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Factors that Influence the Adoption of Agricultural Revolution 4.0 (AR4.0) among Malaysian Agro-Based Industries

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Abstract The agricultural sector plays a pivotal role in poverty reduction and the stimulation of economic growth. Nevertheless, small-scale farmers in developing nations often encounter numerous obstacles that impede their ability to adopt sustainable agricultural technologies. These challenges include, but are not limited to, information asymmetry throughout the supply chain, elevated transaction costs, inadequate agricultural services, and limited access to credit. Therefore, the development and growth of digital agriculture or Agricultural Revolution (AR4.0) can transform agricultural practices across the world to ensure food security, boost productivity and turn the agriculture sector into a more dynamic, sustainable and competitive industry. This study focuses on Malaysia as a case study with the primary aim of examining the factors that influence the adoption of Agriculture 4.0 (AR4.0) technology in agribusiness, specifically concerning its sustainability. A quantitative approach was used to analyse the adoption of AR4.0 technologies in the “core” productive processes. Using approximately 378 agro-based Small-Medium-Industries or SMIs as a sample, results revealed that most SMIs were early adopters of AR4.0. The findings also showed that antecedents such as strategy, technology readiness, food security and food safety had positive relationships with the adoption of AR4.0 technology. This adoption and its implications may draw attention of policymakers, industrial players and government to deal with the challenges in adopting AR4.0, thus being able to support agricultural actors in adopting AR4.0 technologies.

Keywords Agricultural Revolution 4.0, Adoption, Sustainability, Business Performance, Food Security, Malaysia

1. Introduction

The agricultural market has experienced substantial transformations in recent years as a result of the profound influence of globalisation and a range of elements, including sociology, technology, economics, and politics. The domains of food and agriculture are of utmost importance in the context of guaranteeing food security and nutrition, as they are responsible for the provision of sustenance and fulfilment of the populace through the cultivation and harvesting efforts of farmers and fishermen [1]. In ensuring this, the basic principles of food supply chain management comprising production, processing, distribution, retailing and consumption of food need to be established. Food security is primarily determined by the availability of food in terms of its quality and quantity, which in turn affects utilisation and nutrition outcomes [2].

The World Bank [3] highlights that the Agriculture Food Supply Chain (AFSC) encounters numerous global challenges such as limited resources, declining ecosystems, and shifting climates. These challenges underscore the need to establish sustainable food systems that prioritise food and nutrition security. The emergence of the COVID-19 pandemic has posed a significant threat to numerous sectors, with particular implications for the agricultural industry. The concept of food security encompasses several dimensions involving food supply, accessibility and utilisation in terms of safety and nutrition. It is worth noting that the COVID-19 crisis has directly and indirectly affected food security and the food supply chain by influencing supply and demand dynamics, altering consumers' behaviour and impacting the production and distribution of food [4]. The implementation of Movement Control Order (MCO) has led to an increase in online grocery shopping and takeout orders from restaurants as people sought to purchase both staple food items and convenient ready-to-eat meals. This has resulted in a surge in e-commerce deliveries and higher levels of home consumption. As a consequence, these shifts in consumer behaviour may have long-lasting and potentially permanent effects.

Therefore, COVID-19 has re-emphasised the importance of massive digitalisation, which is rapidly posing new challenges to Malaysia's food supply chains. The implementation of precision farming and advanced technologies can significantly enhance the effectiveness, productivity, safety and environmental sustainability of farms. Furthermore, the incorporation of advanced technologies like big data analytics, cloud computing, blockchain, and artificial intelligence has the potential to enhance the efficacy of agricultural systems while also optimising supplier relationships and streamlining logistics operations.

The Agriculture Food Supply Chain (AFSC) stakeholders faced ongoing pressures to enhance transparency within their supply chains and devise new strategies for market expansion and specialisation, facilitated by food tracking and tracing methods, commonly known as traceability [5]. Businesses are expected to provide comprehensive information regarding specific attributes of their products, including quality, safety, traceability, origin, as well as production and supply conditions [6]. Additionally, end consumers are now more informed and seek real-time news and information through digital media platforms. Their concerns extend to the environmental and social sustainability aspects of the food they consume [7]. Consequently, food retailers, distributors, processors and farmers are increasingly prioritising food product traceability, security and sustainability [8]. There is growing tension among supply chain participants to reduce costs by leveraging digitalisation and data analytics to make more informed decisions [9]. According to Song et al. [7], the digital integration of supply chain operations is pursued to minimise waste, labour and excess inventory. Hence, the AFSC production and distribution models should be designed to make harvesting plans more efficient and meet customer demands.

Thus, increased demand for information is propelling emerging technologies. Although digitalisation has gained significant attention as a crucial element in modernising supply chains, it is not a novel concept [10]. Several firms have previously employed RFID technology to enhance visibility and traceability, reduce food waste, streamline forward tracking, improve operational efficiencies, automate data collection, prevent order picking and shipping errors, as well as intelligently monitor conditions such as temperature and humidity throughout the supply chain processes. Several digital technology and data systems have been used by the food and agriculture industry for decades to help them streamline their supply chain processes from upstream to downstream and improve efficiency [8]. Digitalisation plays a vital role in supply chain management by enabling effective food traceability, thereby offering competitive advantages through enhanced productivity, flexibility and performance, thanks to advancements in tracking technologies. In practical terms, "traceability" refers to the information and documentation framework within the AFSC that enables the tracking of food composition and flow. Food traceability serves as a dual mechanism, providing practical guidance to the food industry on making their products traceable across the supply chain and facilitating the sharing of information with other stakeholders in the AFSC. Additionally, food traceability benefits consumers by providing them with valuable information to make informed choices and ensure food quality.

