, Moisescu, & Ringle, 2022). Figure 2 shows that both dependent variables of adoption industry 4.0, sustainable culinary production system, circular economy capability, and sustainable business capability are above 0.75. So, it can be concluded that both the dependent variables of adoption industry 4.0, sustainable culinary production system, circular economy capability, and sustainable business capability are strongly influenced by independent variables.

R-Square Testing and Research Hypothesis

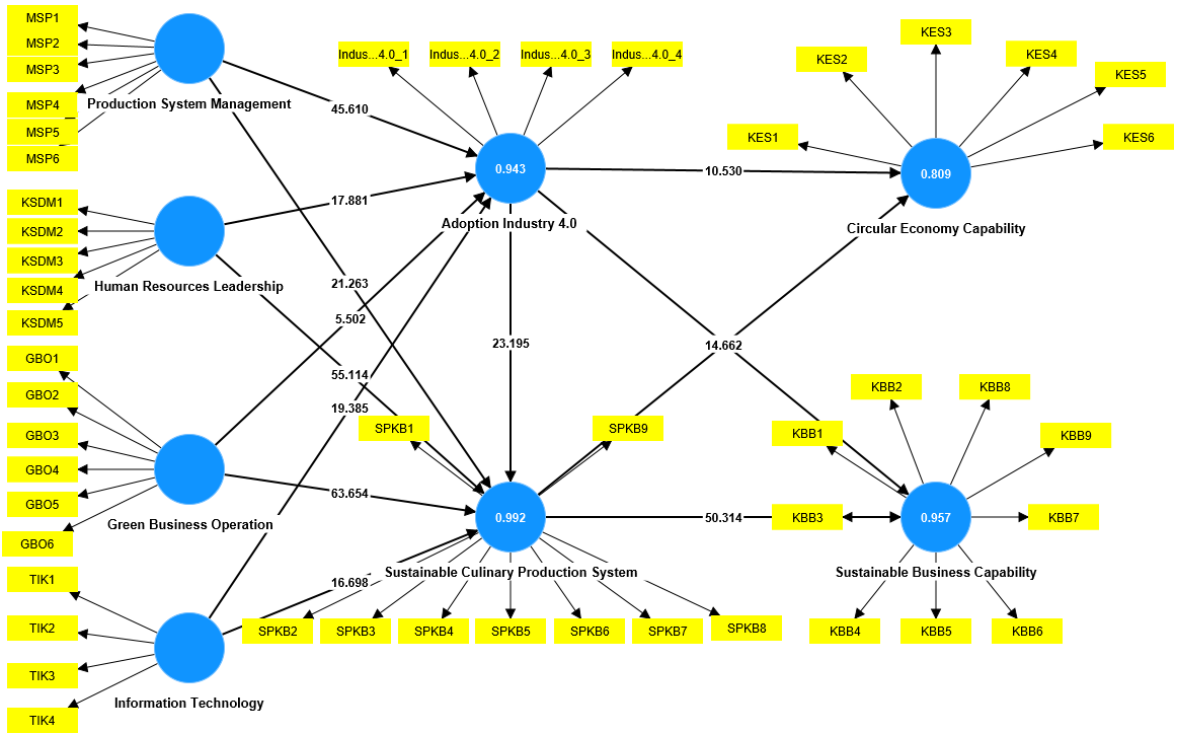

Figure 2: R-Square Result

When determining the proof in the final hypothesis, it can be known by looking at the statistical t-value and p-value. The hypothesis can have a significant positive effect if the statistical t value > 1.96 and the value at p-value < 0.05 (Memon et al., 2021). This is inversely proportional if the statistical t-value < 1.96 and p-value> 0.05 can be said to be hypothetical and has no effect or no effect.

Table 4 found the results of the Path Coefficient analysis of the entire hypothesis proposed accepted. The sixth hypothesis becomes the strongest influence hypothesis based on the T-Test value. In comparison, the fifth hypothesis becomes the hypothesis with the weakest influence.

Table 3: Hypothesis Testing Results

Hypothesis	Path Coefficient	T-Test	P-Value	Decision
H1: Production System Management → Adoption Industry 4.0	1.121	45.610	0.000	Accepted
H2: Production System Management → Sustainable Culinary Production System	0.329	21.263	0.000	Accepted
H3: Human Resource Leadership → Adoption Industry 4.0	0.282	17.881	0.000	Accepted
H4: Human Resource Leadership → Sustainable Culinary Production System	0.573	55.114	0.000	Accepted
H5: Green Business Operation → Adoption Industry 4.0	0.098	5.502	0.000	Accepted
H6: Green Business Operation → Sustainable Culinary Production System	0.558	63.654	0.000	Accepted
H7: Information Technology → Adoption Industry 4.0	0.495	19.385	0.000	Accepted
H8: Information Technology → Sustainable Culinary Production System	0.167	16.698	0.000	Accepted
H9: Adoption Industry 4.0 → Sustainable Culinary Production System	0.302	23.195	0.000	Accepted
H10: Adoption Industry 4.0 → Circular Economy Capability	0.390	10.530	0.000	Accepted
H11: Adoption Industry 4.0 →Sustainable Business Capability	0.221	13.852	0.000	Accepted
H12: Sustainable Culinary Production → Circular Economy Capability	0.556	14.662	0.000	Accepted
H13: Sustainable Culinary Production → Sustainable Business Capability	0.792	50.314	0.000	Accepted

