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Enablers for Adopting Restriction of Hazardous Substances Directives by Electronic Manufacturing Service Providers

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Abstract: The Electronic Manufacturing Service (EMS) industry contributes significantly to toxic waste generation due to its fabrication processes. Notably, adherence to the Restriction of Hazardous Substances (RoHS) Directive varies amongst EMS providers, despite its aim to reduce electronic waste. This study explores the factors influencing EMS providers' decision to adopt the RoHS directive, utilizing the technology–organization–environment (TOE) and the human–organization–technology (HOT) fit, or the TOE-HOT fit framework. We validated our framework using partial least squares structural equation modeling (PLS-SEM), based on responses from 379 questionnaires from major EMS providers. The results demonstrated that expert resources, adequate resources, perceived industrial pressure, institutional pressure, and costs were positively associated with RoHS adoption. However, innovation, relative advantage, and verification ability were identified as significant barriers. In particular, innovation in the human dimension was the key determinant for RoHS adoption. Therefore, clear policy instruments and regulations may enhance RoHS adoption by EMS providers. These findings can guide environmental policy definitions in governmental laws and strategies, encouraging EMS providers and other firms to adopt RoHS standards.

Keywords: Restriction of Hazardous Substances (RoHS); partial least squares structural equation modeling (PLS-SEM); green manufacturing; technology–organization–environment (TOE); human–organization–technology (HOT) fit; TOE-HOT fit; electronic manufacturing service (EMS)

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1. Introduction

In the past decade, the amount of global electrical and electronic waste (or e-waste) has grown rapidly [1]. The appropriate recycling of e-waste and the prevention of the use of toxic substances have become critical challenges, especially for developing economies, where environmental regulations are not well developed. The European Union (EU) has initiated regulating the production of electrical and electronic products through Directive 2002/95/EC on the Restriction of Hazardous Substances (RoHS). It is anticipated that the utilization of particular hazardous chemicals and compounds will be regulated and restricted as a result of this directive, which will apply to the manufacturing of electrical and electronic devices and systems.

Despite the establishment of the RoHS directive, such regulations are comparatively loose in emerging or rapidly developing economies due to economic and political factors, especially since many underdeveloped countries continue to adhere to the "pollution first, treatment later" policy [2]. Without appropriate interventions or government policy regulations, e-waste and dissipated hazardous materials in the fabrication process of electronic devices and systems will continue to damage the health of people and the environment of the above-mentioned economies.

In the past years, leading electronic manufacturing service (EMS) providers have introduced advanced manufacturing technologies and processes to upgrade their manufacturing capabilities. It is worth noting that electronic manufacturing waste, or end users' e-waste, is a growing concern globally because of the rapid technological innovation and the growing consumption of electronic devices, and increased electronics production can lead to a corresponding increase in e-waste. However, not all manufacturing processes of EMS providers comply with the RoHS directive due to the extra cost of lead-free materials and processes. Therefore, numerous researchers (e.g., [3,4]) have discussed why certain firms have adopted RoHS. Moreover, a firm's environmental practices (e.g., RoHS) are affected by its organizational context and operations [5].

Many researchers have examined the problems associated with the adoption of RoHS, looking at them from the perspectives of technology, organization, and environmental sustainability; Hwang, Huang, and Wu [6] used the technology–organization–environment (TOE) theory to investigate the green supply chain adoption and environmental issues in the semiconductor industry. However, few researchers have considered these aspects concurrently, despite their close relation. Moreover, few scholars, if any, have investigated the human-related issues surrounding the adoption of RoHS.

Therefore, a theoretical model is required to identify the critical factors that impact the adoption of the RoHS directive by EMS providers from the aspects of technology, organization, environment, and human factors. Over the course of the previous few years, the TOE framework has been proven to be useful in gaining an understanding of the vital factors that are involved in the adoption of innovation within a specific organization. The human–organization–technology (HOT) fit, or HOT-fit model, has been widely adopted to identify the factors related to the adoption of information systems (IS). Hence, this study uses the TOE-HOT fit framework [7] to confirm the correlations between human, organizational, technological, and environmental factors from the perspective of an EMS provider adopting RoHS.

The hypotheses will be tested based on the TOE-HOT fit model using the partial least squares structural equation modeling (PLS-SEM) technique. A total of 379 respondents from Taiwanese EMS providers were invited to provide their opinions by completing an online questionnaire. The well-verified theoretical framework and empirical results can serve as the foundation for future research on the adoption of green regulations and other guidelines on the part of EMS providers.

The following outline constitutes the framework for this investigation. The principles of EMS, green manufacturing, RoHS, TOE, HOT-fit, and the TOE-HOT fit framework will be reviewed in Section 2. At the very end of this section, a proposed analytic framework together with research hypotheses will be presented. The PLS-SEM is presented in Section 3, along with some background information. The empirical study that was carried out to confirm the hypotheses is presented in Section 4. After that, the primary factors that are correlated with the adoption of RoHS by EMS providers are identified, and the findings are reviewed, along with some suggestions for further investigation. The work concludes with Section 5.

2. Literature Review

The first EMS provider, Solectron (Flex), entered the market in 1977, by providing contract manufacturing at that time. In the 1980s, more EMS providers emerged. In the last decade, EMS providers have adopted green manufacturing practices (e.g., lead-free processes, RoHS-compliant lines, etc.), primarily due to strict environmental regulations like the RoHS directive. However, some firms still do not comply with the RoHS directive.

In light of this, a number of researchers have discussed why firms adopted RoHS [8]. Several scholars (e.g., [3,4]) have examined the topic from multiple perspectives, including rapid technological changes. Furthermore, an organization's environmental practices (for example, RoHS) may be affected or influenced by its organizational context as well as its operations [5]. In addition, the adoption of Information Technology (IT) by manufacturers has become increasingly important in order to achieve sustainability [9]. The extended TOE framework, which integrates the TOE and HOT-fit models, has been updated in order to find the factors that correlate with the adoption of RoHS. These aspects are analyzed from a four-pronged approach: technological, organizational, environmental, and human.

This section consists of the following subsections: Section 2.1 reviews the literature on EMS providers. Section 2.2 reviews green manufacturing and RoHS-relevant research. Section 2.3 reviews the concept of sustainability and recent developments. Section 2.4 introduces the framework of the TOE, and Section 2.5 introduces the HOT-fit model. Section 2.6 introduces the integrated TOE-HOT fit framework. Section 2.7 introduces the research gaps. Finally, Section 2.8 reviews the factors correlated with the adoption of sustainable materials and green processes in the extended TOE-HOT fit model, which will serve as this research's theoretical framework.

2.1. EMS and Global Market

EMS providers design, manufacture, verify, validate, distribute, and provide return/repair services for electronic products [10]. The emergence of the EMS industry in the 1980s was mainly driven by brand-name IT companies (like IBM and Alcatel), who used business process outsourcing (BPO) to acquire manufacturing and service operations from these EMS providers, were primarily responsible for the emergence of the EMS industry in the 1980s. The major purpose was to save on large operating expenses by optimizing production capacities and organization [11].

Transferring the manufacturing process to EMS providers enabled those brand-name IT companies to concentrate on their core competencies (e.g., research and development, industrial design, and marketing) without investing in production facilities [11]. Through this, EMS providers offered the brand-name IT companies benefits from the perspectives of international market assessment, labor cost reduction, resource efficiency enhancement, and increased demand fulfillment [12]. These advantages contributed toward securing the competitiveness [10] of the brand-name IT companies.

The top 10 EMS providers are Hon Hai Precision (Foxconn), Pegatron, Wistron, Jabil, Flex, BYD Electronics, USI, Sanmina, New Kinpo Group, and Celestica [13]. Over half of the top companies were registered in the Asia-Pacific (APAC) region. The selection of an EMS manufacturing site affects the business's operational efficiency, effectiveness, and, thus, profitability [14].