The fourth agricultural revolution (AR4.0), like the fourth industrial revolution (IR4.0), refers to anticipated technological changes, especially the use of artificial intelligence to make better planning decisions and power autonomous robots [11]. With the challenges of increasing populations and climate change, the concept of Industry 4.0 (AR4.0) emerges as a crucial driver for the industry's future advancements. This includes a strong emphasis on precision farming and leveraging the Internet of Things (IoT), besides harnessing big data to enhance operational efficiencies and effectiveness. For decades, the agricultural sector has been at the forefront of digital innovation. Mario et al. [12] posited that the advent of precision agriculture, remote sensing, robotics, farm management information systems, and decision support systems has sparked a significant digital revolution within the agricultural and food industry. Recent technological advancements, such as cloud computing, the Internet of Things, Big Data, Blockchain, and Artificial Intelligence, have facilitated the convergence of previously isolated development lines into smart, interconnected device systems [13]. As a result, agriculture has the potential to evolve into a data-driven, intelligent, agile and autonomous system comprising interconnected components, thanks to the transformative capabilities of these technologies.

Nevertheless, developing, maintaining and sustaining agro-food supply chains pose unique challenges compared to other supply chains due to the heightened levels of uncertainties and risks they encounter in terms of economic, environmental and social factors, as well as those specific to the agricultural sector [14, 15]. Several studies have explored how to model and address these uncertainties, shedding light on the performance concerns and questions surrounding agro-food supply chains. Esteso et al. [15] described products (shelf-life, rate of degradation, lack of homogeneity, quality of food and protection of food), process (harvest yield, lead time of delivery, resource needs, production), market (demand, market prices) and environment (weather, pests and disease, as well as regulations) as the four types of crop-based uncertainties. Inadequate management of these uncertainties can result in detrimental consequences for product safety, quality, quantity and waste management, along with various human, natural and technological aspects. In addition, Iakovou et al. [16] mentioned the immense economic and political significance of the agro-food sector worldwide, with profound implications for sustainability that extend beyond fulfilling food requirements, encompassing employment opportunities, economic growth and the preservation of the natural environment.

The biggest challenge for producers and suppliers in today's dynamic global environment is continuously improving product quality while remaining compliant with government regulations and industry standards. HACCP, GMP, GVP, GAP and ISO9000 have been the international general methods of food safety regulation for a long time. These requirements are primarily concerned with controlling food production and processing environments to prevent food contamination caused by potential biological, chemical and physical influences during the entire food production process [17].

These standards, on the other hand, are unable to monitor problems arising from the circulation phase and have yet to establish accurate and quick methods for identifying the problem's root causes. As a result, these procedures take longer and are less effective at mitigating the massive damage that could be caused to human health, as well as identifying the individuals, agricultural producers and actors or firms involved. As a result, monitoring the entire supply chain from production to consumption is becoming increasingly critical in ensuring product traceability to control food safety and protect consumers' health [18]. Consequently, promoting the adoption of digital technologies and smart farming practices among agricultural Small and Medium-Sized Industries (SMIs) has become a prominent policy agenda in various countries, including Malaysia. Nevertheless, the existing scholarly literature on the subject of agricultural enterprises' inclination to adopt AR4.0 technologies is relatively scarce. This inquiry pertains to the extent of adoption of AR4.0 technologies inside agricultural enterprises as well as the underlying causes that drive organisations to embrace this technological revolution. Hence, the primary objective of the present study is to ascertain the variables or factors that impact the adoption of AR4.0 among agro-based SMIs in Malaysia, an area that has not been explored in previous studies. Therefore, the subsequent hypotheses were formulated in the following manner:

H1: The implementation of strategies has a beneficial influence on the adoption of AR4.0.

H2: The level of technology readiness has a beneficial influence on the adoption of AR4.0.

H3: Organisational support has a favourable influence on the adoption of AR4.0.

H4: Individuals have a beneficial influence on the adoption of AR4.0.

H5: The environment has a beneficial influence on the adoption of AR4.0.

H6: Food security has a positive impact on the adoption of AR4.0.

H7: Food integrity has a beneficial influence on the adoption of AR4.0.

H8: The implementation of food safety measures has a beneficial influence on the adoption of AR4.0.

H9: Food waste management has a favourable influence on the adoption of AR4.0.

The outcomes of this study can offer initial insights into the significance of Agricultural Revolution 4.0 for establishing sustainable agricultural supply chains, along with the key drivers that incentivise agro-food companies to adopt these technologies or innovations in their business operations.

2. Materials and Methods

2.1. Population and Sample Size

The study population consisted of Managing Directors and Operations Managers representing various firms. The unit of analysis in this study was the individual firm, encompassing both companies and specific units or sites within those companies. These firms were selected based on their anticipated involvement in the adoption of Agricultural Revolution 4.0 technology. Specifically, the chosen companies were registered under The Federal Agricultural Marketing Authority or FAMA company owing to its status as a marketing agency established under the Ministry of Agriculture and Agro-Based Industry Malaysia. FAMA is responsible for overseeing, coordinating, monitoring and promoting agricultural products, including import and export activities. Additionally, FAMA is in charge of the marketing of agro-food and agro-based industrial products, including vegetables and fruits.

In the context of probability sampling, the sampling frame refers to a comprehensive list of all the cases present in the population, from which the sample will be drawn [19]. Sekaran [20] defines the sampling frame as a compilation of all the elements that constitute the population. Samples are a set of data from a population that will be chosen for the research, which is taken by randomly choosing a few people from a community that the researchers believe represents the entire population [21]. Sekaran [20] also added that the key purpose of sampling is to show that by choosing a portion of elements from a target population, a conclusion can be drawn on the entire population via generalisation. Sampling is a crucial method for obtaining a sample of a subject that will be representative of a larger population or provide specific information. The sampling frame of this study represented all the players involved in the supply chain, which consisted of Managing Directions and Operation Managers under FAMA Agro-based SMIs in Malaysia (Northern, Central, Eastern and Southern) for this study. The sampling frame for this study was derived from the FAMA organisation.