Discussion

The results of the Path Coefficient test in Table 3 show that production system management affects the adoption of Industry 4.0 and sustainable culinary production system (H1-H2). These results are in line with previous research that examined the same relationship with different objects of analysis (Bag et al., 2021; Burgmann, Burger, & Krüger, 2022). The regulation of the production system in the era of Industry 4.0 affects the acceptance of Industry 4.0 because the changes produced by Industry 4.0 take place at an increasing pace, that is, slowing down at an early stage but increasing drastically afterward. This has significantly impacted the industrial sector in various countries, covering all aspects of production systems, management, and regulation. Incorporating cyber technology and automation within the framework of Industry 4.0 focuses on automation, where human intervention in the process can be suppressed through information technology. This contributes to increased efficiency and productivity in the MSME environment. The advantages obtained from Industry 4.0 include optimization of production processes, more personalized product adaptation, emphasis on research exploration, strengthening safety aspects, and efficient utilization of human resources. However, keep in mind that the adoption of Industry 4.0 also carries the risk of replacing the role of humans with machines, which can potentially increase unemployment. Therefore, it is important to develop education that encourages the development of relevant skills in the Industry 4.0 era, such as vocational education in grooming. In Indonesia, the development of Industry 4.0 is driven by the Ministry of Industry, which aims to direct industrial transformation towards improvement through integration between the online world and production lines in various industrial sectors, especially the culinary sector. In this context, the production process as a whole can be carried out with the Internet as the main foundation.

Next, the results of hypothesis testing accept H3-H4, which means human resource leadership affects industry 4.0 adoption and sustainable culinary production system. These results are in line with previous research that examined the same relationship with different objects of analysis (Bag et al., 2021; Burgmann et al., 2022; Mukhuty et al., 2022). Human resource management leadership in the era of Industry 4.0 affects the adoption of Industry 4.0

because the implementation of Industry 4.0 requires a skilled workforce that can operate and maintain advanced technology used in culinary production and marketing processes. The concept of human resource management in Industry 4.0 emphasizes the importance of developing human resources that adapt to technological changes and rapid work environments. The benefits of Industry 4.0 include production optimization, customization, emphasis on research, safety, and labor efficiency. Therefore, human resource management leadership plays an important role in applying Industry 4.0 by providing training and development programs that can improve the workforce's skills and prepare them for future challenges. The leadership of Human Resource (HR) management in the era of Industry 4.0 has a striking impact on the sustainable culinary production system. This era brought profound technological changes and shifts in labor needs, directly affecting the culinary industry. One of the affected aspects is the adaptation of technology. In Industry 4.0, automation and data analysis are central to culinary production. HR management leadership must ensure employees have the necessary technical skills and design relevant training programs to operate efficiently in an increasingly automated environment.

The results of the Path Coefficient test in Table 4 show that green business operations affect industry 4.0 adoption and sustainable culinary production system (H5-H6). These results are in line with previous research that examined the same relationship with different objects of analysis (Hennemann, Draser, & Stofkova, 2021; Kim, Lee, & Lim, 2021; Vasileva, Hristova-Pesheva, & Ivanova, 2018). The concept of green business operation combines the principles of sustainability and efficiency in business operations with advanced technology offered by Industry 4.0. This impact affects how companies adopt and implement Industry 4.0 concepts. First, sustainability principles in green business operations contribute to a deeper understanding of the sustainable values recognized by Industry 4.0. Companies that embrace green business operations tend to have a greater awareness of their business operations' environmental and social impacts. This creates a natural fit with the sustainability values espoused by Industry 4.0, ultimately encouraging them to be better prepared to adopt Industry 4.0 technologies and practices.