2.2. Green Manufacturing

Green manufacturing is an integrated and economically driven approach aimed at minimizing and eliminating all waste streams associated with the design, production, use, and disposal of products and materials. It focuses on creating products in an environmentally friendly and efficient manner, reducing pollution, and conserving energy and natural resources. Green manufacturing also promotes the use of renewable resources and recycled materials [15]. When addressing a number of green practices, some scholars [16–18] used the phrase "green manufacturing" to define manufacturing companies' efforts to decrease their environmental impacts through reducing toxics, waste, and pollution, as well as making the best use of raw materials and energy through the use of "end of life" (EOL) in their product lifecycle management (PLM) [19]. With regard to product lifecycle concerns, the green manufacturing guideline focuses on utilizing clean manufacturing processes, avoiding overpackaging, reducing transportation, ensuring proper waste disposal, and recycling to minimize negative environmental impacts and maximize resource efficiency [17].

Numerous researchers have studied green manufacturing from various perspectives. According to ElMaraghy et al. [20], the paradigms of green manufacturing have often been divided into internal and external aspects. The internal perspective includes the operational level (machines, materials, and processes), the technological level (design for manufacturing and appropriate manufacturing techniques), the organizational level (functional, divisional, matrix, and flat), and the resource level (labor, experts, and managers). From an external perspective, market competition, green supply chain management, and government regulations can influence a firm's adoption of green manufacturing [20]. In general, the adoption of environmentally friendly manufacturing practices by a company is influenced by a variety of factors, both inside and outside of the organization.

2.3. RoHS

The EU published the RoHS directive to forbid manufacturers of electronic equipment and products from using particular hazardous substances. Since 2002, all electrical equipment and electronic products imported to any European nation should be compatible with the RoHS directive. Restrictions have been placed on the use of substances that are known to be particularly harmful to the environment, such as lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBBs), and polybrominated diphenyl ethers (PBDEs) [21]. Only very limited exceptions, such as the soldering materials used in magnetic resonance imaging (MRI), exist [22].

In today's world, the majority of production sectors must contend with the pressure to adhere to strict environmental rules as a result of dwindling natural resources, climate change, and waste management concerns [17]. Well-crafted environmental policies, such as RoHS, can enhance a company's competitiveness while also promoting a more sustainable environment [23]. The growing awareness and concern for the environment serve as catalysts for manufacturers worldwide to embrace eco-friendly production methods [24].

Chien and Shih [8] highlight that many firms have adopted green manufacturing practices and green purchasing practices to comply with environmental directives, particularly RoHS [24]. The certification of RoHS products can be provided by third-party laboratories (e.g., SGS, TÜV Rheinland, etc.), which check whether hazardous chemicals or compounds exist in the raw materials and components of finished products. After certification, the providers of electronic products and equipment can declare that their finished products are compatible with RoHS standards [21].

Though the RoHS directive has restricted the commercialization of new electronic products containing harmful substances [25], it allows for conditional exemptions for certain substitutes based on scientific and technological requirements. That said, the exemptions may not be renewed on a regular basis. For most electronic companies, such uncertainty may have negative effects on the development of new products and even potentially impact on their ability to take advantage of new market opportunities [24].

2.4. TOE Theory

The TOE framework, developed by Tornatzky and Fleischer [26], examines both external and internal factors that influence the adoption of technology [15]. This framework offers a holistic understanding of the technology adoption process by analyzing the interactions among three key elements: (1) technology, which includes factors such as system security and complexity; (2) organization, which considers variables like organization size and top-management support for replacing existing systems; and (3) environment, encompassing aspects such as market uncertainty, governmental pressure, and competitors' influence [15]. By considering the interplay between these elements, the TOE framework provides a comprehensive perspective on the process of technology adoption.

According to previous works in the literature, the firm's adoption of innovation based on the TOE model is a highly adaptable and powerful tool for explaining the categories of new technologies [27]. Thus, previous research conducted in different regions of the world, including Europe, America, and Asia, as well as in both developed and developing countries, has tested and validated the TOE model [28]. When it comes to recognizing, exploring, and implementing innovation, the studies have repeatedly demonstrated that the three components of technology, organization, and environment are essential aspects that influence a company's decision-making process.

In addition to the factors belonging to the traditional TOE framework, researchers may need to consider other factors outside of the three dimensions, as technological, organizational, and environmental aspects may not fully cover all of the criteria required for decision making. Additionally, some researchers have argued that the variables relevant to specific technologies or contexts have failed to provide insight into observed technology and cannot help researchers determine how it was adopted [28]. For instance, human resources and behavior are both considered core features of a firm's adoption of specific technology; however, the human aspect has not been addressed in traditional TOE contexts.

2.5. HOT-Fit Theory

The HOT-fit model was developed by Yusof and colleagues [29] to emphasize the crucial influence of human, organizational, and technological factors on enhancing environmental and economic performance [30]. This model builds upon existing frameworks for evaluating IS, specifically the models of IS success and IT-organization fit. Originally designed for assessing health IS, the HOT-fit model recognizes the significance of considering human and organizational aspects in addition to technological advancements [30]. Initially applied in the healthcare industry, this analytical framework enables a comprehensive, rigorous, and ongoing evaluation of technology or systems' performance, effectiveness, and impact on medical information. Furthermore, it facilitates the identification of relationships and alignment between individuals, organizations, and technology [30], as well as the challenges and system improvements that can be tailored by EMS companies to achieve a more comprehensive and holistic approach to evaluating RoHS adoption.

2.6. Integrated TOE-HOT Fit Framework

By integrating the TOE and HOT-fit models, a comprehensive framework can be developed, enriching the research by taking all perspectives (human, technology, organization, and environment) into a theoretical framework (Figure 1). Organizations will be able to assess the pros and cons of both their internal and external environments accordingly. Furthermore, since the adoption of an innovation in a manufacturing firm is a complex process, a single theory cannot adequately explain the entire process [31]. In light of this, the integrated TOE-HOT fit model is presented in this study for factors influencing EMS providers' adoption and decision-making analyses, which are characterized by human, environmental, technological, and organizational issues. Aspects of the theoretical framework are abbreviated and explained in Table 1.

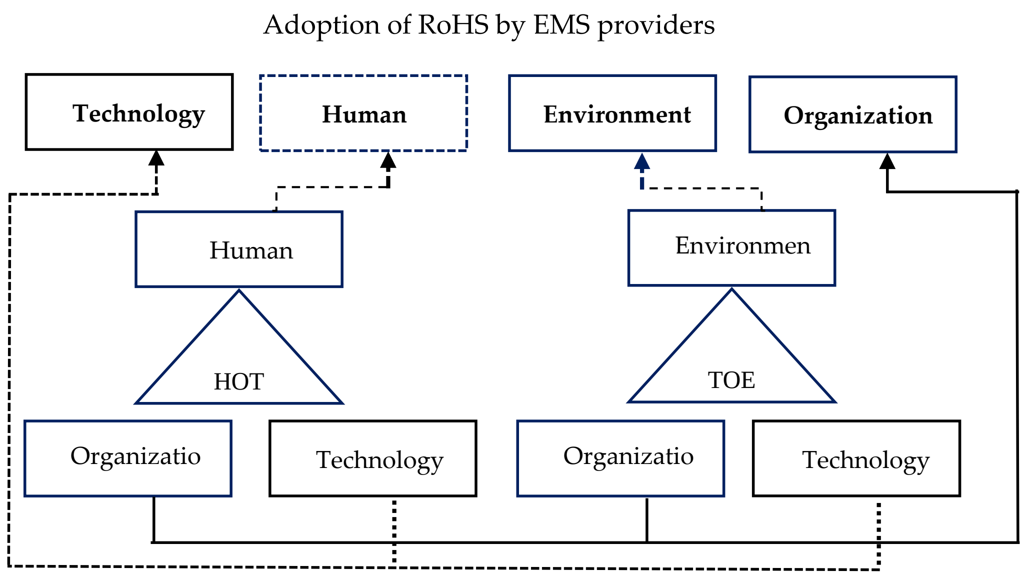

Figure 1. Integrated TOE-HOT fit framework (Adapted from [32]).