The sample size was selected via cluster random sampling. A sample size of 378 respondents was taken from a total population of 800 individuals, representing various companies. A total of 378 respondents were obtained from FAMA-listed enterprises in Peninsular Malaysia through the administration of a questionnaire sent via Google Survey and conducted face-to-face. The data presented indicates that the respondent's rate is 47.25%, a value that is deemed acceptable and fair within the context of the study. This study employed primary data collection methods, specifically utilising standardised questionnaires, to gather information.

2.2. Tools and Data Collection Methods

2.2.1. Data Collection Tools

A cross-sectional survey was carried out to gather quantitative data for statistical hypothesis testing. The analysis was performed using a primary questionnaire administered via telephone and a digital survey conducted using Google Forms. The targeted respondents were contacted through their email addresses and telephone numbers, utilising the database of relevant contacts. The digital survey forms were then emailed to the designated respondents to collect the required data for this study.

Following that, a survey method was generated using a multi-item scale that could minimise the random error that results from the uncertainty through time or over the measure [22,23]. In the questionnaire, survey questions were developed to be used later for data collection. This study used a 5-point Likert Scale for all factors of agricultural revolution technologies adoption and performance to estimate the opinion of respondents. The scale ranged from “1” “extremely disagree” to “5” representing “extremely agree”. Likert scaling is much better as it can eliminate the respondent’s subjective experience as a unidimensional scaling method is used [24].

The questionnaire was divided into three sections. Section A of the questionnaire asks about the general profile of the firm from which the demographic and descriptive part of the study is conducted. This section comprises of background on the firm including the involvement in the firm, types of services provided by the firm, types of products produced by the firm, number of employees to measure the size of the firm, age of the firm, as well as the reputation quality of the product in Malaysian market.

Section B focuses on the questions pertaining to the adoption of Agricultural Revolution 4.0 (AR4.0). The objective of this section is to find out the types of AR4.0 technologies and systems adopted by the firm and the level of AR4.0 technology adoption that helps in identifying the extent of adoption of these technologies in the agricultural sector. Finally, Section C encompasses the factors influencing the adoption of Agriculture 4.0, including strategy, technology readiness, organisational support, human resources, environmental considerations, food security, food integrity, food safety, food waste and food availability.

2.2.2. Data Collection Methodologies

Percentage analysis, frequency analysis, correlation and multiple linear regression were employed in this study to analyse the data. Descriptive statistics of frequency analysis or percentage analysis were used to analyse the general profile of the firm and its demographic and descriptive part of this study.

The data collected was analysed using Pearson's correlation coefficient. McCombes [25] posits that correlation serves as a methodological approach for quantifying the association between variables. Pearson's correlation is often regarded as the predominant metric of correlation. Pearson's correlation analysis is a statistical method used to assess the presence and quantify the magnitude and direction of the relationship between two variables.

Next, to identify the factors or antecedents that influence firms to adopt AR4.0, a multiple regression analysis was used in this study formulated as below:

$$\mathbf{Y}=A+\beta_1\mathbf{X_1}+\beta_2\mathbf{X_2}+\beta_3\mathbf{X_3}+\beta_4\mathbf{X_4}+\ldots\beta_9\mathbf{X_9}+\mathcal{E} \quad (1)$$

where Y is a dependent variable known as the adoption of firms towards AR4.0; A is constant, $\beta_1 - \beta_9$ are the coefficients to be estimated; the variables X_1 to X_9 represent independent factors that influence enterprises' adoption of AR4.0. These elements include strategies (X_1), technology readiness (X_2), organisational support (X_3), people (X_4), the environment (X_5), food security (X_6), food integrity (X_7), food safety measures (X_8), and food waste management (X_9). The error term is denoted as ε.

3. Result and Discussion

3.1. Descriptive Statistics

A total of 378 agro-based SMI firms were interviewed in this study. The summary of demographic variables, including the number of employees, years in the industry, category of supply chain, type of business, sales turnover and others are tabulated in Table 1. The results of demographic information showed that the majority of the firms are operating in the business between 6-10 years (n=214, 56.6%), having an annual sales turnover of less than RM100,000 (n=177, 46.8%) and working with less than 100 employees (n = 277, 73.3%). Most of these firms were retailers (n=143, 37.8%) with most of them selling their vegetables to consumers (n=107, 28.3%).

Table 1. Demographic profile of the firms

Variables	Category	Frequency (n = 378)	Percentage (%)
Firm’s business operations	Up to 5 years	55	14.6
	6–10 years	214	56.6
	11–20 years	68	18.0
	21–30 years	35	9.3
	More than 30 years	6	1.6
Number of employees	Up to 100	277	73.3
	101-250	53	14.0
	251-500	24	6.3
	501-1000	12	3.2
	More than 1000	12	3.2
Annual sales turnover (RM)	Up to 100,000	177	46.8
	100,001-500,000	93	24.6
	500,001-1,000,000	71	18.8
	More than 1,000,000	37	9.8
Supply chain categories	Producers	42	11.1
	Manufacturers	80	21.2
	Wholesalers	112	29.6
	Retailers	143	37.8
	Others	1	.3
Type of products	Consumer products	317	83.9
	Industrial products	61	16.1
Stage of the agro-food supply chain	Input providers (fertiliser, feed supplier)	36	9.5
	Farmers	13	3.4
	Manufacturers (processing agricultural or intermediate products into food products)	126	33.3
	Retailers (selling food products to consumers)	127	33.6
	Food service providers	76	20.1
Firm’s involvement with FAMA	Less than 5 years	208	55.0
	6–10 years	159	42.1
	11–20 years	2	.5
	21–30 years	9	2.4
Type of agriculture or business	Local fruits	101	26.7
	Vegetables	107	28.3
	Poultry	59	15.6
	Agro-based Industries	50	13.2
	Agricultural Input	15	4
	Livestock	46	12.2

Source: Own survey (2022)

In addition, most of the firms engaged with FAMA for up to 5 years (n=208, 55%), followed by 6-10 years (n=159, 42.1%). Majority of SMI firms who adopted AR4.0 in this study area were involved in activities such as vegetables, local fruits and poultry.