Furthermore, green business operations encourage companies to look for more efficient ways of production and resource management. Companies must leverage advanced technologies provided by Industry 4.0, such as the Internet of Things (IoT), data analytics, and automation, to achieve these efficiency goals. Adopting these technologies is becoming increasingly important for companies striving to achieve operational efficiencies and reduce environmental impact. Green business operations also affect the company's innovation strategy. Industry 4.0 opens up new opportunities for innovation in various aspects of business. Companies that adopt green business operations can direct their innovation towards environmentally friendly and sustainable solutions. This includes developing more energy-efficient products, more sustainable utilization of raw materials, and waste reduction. Not only affecting internal operations, but green business operations also affect the supply chain. Companies that value sustainability principles look for business partners who align with their values. This can drive the adoption of Industry 4.0 technologies and practices throughout the supply chain, creating more efficient and sustainable cooperation. In addition, green business operations can inspire other companies to adopt Industry 4.0. As companies that apply sustainability principles achieve success through adopting Industry 4.0 technologies, it can be an inspiring and eye-opening example for other companies about the benefits of integrating this concept. In addition, this concept also combines environmentally friendly business principles with advanced technology to create more efficient production and positively impact the environment. This impact is also felt in the culinary industry.

Next, the results of hypothesis testing accept H7-H8, which means information technology affects adoption industry 4.0 and sustainable culinary production system. These results are in line with previous research that

examined the same relationship with different objects of analysis (Anshari & Almunawar, 2021; Chen, 2019; Ratana Singaram et al., 2023). Information technology such as the Internet of Things (IoT), data analysis, and automation have a major role in driving the adoption of Industry 4.0 among culinary MSMEs. First, IoT technology allows appliances and devices to connect and communicate. In the culinary world, appliances such as ovens, stoves, and refrigerators can be monitored and controlled over a network. This allows culinary MSMEs to optimize production processes, reduce waste, and increase efficiency. In addition, data analysis also has a significant impact. Culinary MSMEs can collect data on sales, consumer preferences, and market trends through food ordering platforms and social media. By analyzing this data, culinary MSMEs can gain deeper insights into what customers are interested in and how to drive product innovation. By understanding these trends, they can design menus that better match demand and provide a more satisfying experience for customers. Automation is also an important aspect of Industry 4.0 adoption. Automation technology allows culinary MSMEs to automate routine tasks such as ordering, payment, and delivery. Not only does this save time and effort, but it also helps reduce the risk of human error. In the long run, automation can provide higher efficiency in daily operations. It is also important to note that the accessibility of information technology is increasing. Many tools and devices supporting Industry 4.0, such as smartphones and software, are becoming more affordable and accessible. This makes culinary MSMEs with limited budgets can also benefit from this technology. Information technology of the Industrial Era 4.0 has a major influence on sustainable culinary production systems by enabling more efficient monitoring and management of resources, optimization of production processes, data analysis for better decision-making, and facilitating innovation in menu development and sustainable practices.

The results of the Path Coefficient test found that adoption Industry 4.0 affects the sustainable culinary production system (H9). These results are in line with previous research that examined the same relationship with different objects of analysis (Bag et al., 2021; Nasrollahi, Fathi, & Hassani, 2020). This interprets the adoption of culinary MSMEs towards Industry 4.0-based business concepts providing access to advanced technologies such as automation, data analysis, and connectivity that enable MSMEs to increase efficiency, reduce waste, improve product quality, and develop sustainable solutions. With the adoption of Industry 4.0, MSMEs can innovate in production, reduce environmental impact, and remain competitive in an increasingly complex market.

Following the hypothesis testing, the adoption of Industry 4.0 also affects the circular economy capabilities and sustainable businesses capabilities (H10-H11). These results are in line with previous research that examined the same relationship with different objects of analysis (John, Adekunle, & Aigbavboa, 2023; Pereira et al., 2022; Sohal, Nand, Goyal, & Bhattacharya, 2022; Suchek, Ferreira, & Fernandes, 2023). Industry 4.0 is an industrial revolution combining digital technology, automation, connectivity, and artificial intelligence to improve production efficiency, decision-making, and interaction between humans and machines. Advanced technologies such as the Internet of Things (IoT) and sensors can help culinary MSMEs more accurately monitor energy consumption, raw materials, and other resources. This allows for better management in minimizing waste and overuse. With a more controlled and accurate production system, culinary MSMEs can reduce food waste, packaging, and unused raw materials. Improved data analytics and demand predictions also help avoid overproduction that could lead to waste. Industry 4.0 can help culinary MSMEs choose more environmentally friendly energy sources and optimize the use of sustainable raw materials, such as organic or local materials. This aligns with the circular economy principle, emphasizing sustainable use and waste reduction. Industry 4.0 adoption can also stimulate the development of new business models, such as service-based, resource-sharing, or food-sharing platforms, that can support circular economy practices and improve sustainable business capabilities.