Table 1. Abbreviations and explanations for the terms and variables.

Aspect	Variable	Abbreviation	Explanations
Technology	Cost	CA	Cost (CA) refers to an EMS provider's operation cost for RoHS compliance [33].
	Complexity	CO	Complexity (CO) refers to the difficulties faced in implementing the RoHS practice [34].
	Compatibility	CC	Compatibility (CC) is the degree of compliance of an EMS provider's operations with RoHS [34].
	System integration	SI	System integration (SI) offers a systems-based approach to resolving complex issues and serves as a robust foundation for integrating both products and processes [35,36]. As all components of the entire green supply chain may be accountable for any noncompliance with RoHS regulations, the integration of ISs up to a certain level assumes a critical role [37].
Organization	Relative advantage	RA	As per Rogers [38], relative advantage (RA) denotes the perceived superiority of an innovation compared to a current concept or method; the higher the perceived relative benefit of an innovation, the faster its adoption rate within an organization [33].
	Adequate resource	AR	Adequate resources (ARs) have a direct effect on a firm's decisions about innovation, investment, and business strategies [39].
Environment	Institutional pressure	INP	Institutional pressure (INP) refers to the influence stemming from the institutional environment, including governmental and non-governmental entities, which can impact a company's managerial choices and practices [40,41].
	Perceived industry pressure	PIP	Perceived industry pressure (PIP) alludes to the environmental influence originating from supply chains, competitors, and clients that could potentially sway a company's decision-making process [41].
Human	Expert resource	ER	Expert resource (ER) means individuals who are capable of helping with a particular task [42].
	Verification	VA	Verification is a process to measure the firm's policies and procedures to a degree based on the customer's requirements and/or standards [43].
	Innovation	IN	Innovation (IN) refers to the practical realization of ideas that lead to the creation of new products or services, or the enhancement of existing ones [44].

2.7. Research Gap

Because of economic and political considerations, rising economies or economies that are rapidly catching up have laxer rules governing e-waste and dangerous materials. This is especially true given that many developing countries still adhere to the "pollution first, treatment later" policy [2]. The application of RoHS standards calls for an increase in the number of empirical studies that have been conducted on the topic. The following is a list of the research gaps that were found and addressed in this study.

(1) Some companies that provide electronic manufacturing services have introduced more advanced technologies (for example, greentelligence [45]) in order to address these issues; nevertheless, because of cost considerations, not all of these companies comply with the RoHS directive. On the other hand, either very few or no previous studies attempted to study what the most important criteria are for permitting the adoption of RoHS by these companies.

(2) According to academics [6,46], one of the reasons firms apply RoHS is because of the advancement of technology. Other reasons include corporate culture, environmental sustainability, human resources, and other factors. In addition to this, it is mentioned that academics have studied the implementation of RoHS standards from the perspectives of technology, organization, and environmental sustainability, but rarely all three at the same time. In addition, studies have not examined how human-related factors impact the adoption of RoHS in general, nor have they investigated how the human aspect interacts with the three aspects discussed previously.

(3) A better knowledge of the steps that are essential for EMS providers to achieve RoHS compliance can be obtained by addressing the gap in RoHS adoption that exists in the EMS industry. However, the EMS industry does not present any actual facts to explain why these providers are not willing to comply with RoHS. This is a significant gap in the available information. In addition, there has been very little discussion regarding how policies or strategies developed by customers might assist in the adoption of RoHS by EMS providers.

2.8. Research Hypotheses

The hypotheses based on the TOE-HOT fit framework will be defined according to the technological, organizational, environmental, and human dimensions in order to bridge the research gaps highlighted in the previous subsection.

2.8.1. Technological Dimension

According to Grinstein and Goldman [47], a technological context includes all relevant technologies for a firm, regardless of whether they are currently in use, as well as technologies that suppliers or customers are developing for upcoming products and production plans. Based on previous findings [32,33,47,48], firms adopting new technologies require measurable factors such as cost (CA), complexity (CO), compatibility (CC), and system integration (SI). In the following subsections, the rationale for defining hypotheses based on the four factors belonging to the technological dimension, which are cost (CA), complexity (CO), compatibility (CC), and system integration (SI), will be introduced.

Cost

According to Rounaghi, Jarrar, and Dana [49], manufacturing firms must consider various cost factors associated with selling their products or services, such as material procurement, inventory replenishment, and employee wages. When cost pressures arise, well-known IT companies often collaborate with EMS providers that specialize in sourcing raw materials and achieving manufacturing efficiencies at the lowest possible cost [50]. These IT companies require their manufacturing partners to adhere to environmental guidelines, such as RoHS, despite the potential additional expenses involved. Additionally, Huang, Raj, Osterman, and Pecht [51] discovered that the adoption of RoHS by firms can impact their existing practices, budgets, and cost-saving strategies. Consequently, the hypothesis can be formulated as follows:

H_1. *The cost (CA) is positively correlated with the adoption of RoHS.*

Complexity

According to ElMaraghy et al. [20], a growing number of challenges stemming from globalization, governments, and regulations have resulted in more complicated manufacturing processes, technology, and ecosystems. In addition, technology and innovation have contributed to the development of highly complicated products and equipment that involve a variety of mechanical and electronic components, computer programs, and control modules [52]. Through this, we propose the following hypothesis:

H_2. *Complexity (CO) is positively correlated with the adoption of RoHS.*

Compatibility

Compatibility refers to the extent to which an innovation is perceived as aligning with the existing values, past experiences, and needs of potential adopters. In the context of a manufacturing firm, compatibility also encompasses the degree to which the surrounding business environment is seen as consistent with the firm's current operational processes, such as compliance with RoHS and ISO 14000 standards [6]. According to Amini and Javid [53], compatibility serves as a measure of the fit between an innovation and a firm's experiences, values, and adoption requirements. Compatibility is also an important factor, closely related to the technological perspective, in the success of a manufacturing organization. Cenci et al. [54] state that compatibility serves as a measure of the fit between an innovation and a firm's experiences, values, and adoption requirements. It is also a crucial factor closely related to the technological perspective for the success of a manufacturing organization. For example, in the selection of green materials, compatibility plays a significant role, as choosing incompatible materials could increase the challenges associated with product disassembly and reclamation [54]. Therefore, we put forth the following hypothesis:

H$_3$. *Compatibility (CC) is positively correlated with the adoption of RoHS.*

System Integration

Paez and colleagues [55] define SI as the process of uniting subsystems to achieve the desired outcomes and ensuring that these subsystems interact effectively to meet customer requirements. According to Pelliene, Teittinen, and Järvenpää [56], in an organization, SI is a complex process of building connections between its various functions. A study by Rajaguru and Matanda [57] explored how SI affects a firm's internal workflow and its supply chain capabilities. According to Gong et al. [37], SI plays a significant part in the implementation of RoHS to some extent. In light of this, we suggest the following hypothesis:

H$_4$. *The capabilities of system integration (SI) are positively correlated with the adoption of RoHS.*

2.8.2. Organizational Dimension

Manufacturing firms face the managerial challenge of balancing conflicting objectives, such as green investment and maximizing profits, when dealing with environmental pressure. Limited resources can hinder organizations lacking a green culture from investing in green strategies. In such cases, upper management may prioritize other organizational priorities over environmental regulations. However, it is crucial to allocate resources towards environmental action to effectively support green initiatives. As a result, these firms often lean towards prioritizing the objective of maximizing profits [58]. The key elements that contribute to the organizational context include organizational resources and relative advantage, adequate resources, internal stakeholders within the organization, and the procedures implemented to foster innovative business practices. These factors collectively influence the organization's capacity to embrace and implement organizational innovations [6], which includes whether an organization has its own environmental plan, can recognize the right instance to adopt innovation, and is able to capitalize on environmental policy management in order to improve its competitive advantage [55]. Meanwhile, RoHS adoption and implementation may entail the integration of resources and the reengineering of the organizational system, as well as customized processes, including system modernization, code conversions, and implementation consulting, to reduce the risk of hazardous substances [37]. Thus, we will examine the key organizational factors: relative advantage and adequate resources.