3.2. Technology Adoption

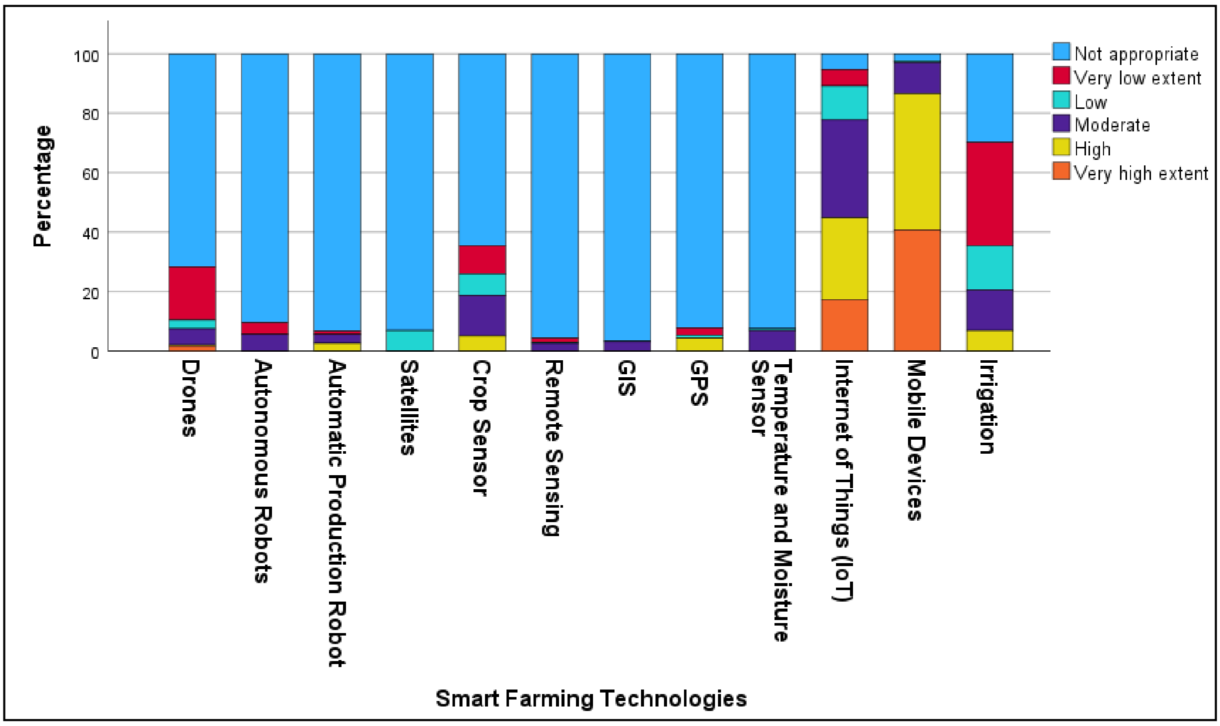
To assess the firm's adoption level, respondents were asked to indicate their stance based on the following categories: Early Adopter (individuals who promptly embrace technology as soon as it becomes available), Early Majority or Follower (a group that adopts the technology after a smaller population of innovators and early adopters have already implemented it), Late Adopter (individuals who adopt a new technology later than many others) and Laggard (the final individual to adopt the technology). Analysis of the responses revealed that none of the respondents fell into the Laggard category (0.0%), while 21.2% were classified as late adopters, 28.8% as early majority and 50% as early adopters (Table 2). Notably, the combined proportion of early majority and early adopters accounted for over 80% of the total respondents. This suggests that individuals in the early majority and early adopters categories play a pivotal role in driving innovation adoption in Malaysia. The results identified that firms in the study area are high in innovativeness; therefore, any new technologies in the area could be introduced with appropriate marketing strategies to help in expediting technology adoption.

Table 2. Technology Adopter Level Grouping of SMIs

Category	Percentage (%)
Early adopter	50.0
Early majority or follower	28.8
Late adopter	21.2
Laggard	0.0

Source: Own survey (2022)

Figure 1 displays the descriptive statistics depicting the adoption level of AR4.0 technologies. The respondents were asked to what extent these technologies have been adopted by their firms. They then expressed their agreement by choosing the options very high extent, extent, moderate, low, very low extent and not appropriate listed in the questionnaire. The number of respondents who responded with the given statement was calculated and expressed in percentage for each statement. Figure 1 shows how the respondents (SMIs) perceived the adoption of smart farming technologies in the cultivation of food commodities to help increase efficiency, productivity and profitability, as well as reduce undesirable excessive chemical applications that could negatively impact the environment.