Finally, the results of hypothesis testing support H12-H13. This means a sustainable culinary production system affects the circular economy capabilities and sustainable businesses capability. These results are in line with previous research that examined the same relationship with different objects of analysis (Bag et al., 2021; Nasrollahi et al., 2020; Soltanmohammadi, Andalib Ardakani, Dion, & Hettiarachchi, 2021). A sustainable culinary production system is an approach that guides culinary MSMEs in processing food in a way that is environmentally and socially responsible. In this system, every step in the production process is maximized to reduce negative environmental impacts and generate wider benefits. For example, culinary MSMEs implementing a sustainable production system will carefully choose raw materials (Hosseininia & Ramezani, 2016). They tend to choose materials obtained from natural resources that are managed sustainably. The main choice is local ingredients produced by environmentally friendly farming or fishing methods. In addition, to reduce waste, these MSMEs will be more creative in processing raw materials, utilizing parts that are usually considered leftover or wasted, thereby reducing waste. Applying renewable energy technology is also an important aspect of sustainable production systems. Culinary MSMEs can include solar panels or other energy sources in their operations, reducing dependence on fossil energy sources that harm the environment. In addition, the selection of energy-efficient equipment also plays an important role in reducing the carbon footprint of operational activities. One striking aspect of sustainable production systems is the sustainable approach to managing waste. Culinary MSMEs focusing on sustainability will implement recycling practices and organic waste composition. For example, food waste can be converted into organic fertilizers useful for agriculture or energy through recycling. It is also important to emphasize collaboration in sustainable supply chains. Culinary MSMEs can establish partnerships with local suppliers, farmers, and raw material producers to ensure their supply runs sustainably. This improves the quality of raw materials and reduces the environmental impact of remote distribution.

To educate consumers, sustainable culinary MSMEs have an important role in communicating their sustainable values. This can be done through explanations on the menu, social media, or direct interaction with customers. Culinary MSMEs can form communities that support their businesses by involving consumers in sustainable practices. Finally, menu innovations and presentations are an interesting aspect of sustainable production systems. Culinary MSMEs can create creative dishes by utilizing sustainable ingredients and serving them aesthetically pleasingly. This attracts customers and reduces food wastage as consumers tend to engage more with beautifully presented food.

Conclusion

The main conclusion from the results of the analysis above is that all hypotheses of determination of key resources of Industry 4.0 MSMEs, such as "Production System Management," "Human Resource Leadership," "Green Business Operation," and "Information Technology" have a significant influence on the adoption of Industry 4.0 and the establishment of a Sustainable Culinary Production System. This means that production system management strategies, human resource management leadership, environmentally friendly business operations, and the application of information technology all contribute to the adoption of Industry 4.0 and increased sustainability in culinary production.

Furthermore, the adoption of Industry 4.0 also significantly impacts the development of Circular Economy Capability and Sustainable Business Capability. Similarly, the Sustainable Culinary Production System contributes to the development of Circular Economy Capability and Sustainable Business Capability.

Overall, the test results show that factors related to production management, human resource leadership, sustainable business operations, information technology, and Industry 4.0 adoption are interrelated and positively impact the establishment of a sustainable culinary production system and contribute to a circular economy and sustainable business capabilities.

The study forms a broad three-part recommendation for the Government, MSME Associations, and Academics. The government must encourage the adoption of Industry 4.0 in the culinary MSME sector with concrete steps. This includes providing grants or low-interest loans to help MSMEs access the necessary technology and infrastructure. Training programs on digital skills and technology management should be designed and implemented. In addition, the government can develop a dedicated digital innovation center for culinary MSMEs, which provides access to the latest technology and industry experts to assist in applying the technology.

MSME associations need to play a more active role in supporting their members. This could involve working with tech companies to provide MSMEs with free or affordable technical training and consulting. By building a strong partner network, the association can help MSMEs gain access to the latest technology at an affordable cost. In addition, associations can hold innovation competitions to encourage MSMEs to develop creative solutions that integrate Industry 4.0 technology. Academics are key in developing technology and knowledge related to Industry 4.0. To support culinary MSMEs, academics can conduct deeper research on implementing technologies such as IoT and data analysis in this sector. The results of this research must be directed at the development of tools, systems, or platforms that suit the needs and scale of MSMEs. Academics can also collaborate with MSMEs to hold applied research projects that directly address the challenges faced by MSMEs in adopting Industry 4.0. In addition, academics need to get closer to MSMEs through continuing education programs, workshops, and seminars. This will help MSMEs understand the potential of Industry 4.0 technology and how to integrate it into their operations. In the long term, academics can work with MSME associations to develop specific training and certification programs that emphasize the skills needed in the Industry 4.0 era, such as data analysis, IoT management, and the application of sustainable technologies.

This study has limitations in the absence of variables for evaluating social conditions and comparison with other MSME sectors. In the future, special research with a quantitative-qualitative combination methodology is needed to accommodate research limitations.

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