Relative Advantage

Relative advantage refers to the perception that an innovation is superior to the idea it replaces. Innovations that offer clear and unambiguous advantages in terms of strategic effectiveness (e.g., increased sales) and operational effectiveness (e.g., reduced operational costs) are more likely to be adopted [53]. When the benefits of a technology, such as the relative advantage, surpass existing practices and processes, its adoption is positively influenced. Further, the diffusion of innovations has consistently found the relative advantage to be a significant determinant, underscoring the importance of studying this concept within the context of relative advantage. The decision to adopt a relative advantage is significantly influenced by whether the technology provides advantages that enable companies to perform tasks more quickly, easily, and efficiently [53]. Additionally, relative advantage can enhance the quality, productivity, and overall performance of a company. Therefore, due to these reasons, relative advantage has a positive influence on the adoption of relative advantage. Based on the above works, we propose the following hypothesis:

H_5. *Relative advantage (RA) is negatively correlated with the adoption of RoHS.*

Adequate Resource

According to Gold, Seuring, and Beske [59], having sufficient resources plays a preeminent role in determining the level of overall achievement for a business. When an organization's objectives are formulated, the expertise, resources, skills, and knowledge base have been considered and measured. Fishbein and Ajzen [60] as well as Davis [61] confirmed that a firm's pursuit of improvement in the areas of policies, agility, and sustainability is propelled by adequate quality resources [59]. Therefore, we propose the following hypothesis:

H_6. *Adequate resources (AR) are positively correlated with the adoption of RoHS.*

2.8.3. Environmental Dimension

The environmental context refers to the forces and institutions surrounding an organization that significantly impact its efficiency, operations, and resources [6]. The external environment encompasses all of the components existing beyond an organization's boundaries that have the potential to affect various aspects of the organization. Institutional theory focuses on how firms respond to institutional pressures within their operating environments. It assumes that firms make normatively rational choices based on historical precedent and social justification. The literature supports the application of institutional theory to understand the drivers of green practice adoption. Studies consistently highlight the significant role of external pressures, as conceptualized by institutional theory, in determining the adoption of green practices [6]. This study draws on four constructs from prior research based on institutional theory.

In addition to government regulation, customer pressure, competitor pressures, and pressures from social communities, another important construct related to institutional theory is perceived industry pressure [62]. Perceived industry pressure refers to the belief that other firms in the industry are adopting or are expected to adopt certain practices or standards. This form of mimetic cultural–cognitive isomorphism influences organizations to conform to the perceived norms and practices prevalent in their industry. Perceived industry pressure can arise from various sources, such as industry associations, industry benchmarks, industry publications, and industry events. When organizations perceive that their industry peers are embracing specific practices, technologies, or sustainability initiatives, they may feel compelled to follow suit in order to maintain their competitiveness, reputation, and legitimacy within the industry [63]. The influence of perceived industry pressure is driven by the belief that aligning with industry norms and standards can lead to benefits such as improved collaboration, enhanced market positioning, access to industry networks, and increased opportunities for partnerships and business relationships.

Institutional Pressure

Liu et al. [64] argued that firms' decision making is affected by institutional pressure and organizational culture. In recent decades, many institutions have experienced regulatory pressures from markets, governments, supply chains, and other stakeholders. Environmental requirements, such as RoHS compliance, directly influence the manufacturing firm through the country's law on product import restrictions [65]. Hence, we propose the following hypothesis:

H_7. *Institutional pressure (INP) is positively correlated with the adoption of RoHS.*

Perceived Industry Pressure

According to Wang et al. [41], perceived industry pressure is an essential characteristic that affects green manufacturing practices. Studies have examined whether perceived industry pressure is one of the external factors influencing a firm's management and stakeholder attitudes. In addition, the research of Betts, Wiengarten, and Tadisina [66] shows that perceived industry pressure is one driving factor in a firm's and stakeholders' efforts to adopt sustainable practices to improve environmental performance. Similarly, Liang et al. [67] observed that organizations worldwide are increasingly encouraging manufacturing firms to reduce pollution caused by production and process activities. Based on the above, we propose the following hypothesis:

H_8. *Perceived industry pressure (PIP) is positively correlated with the adoption of RoHS.*

2.8.4. Human Dimension

The HOT-fit model was proposed by Yusof et al. [29], drawing inspiration from the IS evaluation model developed by DeLone and McLean [68]. This assessment model encompasses various dimensions that are intrinsic to the IS itself. Specifically, the HOT-fit model considers the people who assess the information system in terms of their usage, training, experience, knowledge, perspectives, and acceptance or rejection of the system. Organizations evaluate the system based on its design, alignment with organizational planning, management support, system control, and funding. The technology aspect evaluates the quality of the system, information, and services provided. These three factors are linked to the dimensions of the IS success, which include system quality, information quality, service quality, system use, user satisfaction, and net benefit. Each of these elements is encompassed within the HOT component. The human component focuses on aspects such as system development, system use, and user satisfaction. The organizational component considers the organizational structure and environment. Lastly, the technology component examines system quality, information quality, and service quality. This dimension is also associated with the net benefit derived from the IS [30].

Humans are integrated within their organizations and are subject to institutional norms and practices. Organizations, in turn, are collective actors that collaborate and utilize resources to achieve specific goals. The structure, strategies, policies, and regulations of an organization directly influence the attitudes and behaviors of individuals embedded within it. Simultaneously, human behaviors also serve as drivers for shaping organizational structure, processes, and the overall organizational environment over time [69].

Expert Resources

Mishra and Akman [70] identified that many business organizations are still short of IT experts of green IT, as IS had been designed to meet a particular purpose under a particular set of circumstances. Thus, experts belonging to the human dimension may influence a firm's adoption of RoHS. Therefore, we propose the following hypothesis:

H$_9$. *Expert resources (ER) are positively correlated with the adoption of RoHS.*

Verification Capability

Verification capability encompasses various aspects, including software, hardware, documentation, rules, and regulations, which are essential for ensuring compliance with organizational requirements and keeping the final product on track. In the industrial sector, the verification process typically begins with assessing a firm's system capabilities [71]. Relevant agencies provide access to experts or recognized laboratories in the field who can assist in developing a firm's verification capability to ensure compliance with regulations such as RoHS. However, it is important to note that implementing environmental auditing can be costly [72]. Moreover, the outcomes of an environmental audit can have adverse effects not only on a company's financial status, but also on its non-financial aspects, such as corporate reputation. This is particularly true if the company is found to have violated environmental laws and regulations. Thus, we propose the following hypothesis:

H$_{10}$. *Verification ability (VA) is negatively correlated with the adoption of RoHS.*

Innovation

Several academics contend that RoHS compliance is a roadblock to the widespread implementation of environmentally friendly innovations. For example, Gupta and Baura [73] found that several internal challenges occur when manufacturing organizations adopt green innovation, including a lack of resources as well as financial and human constraints. Ullah et al. [74] provided a summary of the obstacles that accompany the adoption of innovation in green practices and noted that insufficient human resources are a major obstacle. This may negatively affect a company's decision to adopt innovation(s) for regulation compliance due to a long and costly payback period as well as concerns regarding financial resources. Meanwhile, electronic material suppliers struggle to adopt RoHS due to a lack of human resources [75]. According to Ghazilla et al. [24] as well as Pumpinyo and Nitivattananon [76], insufficient research and development support (such as a lack of technical expertise) is a barrier to influencing the firm's actual green practices because decision makers believe that implementing green innovation for environmental regulation compliance would be expensive. Considering the obstacles to accelerating the introduction of sustainable and innovative methods, we propose the following hypothesis:

H$_{11}$. *(IN) Innovation in green compliance is negatively correlated with RoHS adoption.*

Moderation Effect

The demographic information collected in this study aims to examine whether gender and age act as moderating variables in the adoption of RoHS practices by EMS providers. Previous research conducted by Byrnes, Miller, and Schafer [77] has established gender as a significant moderating variable in decision making. Studies by Tripathi [78] have further supported the moderating effects of age and experience on the factors influencing the adoption of new technology in a business firm.