Source: Author's survey (2022)

Figure 1. SMIs' level of adoption related to the use of SF technologies

The highest percentage of Smart Farming (SF) technology adoption was using mobile devices, which corresponds to the use of up-to-date information on input and output market transactions, access to weather information and decision-making supports on farm operations, among others. The average total importance score for mobile devices was 4.20. Among all SF (Smart Farming) technologies, mobile devices were rated the highest, followed by IoT (Internet of Things) with a score of 3.24, irrigation with a score of 1.33 and crop sensors with a score of 0.85. These findings suggest that farm management apps, mobile devices and IoT were the most familiar technologies to the respondents and the most significant smart agricultural technologies for their daily agribusiness and farm operations.

In the field of agriculture, mobile applications designed for agricultural purposes have gained significant popularity among modern farmers and growers. This was primarily owing to the numerous benefits they offer, including improved crop performance and increased farm revenue. Using smartphones and cellular data, farmers can conduct many farm operations including creating farm maps, scouting the farm, flying agricultural drones over the field, monitoring various aspects of their farm remotely and having greater access to a wealth of agricultural information, such as weather forecasts, market prices, pest and disease and best agricultural farming practices. The exchange of knowledge and experiences through mobile devices and online platforms may not only facilitate communication and collaboration among the farming community but can also enhance learning and foster innovation in the agricultural field. Additionally, mobile devices can support precision agriculture by allowing firms to respond promptly to changing conditions and control their farming operations such as controlling irrigation systems, adjusting temperature and humidity in greenhouses, applying fertilisation and irrigation, as well as monitoring livestock and machinery from anywhere using mobile apps or web-based interfaces [26,27].

Furthermore, the Internet of Things (IoT) enables remote connectivity of devices, facilitating the implementation of smart farming practices [28]. It has been recognised for its ability to enhance the efficiency and performance of agricultural production [29-31]. IoT plays a crucial role in the agricultural sector through its communication infrastructure, which involves connecting smart objects, acquiring remote data, utilising vehicles and smart sensors via mobile devices and the internet, supporting decision-making processes, enabling cloud-based intelligent analysis, facilitating interfaces, and automating agricultural operations [32]. Respondents asserted that IoT has helped them in controlling, monitoring and observing the plant remotely more than ever before and saving water and irrigation, as well as correcting nutrient deficiencies as they may have observed each plant grow manually.

3.3. Determinants of AR4.0 Adoption

The findings presented in Table 3 demonstrate the outcomes of Pearson's correlation analysis, indicating a statistically significant association between the firm's strategy and the adoption of AR4.0. The correlation coefficient value of 0.829 further supports this relationship. Additionally, a correlation coefficient value of 0.803 shows that there is a notable relationship between technology readiness and the adoption of AR4.0. Furthermore, there exists a noteworthy association between organisational support and the adoption of AR4.0, as indicated by a correlation coefficient of 0.825. The adoption of AR4.0 exhibits a substantial association with individuals, as evidenced by a correlation coefficient of 0.771. The adoption of AR4.0 is found to have a strong association with environmental parameters, as evidenced by a correlation coefficient value of 0.690. Moreover, there exists a notable association between food security and the adoption of AR4.0, as evidenced by a correlation coefficient of 0.160. The adoption of AR4.0 exhibits a notable link with food integrity, as evidenced by a correlation coefficient value of 0.694. There exists a noteworthy association between the adoption of AR4.0 and food safety, as indicated by a correlation coefficient of 0.788. Furthermore, there exists a substantial association between the adoption of AR4.0 and food waste, as indicated by a correlation coefficient value of 0.803.

Table 3. Pearson's Correlation Coefficient of Factors Affecting AR4.0

No	Hypotheses	Pearson's Correlations	Remark
H1	The implementation of strategies has a beneficial influence on the adoption of AR4.0.	0.829	Supported
H2	The level of technology readiness has a beneficial influence on the adoption of AR4.0.	0.803	Supported
H3	Organisational support has a favourable influence on the adoption of AR4.0.	0.825	Supported
H4	Individuals have a beneficial influence on the adoption of AR4.0.	0.771	Supported
H5	The environment has a beneficial influence on the adoption of AR4.0.	0.690	Supported
H6	Food security has a positive impact on the adoption of AR4.0.	0.160	Supported
H7	Food integrity has a beneficial influence on the adoption of AR4.0.	0.694	Supported
H8	The implementation of food safety measures has a beneficial influence on the adoption of AR4.0.	0.788	Supported
H9	Food waste management has a favourable influence on the adoption of AR4.0.	0.803	Supported

Consequently, the findings may be succinctly described as follows: all of the constructs utilised in this investigation exhibited statistical significance in relation to the hypothesised association. The findings of the study revealed that the construct of strategy exhibited the most significant beneficial impact on the adoption of AR4.0.

Table 4. Multiple Regression of Factors Affecting AR4.0 Adoption

Factors	Coefficient	Std. Error	p-value
(Constant)	-.321	.175	.067
Strategy	.515***	.060	<.001
Technology readiness	.281***	.071	<.001
Organisation	.072	.071	.311
People	-.039	.065	.550
Environment	-.034	.061	.578
Food Security	.044**	.025	.084
Food Integrity	-.011	.056	.840
Food Safety	.153***	.071	.031
Food Waste	.094	.072	.189
No of observations	378		
R^2	0.693		

***significant at the 1% level, **significant at the 5% level

Table 4 presents the factors affecting the adoption of AR4.0 among SMIs using multiple linear regression analysis. A multiple linear regression analysis was conducted in order to know the relationship between the dependent and independent variables. According to the data presented in Table 4, the coefficient of determination, denoted as R^2, is calculated to be 0.693, or 69.30%. This value signifies the proportion of variability in the dependent variable, specifically the adoption of AR4.0, that can be accounted for by the independent variables considered in this study. These independent variables include strategy, technology readiness, organisational support, individuals, the environment, food security, food integrity, food safety measures, food waste management, and food availability. The number also signifies that the model effectively captures around 69.3% of the data points and demonstrates a reasonably robust association between the variables in the model.