Regarding age moderation, differences were observed, indicating that younger individuals tend to adapt more readily to new technologies and work patterns compared to older individuals. This finding aligns with previous studies that have identified attitudinal differences between different age groups [79]. Consequently, the present study classifies the age of EMS employees into four categories: under 30, 30–40, 40–50, and above 50 years old.

Based on the potential moderating effects of gender and age on various factors associated with RoHS adoption, additional hypotheses were developed. These hypotheses propose that age moderates the relationship between costs (CA), complexity (CC), compatibility (CO), system integration (SI), relative advantage (RA), adequate resource (AR), institutional pressure (IP), perceived industry pressure (PIP), expert resource (ER), verification ability (VA), and innovation (IN) with the EMS provider's adoption of RoHS regulation. Additional hypotheses were subsequently developed, as follows:

H$_{12}$. *Age moderates the relationship between costs (CA), complexity (CC), compatibility (CO), system integration (SI), relative advantage (RA), adequate resource (AR), institutional pressure (IP), perceived industry pressure (PIP), expert resource (ER), verification ability (VA), and innovation (IN) with the EMS provider to adopt RoHS regulation.*

H$_{13}$. *Gender moderates the relationship between costs (CA), complexity (CC), compatibility (CO), system integration (SI), relative advantage (RA), adequate resource (AR), institutional pressure (IP), perceived industry pressure (PIP), expert resource (ER), verification ability (VA), and innovation (IN) with the EMS provider to adopt RoHS regulation.*

The theoretical framework based on the aforementioned research hypotheses is defined below in Figure 2. A total of 11 hypotheses derived from the literature will be confirmed by the modified Delphi method introduced in Section 3.1. Then, the causal relationship will be confirmed by utilizing the PLS-SEM introduced in Section 3.2. The statistical significance of these test results can confirm the correlations between the variables. The research methods adopted will be introduced in Section 3, and the empirical study process will be demonstrated in Section 4.

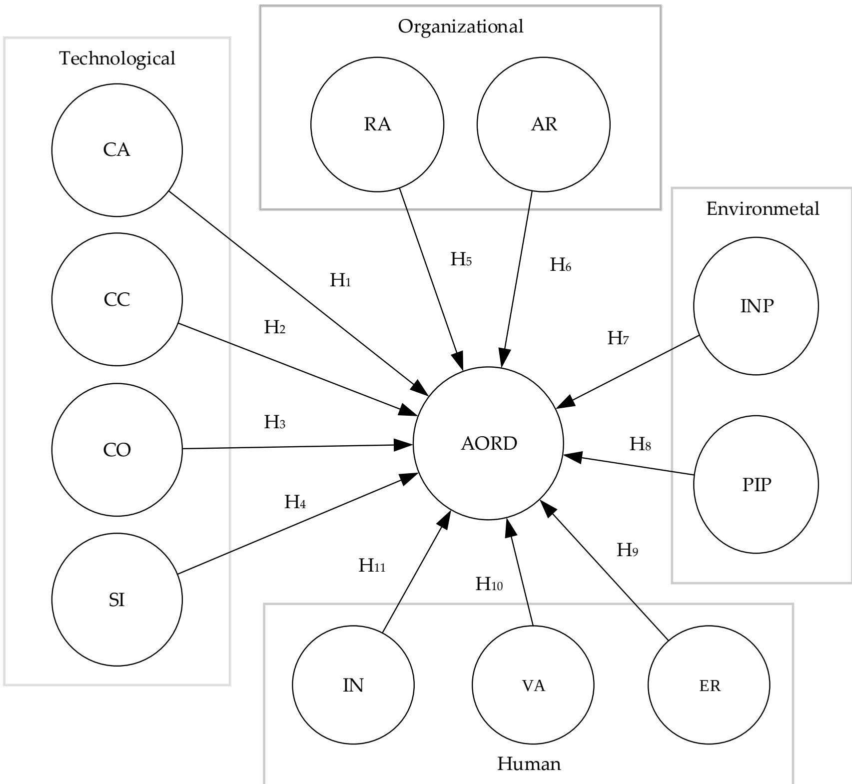

Figure 2. Proposed research model. **Remark:** The aspects are abbreviated as follows: CA (Cost), CC (Compatibility), CO (Complexity), SI (System integration), RA (Relative advantage), AR (Adequate resource), INP (Institutional pressure), PIP (Perceived industry pressure), ER (Expert resource), VA (Verification ability), and IN (Innovation).

3. Research Method

The modified Delphi method will be introduced in Section 3.1. Then, the PLS-SEM will be introduced in Section 3.2. After that, the sample and measures will be introduced in Section 3.3. The results in Section 4.1 will be assessed against the measurement model. Section 4.2 will be assessed against the structural model, and Section 4.3 will be used to test the hypotheses.

3.1. Modified Delphi Method

The Delphi method has since been extensively employed for gathering data from groups of experts. One distinctive feature of this method is that experts are surveyed individually in multiple rounds with no knowledge of the other participants' responses. Through the use of predetermined parameters and a multi-round structure, the results obtained in each round are fed back to the expert panel in subsequent rounds. This iterative process continues until a consensus is reached among the experts or until the study's objectives have been fulfilled [80]. It is believed that this modification to the Delphi method provides two primary benefits: (a) an increase in the response rate in the first round and (b) the ability to provide a solid grounding in previous research. Compared to the traditional Delphi method, the modified Delphi method offers a few other advantages, including a reduction in data collection bias, a controlled feedback process for participants, an assurance of anonymity, and a reduction in the effects of group interaction [81].

3.2. PLS-SEM

As early as the 1970s, Wold [82] and his colleagues introduced the techniques of PLS-SEM to deal with multicollinearity in regression analysis. Through continued development and refinement, this method has evolved into a powerful tool that forms the basis for further statistical analysis. As found in the previous literature, the PLS-SEM method is widely adopted in environmental management research across various fields [83].