Based on regression results, the results showed that strategy and technology readiness were the most significant factors affecting SMIs to adopt AR4.0. The strategy factor encompasses the establishment of goals and the exertion of control by top management to ensure their attainability [33], which involves making investments in digital technology and its components, formulating strategies and policies facilitating the digital transformation of the firm, providing organisational and technological infrastructure to streamline digitalisation and enhance competitiveness, as well as considering the unique characteristics and background of the firm to ensure realistic goal setting and strategic planning.

Besides, technology readiness has significantly influenced SMIs towards adopting AR4.0. Tornatzky and Fleischer [34] stated that technology readiness refers to the technical processes, competencies and infrastructures supporting the adoption of technology. Technology context explains the internal and external technologies applicable and relevant to the organisation. This covers current technologies within the business, as well as those available in the market [35]. The study findings indicated that a majority of firms are utilising information, communication and networking technology, along with smart devices and appliances to minimise waste and conserve energy. Furthermore, these firms prioritise equipping their employees with the necessary skills and technical knowledge to effectively manage these new technologies and smart devices.

Unfortunately, the present findings showed that organisations and people do not significantly affect AR4.0 technology adoption in SMIs. This negligible effect can be explained by different organisational sizes or management structures, which may affect technology adoption differently. Shahadat et al. [36] carried out a study revealing that organisational structure or size alone does not solely determine technology adoption. Instead, intervening variables such as organisational readiness, internal expertise and other internal factors play equally influential roles in the adoption of technology. However, Karunagaran [37], in their study on the adoption of cloud-based technology in relation to firm size, reported mixed results. They discovered that large firms faced challenges in terms of regulatory support, technological integration and compatibility when adopting cloud-based technology. On the other hand, small firms showed a positive correlation between cloud adoption and compatibility, indicating the existence of differences in the advantages and disadvantages of cloud-based technology based on organisation size.

The findings of this study indicated that food integrity is an insignificant factor influencing technology adoption in agriculture SMIs. This result is consistent with that of earlier studies [38,39] highlighting how concerns about food integrity are primarily associated with specific concerns related to genetically modified (GM) and nanotechnology applications in food. These studies suggested that individuals who generally trust people are less likely to express concerns about food integrity. For instance, the use of genetic technologies for traceability in the food industry may be discouraged due to concerns about potential risks to health and the environment [38].

Furthermore, Leroy et al. [40] defined food security as the condition in which all individuals have consistent access to adequate safe and nutritious food that meets their dietary requirements and personal preferences, enabling them to lead an active and healthy life. The results revealed that food security has become the most important factor influencing firms in adopting AR4.0 technologies. The firms understood that by adopting AR4.0, they may ensure effective harvest and post-harvest practices to minimise the loss, increase market access, ensure food quality to reduce waste, enhance distribution efficiency, as well as provide traceability and accountability to enhance the efficiency of the supply chain.

Furthermore, the findings indicated that food safety played a crucial role in influencing the adoption of AR4.0 technologies by SMIs. Food safety refers to the assurance that food, when prepared and consumed as intended, will not cause harm to the consumers [40]. In this context, the majority of SMIs firms were aware that AR4.0 adoption reduces operational mistakes including undeclared ingredient and biological causes, helps to avoid food fraud, prevents counterfeiting, mislabelling, reduces food contamination, chemical residue, food being polluted and foodborne illness. Additionally, the results confirmed that food safety is important for many firms, which is exemplified by the details of each product’s origin and traceability.

Furthermore, no significant positive effect of food waste and loss concern on the adoption of AR4.0 technologies among Malaysian SMIs was observed in this study. The causes of food loss vary between developed and developing countries, as it occurs at various stages of the supply chain [41,42]. In developing countries, significant losses occur during the harvest and post-harvest stages, primarily due to constraints in cultivation and harvesting, inadequate food-chain infrastructure, transportation limitations and limited investment in technologies [43]. On the other hand, in many developed countries, food loss tends to occur at the consumption stage towards the end of the supply chain where concerns revolve around surplus food generation and consumer behaviour [42,44].

4. Conclusions

This study focused on the factors influencing the adoption of AR4.0 among SMI firms in Malaysia. Results demonstrated that many Malaysia SMI operators can be described as early adopters. Most of them operated in various fields of agriculture for less than 5 years. Among the factors that influence their adoption towards AR4.0 technologies include strategy, technology readiness, food security and food safety. Stakeholders must identify current equipment and technology trends in agriculture. This can be achieved through specific funding programs that support the digitalisation of agriculture, enabling family farms and firms to leverage the opportunities presented by digital technologies. When implementing funding programs for innovative and sustainable technologies, it is essential to consider food security issues that still pose a high investment risk, potentially impeding their adoption in agricultural practices and digital technologies. Furthermore, staying updated on the adoption rates of these technologies is equally important. This information allows for targeted funding allocation towards technologies that address the most relevant issues faced by farmers and firms. Examples of these issues include animal welfare, reduction of pesticide use, prevention of pollutants and chemical residue, as well as mitigation of food waste. Additionally, these technologies contribute to the conservation of resources and the environment. Such technologies include smart farming systems, drones, sensor systems and field robotics.

This current study has some limitations that need to be acknowledged. First, it focused only on small and medium-sized agricultural enterprises in Malaysia using a limited sample of 378 SMIs affiliated with the FAMA organisation. This may limit the generalisability of the findings and overlook geographical and cultural diversity. Thus, future studies should include a larger and more diverse sample, covering different types of farmers, processors and retailers to better understand the impact of AR4.0 technologies across the agricultural value chain. Additionally, this study mainly considered external and organisational factors, without examining individual and behavioural factors that influence technology adoption. Therefore, future research should explore these aspects to gain a more comprehensive understanding. In conclusion, while this study provides valuable insights, addressing these limitations in future studies will enhance the understanding of AR4.0 technology adoption in the agricultural sector.