PLS-SEM is particularly suitable for analyzing complex and high-dimensional data sets, especially when little prior knowledge of the underlying structure of the data is available [84]. The PLS-SEM uses latent variables to model relationships between both observed and unobserved variables, in contrast to traditional SEM, which aims to estimate covariance structure among observed variables [85]. Additionally, PLS-SEM is capable of handling non-normal data and does not require the large sample sizes that are often required for traditional SEM [86]. In PLS-SEM modeling, the path model is defined by two sets of linear square programs, one of which is the measurement model (also known as the outer model or reflective model), also known as the external model, used to explain the relation between a potential construct structure and its observed indicators [86]. Alternatively, the structural model (also known as the inner model or formative model) refers mainly to the relationship between the potential constructs. The PLS-SEM algorithm estimates all partial regression models through iterative procedures [87] (Figure 3) through a three-stage approach defined by Lohmöller [88] and summarized by [89] as follows: The procedure calculates initial latent variable values during the initialization stage by assigning unit weights (i.e., 1) to every single indicator in the measurement model [86]. The first stage of the algorithm consists of iteratively calculating inner weights and latent variable values. The term "path coefficient" is used to describe the inner weights of the algorithm, while "indicator weights" and "outer loadings" are the terms used to describe the outside weights. Step #1: The first phase in the process involves determining the inner weights b_{ji} between the latent variables y_j (the dependent variable) and the independent variable y_i by using the initial latent variable values from this step as a basis. There are three different approaches to calculating the inner weights, which are described in the research [88,90,91]. When there is a positive value for the covariance between y_j and y_i, the values of the inner weights are increased by one. If the covariance between two variables is found to be negative, then the values of the inner weights are changed to -1. The weight is set to 0 whenever there are no correlations between these two variables [89].

The inner weight in the factor weighting algorithm is equal to the covariance between y_j and y_i. If there is no connection between the latent variables, the inner weight is assigned to zero. Lastly, the path-weighting algorithm considers the direction of inner model relationships [88]. The path-weighting algorithm, according to Chin [90], tries to create a component that can be predicted and is also a good predictor for subsequent dependent variables. As a result, the path-weighting algorithm yields a little higher R^2 values for the endogenous latent variables and should therefore be favored. In most cases, however, the selection of the inner weighting scheme has a negligible impact on the results [88,92].

Step #2: The step approximates every latent variable $\widetilde{y}_j$ by utilizing the weighted sum of adjacent latent variable values y_i.

Initialization

Stage 1: Iterative estimate of weights and latent variable values constitutes the first stage.

Starting at step #4, re-Iterate steps #1 through #4, until convergence can be reached.

#1 Internal weights (obtained in this case by making use of the factor weighting technique).

$$v_{ji} = \begin{cases} \text{cov}(y_j, y_i) & if \;\; y_j \;\; \text{and} \;\; y_i \;\; are \;\; adjacent \\ 0 & otherwise \end{cases}$$

#2 Inside approximation

$$\widetilde{y}_j := \sum b_{ji}\, y_i$$

#3 Outer weights; solve for

$\tilde{y}_{jn} = \sum_{k_j} \widetilde{w}_{k_j}\, x_{k_{jn}} + d_{jn}$ in a block for correlation weights (Mode A)

$\chi_{kjn} = \widetilde{w}_{k_j} \tilde{y}_{jn} + e_{k,\mathrm{n}}$ in a block for regression weights (Mode B)

#4 Outside approximation

$$\mathrm{y}_{jn} := \sum_{k_j} \widetilde{w}_{k_j}\, x_{k_1 \mathrm{n}}$$

Stage 2: Estimation of outer weights, outer loadings, and path coefficients

Stage 3: Estimation of location parameters

Figure 3. Basic PLS-SEM algorithm (adapted from Lohmöller [88], p. 29).

Step #3 follows Step #2 to calculate new outer weights for all of the latent variables $\widetilde{y}_j$. These outer weights indicate how strongly these latent variables are related to the corresponding indicators. To achieve this goal, the PLS-SEM algorithm adopts either the correlation weights (Mode A) or the regression weights (Mode B). The outer weights are determined by bivariate correlations between the indicators and the constructs in Mode A. Mode B, on the other hand, regresses each construct on its associated indicator to derive indicator weights. Estimating reflectively defined structures is carried out in Mode A by default, whereas estimating formatively specified constructs is performed in Mode B. Becker et al. [93] demonstrate that this reflexive adoption of the two modes is not the best in every instance. Model estimation utilizing Mode A, for example, results in superior out-of-sample predictions when more than 100 observations are drawn on the construct and the R^2 of the endogenous construct is at least 0.30 [89].

The formal descriptions of both modes are shown in Figure 3. In this context, the initial values for indicators $(k = 1, \ldots, K)$ of latent variable $j(j = 1, \ldots J)$ and observations $n(n = 1, \ldots, N)$ are denoted by the symbol $x_{k_j n}$. $\widetilde{y}_{j_n}$ is the notation for the values of the latent variable that were generated from the inside approximation in Step #2, and $\widetilde{w}_{k_j}$ is the notation for the outer weights that were produced from Step #3. The error term is denoted by the letter d_{j_n} in a bivariate regression. The error term from a multiple regression is denoted by the symbol $e_{k_{j_n}}$. In the fourth step, the updated weights from the third step (i.e., $\widetilde{w}_{k_j}$ and the indicators (i.e., $x_{k_{j_n}}$) are linearly combined with the intent to update the values of the latent variable (i.e., y_{j_n}). It is important to remember that the PLS-SEM algorithm accepts as input only standardized data and always standardizes the ratings of the latent variables that result from applying the algorithm in Steps 2 and 4.

Following Step #4, the next iteration commences; the algorithm ceases if the weights calculated in Step #3 alter slightly from iteration to iteration, with variations among iterations lesser than 1×10^{-7}, or if a maximum number of iterations (typically 300, according to Henseler [94]) is reached [89].

The final values for the latent variables that were calculated in Stage 1 are used as input for numerous rounds of ordinary least squares regressions in the following Stages 2 and 3. These regressions provide the final outer loadings, outer weights, and path coefficients, along with the addition of other associated elements including indirect and total effects, R^2 values of the endogenous latent variables, and indicator and latent variable correlations [88,89]. Figure 4 outlines the flowchart of the analytic process based on the PLS-SEM method.

Definition of Initial Research Questionnaires → Specificaiton of Measurement Model → Sample and Measurement → Assessment of Measurement Model → Assessment of Structural Model

Figure 4. Research flowchart (adapted from [95]).

The PLS-SEM method considers reflective and formative indicators, the reliability and validity of the methods, multi-group and supplementary analyses, and measurement errors. Also, PLS-SEM integrates principal component analysis (PCA) with regression-based path analysis to estimate the parameters of a set of equations in SEM [96], which is a multivariate analytical method used to analyze complex relationships between constructs and indicators. SEM examines the effects of multiple variables on responses of interest across various dimensions and variables [97]. Both PLS-SEM and covariance-based SEM (CB-SEM) are widely accepted methods for estimating structural equation models. As per Hair Jr. et al. [97], the PLS-SEM and CB-SEM methodologies use distinct approaches to evaluate the quality of an SEM. When the research objective is to test and confirm theories and researchers are unable to correctly identify a research model, CB-SEM is the appropriate method. Conversely, if the objective is to develop theories and make predictions, PLS-SEM is the more suitable method [98]. To be more explicit, the researchers ought to opt for CB-SEM if their major objective is to determine the parameters of a factor-based model. On the other hand, PLS-SEM is the method that should be utilized if the primary purpose is to estimate a model that is based on composites [99].

3.3. Sample and Measures

This study surveyed the opinions of managers and employees from the top three smartphone EMS providers in Taiwan. Before agreeing to participate, respondent consent was obtained to ensure that they are aware of the study's objectives, procedures, risks, and benefits. The findings are utilized in an investigation into the links that exist between the variables as a result of the measurement items. According to the results collected by web-based questionnaires, the appropriateness of obtaining the identified constructs is utilized in subsequent analyses. The questionnaire was developed based on the research hypotheses proposed in Section 2.8.

Accordingly, this study utilized a five-point Likert scale based on previous research by Chen, Yu, and Yu [100] and Weijters, Cabooter, and Schillewaert [101]. These studies demonstrated that a five-point scale is widely recognized and familiar to respondents, and it has been found to be effective. Moreover, the studies indicated that using a five-point scale results in the shortest reaction time, suggesting that it imposes a less cognitive burden on respondents compared to scales with a greater number of response options. Therefore, considering the benefits associated with the use of a five-point scale, such as its familiarity and reduced cognitive effort, it was deemed suitable for implementation in this study.

The dataset collected was used to confirm the research model (refer to Figure 2). Then, the PLS-SEM method was adopted to confirm the correlation between the variables. An online questionnaire was developed via Google Forms. The possible measurement items were obtained and modified from relevant previous research cited in the context of this research. The modified Delphi method was used to confirm all measurement items (refer to Table 2) based on the opinions provided by experts (refer to Table 3).

Table 2. RoHS adoption questionnaire.

Latent Variable	Item Code	Descriptions	Source
Costs	ca_1	The adoption of RoHS improved manufacturing efficiency	Revised from George, Harris, and Mitchell [102], Martens and Teuteberg [103]
	ca_2	The adoption of RoHS increased profits	
	ca_3	RoHS can increase financial performance	
	ca_4	Returning costs has been reduced since the firm adopted the RoHS	
	ca_5	Marketing, customer-related service time, and costs have been reduced after the firm adopted the RoHS	
Complexity	cc_1	Employees' learning about new RoHS regulations is not complicated	Revised from Stacey [104], Teisman [105]
	cc_2	Upgrading existing systems to comply with new RoHS regulations is easy and not difficult	
	cc_3	Maintaining RoHS systems is not complicated	
	cc_4	In the development of a new product, compliance with RoHS regulations was deemed simple to handle	
	cc_5	Introducing RoHS regulations into the supply chain is not complicated	

Table 2. *Cont.*

Latent Variable	Item Code	Descriptions	Source
Compatibility	co_1	The supply chain system is compatible with RoHS	Revised from Giachetti [106], Stacey [104]
	co_2	The current facilities of the software system can be phased into the RoHS requirement	
	co_3	The current quality management system is compatible with the RoHS standard	
	co_4	The conversion process, including establishing a design and tracking system, is followed with RoHS requirements	
	co_5	Our employees are familiar with RoHS regulations	
System Integration	si_1	Supply chain systems can be adapted to the new RoHS regulations	Revised from Paez et al. [55], Stacey [104], Teisman [105]
	si_2	The current firm's operating systems (e.g., PLM, ERP, and shop flow) can be adapted to meet RoHS requirements	
	si_3	The current quality management system (e.g., ISO, Eco-Management and Audit Scheme (EMAS)) is adapted to the new RoHS directive	
	si_4	The ERP system contains our database for tracking RoHS requirements	
	si_5	Our employees are familiar with the firm's system, which is frequently updated with the latest RoHS regulations, and know how to comply with them	
Relative Advantage	ra_1	The adoption of RoHS will substantially increase the business opportunities of our firm	Revised from Giachetti [106], Stacey [104], Lee, Shiue, and Chen [107]
	ra_2	After the firm adopted RoHS, our firm's relationship with the customer improved	
	ra_3	After the firm adopted RoHS, our firm's customer service quality improved	
	ra_4	The core competitiveness of the firm was increased after it adopted RoHS	
	ra_5	The management capability of the supply chain was improved after the firm adopted RoHS	
	ra_6	The firm's image was enhanced after adopting the RoHS	

Table 2. *Cont.*

Latent Variable	Item Code	Descriptions	Source
Adequate Resource	ar_1	In order to promote the RoHS program, management pays adequate attention to dealing with supply chain management	Revised from Bon et al. [108], Boxall and Purcell [109]
	ar_2	In order to promote the RoHS program, management gave an adequate implementation time frame to deal with supply chain management	
	ar_3	In order to promote the RoHS program, management allocated an adequate budget to deal with supply chain management	
	ar_4	In order to promote the RoHS program, management dispatched an adequate team to assist with supply chain management	
	ar_5	To promote the RoHS program, management provided an adequate encouraged and reward for excellent supply chain management	
Institutional Pressure	ip_1	The government asked us for RoHS compliance	Revised from Thong et al. [110], Lee et al. [107]
	ip_2	The government requested us to provide the RoHS tracking records	
	ip_3	The government asked us to follow the most updated RoHS standard	
	ip_4	The government informed us that we have to assist with the supply chain to follow RoHS	
	ip_5	Our firm and supply chain have been audited by government experts	
	Ip_6	In the event that the RoHS certification is not obtained, the government will take enforcement actions	
Perceived Industry Pressure	pi_1	Our major customers believe that our operation should comply with the RoHS directive	Revised from Thong et al. [110], Lee et al. [107]
	pi_2	Our customers treat us as the most competitive firm in the industry since we took a lead in RoHS adoption	
	pi_3	Our major suppliers believe that they should comply with the RoHS directive	
	pi_4	Our suppliers of key components comply with the RoHS directive	
	pi_5	Our major competitors have benefited after they adopted the RoHS	

Table 2. *Cont.*

Latent Variable	Item Code	Descriptions	Source
Expert Resource	er_1	To recruit and select RoHS experts, we formulate proactive recruiting and operating procedures (e.g., system engineering, IT)	Revised from Bon et al. [108], Boxall and Purcell [109], Lado et al. [111]
	er_2	We conduct regular RoHS-related training for all employees	
	er_3	Our suppliers formulated a proactive human resource plan for recruiting and selecting RoHS experts (e.g., system engineering, IT)	
	er_4	Our major competitors formulated a proactive human resource plan for recruiting and selecting RoHS experts (e.g., system engineering, IT)	
	er_5	Our customers formulated a proactive human resource plan for recruiting and selecting RoHS experts (e.g., system engineering, IT)	
Verification Ability	va_1	Internal inspections of RoHS-related work will be conducted irregularly	Revised from Takala, Bhufhai, and Phusavat [112]
	va_2	We provide regular reports on the management of various indicators of RoHS implementation	
	va_3	Our company has formed an audit team to examine the RoHS process	
	va_4	In the company, we use the sampling inspection of raw materials to make sure our products comply with RoHS regulations	
	va_5	Our company or organization sends personnel to important raw material suppliers to conduct RoHS inspections	
Innovation	in_1	Companies or organizations regularly review and improve the RoHS system and reward innovation	Revised from Deif [18], Gupta, Tesluk, and Taylor [113] and Goodland [114]
	in_2	As part of our commitment to RoHS, we send workers to participate in organizations relevant to the issue and transfer effective solutions from other factories	
	in_3	I think universities, the government, and the industry should set up a group to brainstorm RoHS-related policy innovations	
	in_4	RoHS experts from an outside organization are often invited to analyze and improve our company's system	
	in_5	Our company provides an incentive program to the supply chain for the innovation of RoHS	

Source: Adapted from [7].

Table 3. Background of experts.

Type of Firm/Department	Title	Experience (Year)
1. EMS/Procurement	Manager	19
2. Semiconductor/Sales	Director	23
3. EMS/Quality Assurance	Director	20
4. EMS/Production	Senior Vice President	27
5. University/Industrial Management	Professor	18
6. EMS/Logistic	Manager	15
7. EMS/IT	Manager	17
8. EMS/Project Management	Associate Vice President	21
9. EMS/Sales	Vice President	24

A total of 61 items and 11 constructs were constructed based on the five-point Likert-type scale, where a score of 5 indicates "completely agree" and a score of 1 indicates "completely disagree." The data were collected over a three-month period from November 2020 to January 2021. A total of 473 questionnaires were sent. In the first run, only 379 responses were returned. By considering early and late responses, this study has followed Armstrong and Overton's recommendation [115] to test the non-response bias using the *t*-test. For SEM, combining the early 329 responses with the late 50 responses would provide more data in the survey dataset to enable a more detailed analysis of the data. Also, an increased sample size can enhance the statistical power of an analysis and allow for more accurate estimations of potential effects or relationships. At the 5% significance level, the examination of the data revealed that there was no discernible distinction between the early and the late responses.