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REFERENCES

[1] Sundaram J.K., Gen T.Z., Khalidi J.R., “Achieving food security for all Malaysians”, Kuala Lumpur: Khazanah Research Institute, 2019, https://www.krinstitute.org/assets/contentMS/img/template/editor/Discussion%20Paper_Achieving%20Food%20Security%20for%20all%20Malaysians.pdf (accessed June 15, 2022).

[2] El Bilali H., Callenius C., Strassner C., Probst L., “Food and nutrition security and sustainability transitions in food systems,” Food and Energy Security, vol. 8, no.2, pp. 1–20, 2019. DOI: 10.1002/fes3.154

[3] World Bank. (2015). Ending poverty and hunger by 2030: An agenda for the global food system. Washington, DC. Retrieved from http://documents.worldbank.org/curated/en/700061468334490682/pdf/95768-REVISED-WP-PUBLIC-Box391467B-Ending-Poverty-and-Hunger-by-2030-FINAL.pdf

[4] Shri Dewi A., “Study consumption during crisis: New Straits Times”, NST Online, www.nst.com.my/opinion/letters/2020/05/592937/study-consumption-during-crisis%20NST%2015%20MAY%202020 (accessed July 15, 2021).

[5] Kumar A., Liu R., Shan,Z., “Is blockchain a silver bullet for supply chain management? Technical challenges and research opportunities,” A Journal of Decision Sciences Institute, vol. 51, no. 1, pp. 8-37, 2020. DOI: 10.1111/deci.12396

[6] Boselie D., Henson S., Weatherspoon D., “Supermarket procurement practices in developing countries: Redefining the roles of the public and private sectors,” American Journal of Agricultural Economics, vol. 85, no. 5, 2003.

[7] Song M.L., Peng J., Wang J., Dong, L., “Better resource management: An improved resource and environmental efficiency evaluation approach that considers undesirable outputs,” Resources, Conservation and Recycling, vol. 128, pp. 197–205, 2018. DOI: 10.1016/j.resconrec.2016.08.015.2018

[8] Gharehgozli A., Iakovou E., Chang Y., Swaney R., “Trends in global e-food supply chain and implications for transport: literature review and research directions,” Research in Transportation Business and Management, vol. 25, pp. 2–14, 2017. DOI: 10.1016/j.rtbm.2017.10.002

[9] EFoodChain, “The eFood chain project" http://www.efoodchain.eu/ (accessed on May 15, 2022).

[10] Lewis K., “Blockchain: four use cases transforming business,” in IBM: Conferences, 2017,https://www.ibm.com/blogs/internet-of-things/iot-blockchain-use-cases/ (accessed on May 30, 2021).

[11] Zambon I., Cecchini M., Egidi G, Saporito M.G., Colantoni A., “Revolution 4.0: Industry vs. Agriculture in a future development for SMEs,” Processes, vol.7, no. 1: 36, 2019. DOI: 10.3390/pr7010036

[12] Mario L., Jorge E. H., Maria del Mar A. D., Herv éP., Janusz K., “Agri-food 4.0: a survey of the supply chains and technologies for the future agriculture,” Computers in Industry, vol. 117, 2020. DOI: 10.1016/j.compind.2020.103187

[13] Seranmadevi R., Senthil Kumar A., Hariharan R. “Enabling agricultural sector through blockchain technology – farmers perspective,” Universal Journal of Agricultural Research, vol. 10, No. 3, pp. 213-227, 2022. DOI: 10.13189/ujar.2022.100304

[14] Mundi I., Alemany M., Poler R., Fuertes-Miquel V.S., “Review of mathematical models for production planning under uncertainty due to lack of homogeneity: proposal of a conceptual model,” Int. J. Prod. Res., vol. 7543, pp. 1– 45, 2019. DOI: 10.1080/00207543.2019.1566665

[15] Esteso A., Alemany M., Ortiz A., “Conceptual framework for designing agri-food supply chains under uncertainty by mathematical programming models,” Int. J. Prod. Res., vol. 56, no. 13, pp. 4418–4446, 2018. DOI: 10.1080/00207543.2019.1566665

[16] Iakovou E.T., Vlachos D., Achillas C., Anastasiadis F., “Design of sustainable supply chains for the agrifood sector: A holistic research framework,” Agric. Eng. Int. CIGR J., Special Issue 2014, pp. 1–10, 2014.

[17] Abideen AZ., Sundram VPK., Pyeman J., Othman AK., Sorooshian S., “Food supply chain transformation through technology and future research directions—A Systematic Review,” Logistics, vol. 5, no. 83, pp. 1-24, 2021. DOI: 10.3390/logistics5040083

[18] Xiongyong Z., Zhiduan X., “Traceability in food supply chains: a systematic literature review and future research directions,” International Food and Agribusiness Management Review, vol. 25, no. 2, 2022. DOI: 10.22434/IFAMR2020.0065

[19] Saunders M., Lewis P., Thornhill A., “Selecting samples” in Research Methods for Business Students, 5th ed, Pearson Education, 2009.

[20] Sekaran U., “Research Methods for business: A Skill Building Approach,” 3rd ed, John Wiley & Sons, Inc. 2003.

[21] Hair R.P., Bush D.J., Ortinau, “Marketing research: A practical approach for the new millennium,” Irwin Professional Publishing, 2000.

[22] Churchill G. A., “A paradigm for developing better measures of marketing constructs,” Journal of Marketing

Research, vol.16 (February), pp.64-73, 1979. DOI: 10.1177/00222437790160011

[23] Hinkin T.R., "A review of scale development practices in the study of organizations. Journal of management," vol. 21, no. 5, pp. 967-988, 1995. DOI: 10.1177/014920639502100 5

[24] Oppenheim A.N., "Questionnaire design, interviewing and attitude measurement," Bloomsbury Publishing, 2000.

[25] McCombes Sh, (2019). Correlational Research. Retrieved from:https://www.scribbr.com/methodology/correlational-research/7/

[26] Javaid M., Haleem A., Singh R.V., Suman R., "Enhancing smart farming through the applications of Agriculture 4.0 technologies," International Journal of Intelligent Networks, vol. 3, pp. 150-164, 2022. DOI: 10.1016/j.ijin.2022.09.004.

[27] Pongnumkul S., Chaovalit P., Surasvadi N., "Applications of smartphone-based sensors in agriculture: A Systematic Review of Research," Journal of Sensors, vol. 2015, pp.1-18, 2015. DOI: 10.1155/2015/195308

[28] Patil K.A., Kale N.R., "A model for smart agriculture using IoT," in Proceedings of the 2016 International Conference on Global Trends in Signal Processing, Information Computing and Communication, Jalgaon, India, 22–24 December 2016, vol. 2016, pp. 543–545, 2016.

[29] Sisinni E., Saifullah A., Han S., Jennehag U., Gidlund M., "Industrial internet of things: challenges, opportunities, and directions," IEEE Trans. Ind. Inform, vol. 14, pp. 4724–4734, 2018.

[30] Shi X., An X., Zhao Q., Liu H., Xia L., Sun X., Guo Y., "State-of-the-art internet of things in protected agriculture," Sensors, vol. 19, no. 1833, 2019. DOI: 10.3390/s19081833

[31] Elijah O., Rahman T.A., Orikumhi I., Leow C.Y., Hindia M.N., "An overview of internet of things (iot) and data analytics in agriculture: Benefits and challenges," IEEE Internet Things, vol. 5, pp. 3758–3773, 2018. DOI: 10.1109/JIOT.2018.2844296

[32] Dhanaraju M., Chenniappan P., Ramalingam K., Pazhanivelan S., Kaliaperumal R., "Smart farming: Internet of things (iot)-based sustainable agriculture," Agriculture. vol. 12, no. 10:1745, 2022. DOI:10.3390/agriculture12101 745

[33] Choi J., Chang Y.K., Li Y.J., Jang M.G., "Doing good in another neighbourhood: Attributions of CSR motives depend on corporate nationality and cultural orientation," Journal of International Marketing, vol. 24, no. 4, pp.82-102, 2016. DOI: 10.1509/jim.15.009

[34] Tornatzky L., Fleischer M., "The Process of Technology Innovation," Lexington Books, Lexington, MA, 1990.

[35] Aboelmaged M.G., "Predicting e-readiness at firm-level: An analysis of technological, organizational and environmental (TOE) effects on e-maintenance readiness in manufacturing firms," International Journal of Information Management, vol. 34, no.5, pp. 639-651, 2014. DOI: 10.1016/j.ijinfomgt.2014.05.002

[36] Shahadat M. M. H., Nekmahmud Md., Ebrahimi P., Fekete-Farkas, M., "Digital technology adoption in smes: what technological, environmental and organizational factors influence in emerging countries?" Global Business Review, 2023. DOI: 10.1177/09721509221137199

[37] Karunagaran S., Mathew S.K., Lehner F., "Differential cloud adoption: A comparative case study of large enterprises and SMEs in Germany," Inf Syst Front, vol. 21, pp. 861–875, 2019. DOI: 10.1007/s10796-017-9781-z

[38] Ellen G., Violet M., Albert Boaite, "Food integrity and food technology concerns in Canada: evidence from two public surveys," Journal of Food Quality, vol. 2018. DOI: 10.1155/2018/2163526

[39] Mohr P., Golley S, "Responses to GM food content in context with food integrity issues: Results from Australian population surveys," New Biotechnology, vol. 33, no. 1, pp. 91–98, 2016. DOI: 10.1016/j.nbt.2015.08.005

[40] Leroy J.L., Ruel M., Frongillo E.A., Harris J., Ballard T.J., "Measuring the food access dimension of food security: A critical review and mapping of indicators," Food Nutr Bull, vol. 36, no. 2, pp. 167-95, 2015. DOI: 10.1177/037957211 5587274

[41] Aramyan L., Grainger M., Logatcheva K., Piras S., Setti M., Stewart G. and Vittuari M., "Food waste reduction in supply chains through innovations: A review," Measuring Business Excellence, vol. 25, no. 4, pp. 475-492, 2021. DOI: 10.1108/MBE-11-2019-0105

[42] Gustavsson J., Cederberg C., Sonesson U., van Otterdijk R. Meybeck A., "Global food losses and food waste: Extent, causes and prevention," FAO report, www.fao.org/docrep/ 014/mb060e/mb060e00.pdf (accessed 10 August 2017).

[43] Godfray HC., Beddington JR., Crute IR., Haddad L., Lawrence D., Muir JF., Pretty J., Robinson S., Thomas SM., Toulmin C., "Food security: the challenge of feeding 9 billion people," Science, vol. 327, no. 5967, pp. 812-818. DOI: 10.1126/science.1185383

[44] Buzby J., Hyman J. "Total and per capita value of food loss in the United States," Food Policy, vol. 37, no. 5, pp. 561-570, 2012. DOI: 10.1016/j.foodpol.2012.06.002