The profile of the respondents is presented in Table 4. According to the statistics, 92% of the respondents were male and the remaining 8% were female, due to the manufacturing sector in Taiwan still largely being dominated by men. Most of the respondents were between the ages of 30 and 50 (70.5%). Among the respondents, 8.9% were managers, while 24.1%, 14.1%, 10.6%, and 10.2% were from engineering, production, procurement, and IT departments, respectively. The majority (61.8%) of the respondents had 5 to 10 years of work experience, while 13% of the respondents were senior staff with more than 15 years of work experience. The reasons for the uneven distribution of respondents are discussed in Section 4.6.5.

3.4. Data Analysis

The data analysis in this investigation utilized the PLS-SEM technique, employing SmartPLS 3.2.8 [116] and SPSS 22 [117] software. PLS-SEM was selected as the primary analysis method for several reasons. Firstly, with 11 variables and 11 paths in the model, PLS-SEM was capable of accommodating a complex interaction involving multiple indicator variables and paths. Additionally, the assumptions regarding data distribution were not affected by this method. To establish causal relationships, a predictive strategy for model estimation was employed in this study. PLS-SEM was chosen because it addresses the dichotomy between prior associated ideas, information, and prediction, making it suitable for developing a solid theoretical foundation [118]. Moreover, PLS-SEM exhibits greater statistical power compared to other methods such as CB-SEM and simple regression, even for predicting common factor model data. This statistical power enabled the identification of correlations between constructs or variables when they exist in the population, making PLS-SEM particularly valuable for exploratory research examining fewer common ideas.

Furthermore, the software used for analysis, SmartPLS 3.2.8 [116], is known for its user-friendly interface and accessibility. It combines state-of-the-art latent variable modeling techniques and advanced bootstrapping processes [118]. SmartPLS 3.2.8 [116] aimed to predict a specific set of hypothesized associations that optimize the explained variance in the dependent variables. PLS-SEM is especially suitable for testing model relationships and complex path modeling [118].

Table 4. Profile of respondents.

Profile Category	Frequency	Percentage (%)
Gender		
Female	30	7.915%
Male	349	92.085%
Age (years)		
<30	58	15.303%
30–40	170	44.855%
40–50	97	25.594%
>50	54	14.248%
Education		
Bachelor	202	52.299%
Master	173	46.646%
Ph.D.	4	1.055%
Experience		
5 years or less	92	24.275%
10 years or less	234	61.742%
15 years or less	44	11.609%
20 years or less	5	1.319%
Over 20 years	4	1.055%
Department		
Procurement	40	10.554%
Purchasing	33	8.707%
Quality Assurance	34	8.971%
Engineering	91	24.011%
Production	53	13.984%
Logistics (In/Outbound)	33	8.707%
Finance and Sales	22	5.805%
IT	39	10.290%
Management	34	8.971%

The analytical steps in the PLS-SEM analysis were performed following the guidelines provided by Hair et al. [97]. The evaluation process included assessing convergent and discriminant validities, with measurements such as item loadings, Cronbach's alpha, composite reliability, and Average Variance Extracted (AVE) used for convergent validity analysis. For discriminant validity, the Fornell–Larcker criterion and heterotrait–monotrait (HTMT) values were examined. Multicollinearity was evaluated using the variance inflation factor (VIF) value [118]. Following the reliability and validity tests, the analysis proceeded to the structural model and hypothesis evaluation through bootstrapping techniques. This process enabled the assessment of the relationships between variables and the confirmation or rejection of the initial hypotheses.

4. Results

This research adopts a two-step approach proposed by McKinney, Yoon, and Zahedi [119] for confirming the TOE-HOT fit framework, with the empirical results derived from using the PLS-SEM. A measurement model is tested first in order to determine whether the constructs (theoretical concepts) correlate with their indicators, i.e., observable variables. Then, the structural model containing the hypothesized relationship between the antecedent constructs of the theoretical model was calculated. The measurement scale was ensured to prove that the dataset was valid and reliable before the assumptions contained in the PLS-SEM model were concluded. Lastly, the measurement tool used SmartPLS 3.2.8 [116] and SPSS 22 [117] software to analyze the data and test the moderator effect for this study's data analysis.

4.1. Data Normality Analysis

Before proceeding to the measurement model, it is essential to assess the normality of the data by examining the kurtosis and skewness values of each item, as shown in Table 5. According to the established criteria [120], all of the item variables utilized in our study exhibited kurtosis values ranging from −0.737 to 0.982, and skewness values ranging from −0.102 to 1.096. These values were all below the threshold of 2.2, indicating that the variables demonstrated a normal distribution. Thus, we can infer that the data collected for all of the variables in our study followed a normal distribution pattern [118]. Based on Table 5, the majority of the 61 variables deviated significantly from normality. The PLS-SEM is an appropriate research method for this study because of its non-normal distributional characteristics [121].

4.2. Measurement Model

The Kolmogorov–Smirnov (KS) test [122] was used to measure every variable to determine the normality of the distribution. Skewness indicates how skewed the distribution of responses to a variable is [123]. If the responses are skewed to one extreme or another, that distribution is regarded as skewed. Kurtosis describes how much the distribution peaks (see Table 5). According to the test results from SmartPLS 3.2.8 [116], all 61 items in this study deviated from normality based on result of the KS test (see Table 5), indicating that the PLS-SEM is an adequate analytic method for this study.

After that, the 10-times rule is used to determine the minimum sample size. In other words, the sample size should be 10 times the maximum number of latent variables in any model [99]. For the PLS path model to be estimated, the minimum number of observations was 110 (11 × 10). Accordingly, the 379 valid responses received in this study were sufficient based on the 10-times rule mentioned above.

For the assessment of the reliability and validity of the structural model, a procedure was defined as following convergent validity measurement as a redundancy analysis to verify each single-item construct of the conceptual model, the factor loading should be analytically significant and higher than 0.700 [90]. Through this, we found that the convergent validity of each item exceeds 0.700 (see Table A1). This can be explained further with robustness checks, where loadings of all indicators belonging to the structural model are higher than 0.707. That is, more than 50% of the indicators' variances should result from the latent variable [85].

According to Bagozzi and Yi [124], the acceptable reliability of the constructs can be confirmed by measuring Cronbach's alpha, Dijkstra–Henseler's rho coefficients, and composite reliability (CR) [93] to prove the consistency reliability. In this research, we tested the individual item reliability of the measurement model [125] (refer to the analysis result in Table A1). The Cronbach's alpha, Dijkstra-Henseler's rho coefficients, and CR values were 0.819, 0.845, and 0.870, respectively, where a composite reliability value greater than 0.700 confirms that a research model has a high level of reliability.

Reflective measurement models assess each construct measure's convergent validity. Convergent validity is how much the construct explains the variance of its items. Our AVE values ranged from 0.576 to 0.886, all of which were higher than the threshold of 0.500 for AVE for convergent validity set by Bagozzi and Yi [124].

Table 5. Skewness, kurtosis, and normality test results.

Variable	Mean	Mdn	Min	Max	SD	Excess Kurtosis	Skewness	Variable	Mean	Mdn	Min	Max	SD	Excess Kurtosis	Skewness
ar_1	2.201	2	1	5	0.631	0.531	0.184	ip_1	2.087	2	1	5	0.806	0.822	0.569
ar_2	2.137	2	1	5	0.516	0.155	0.039	ip_2	2.087	2	1	5	0.841	0.339	0.475
ar_3	2.206	2	1	5	0.633	0.513	0.18	ip_3	2.087	2	1	5	0.819	0.633	0.532
ar_4	2.124	2	1	5	0.506	0.172	0.041	ip_4	2.071	2	1	5	0.879	−0.059	0.422
ar_5	2.164	2	1	5	0.59	0.77	0.227	ip_5	2.09	2	1	5	0.842	0.317	0.467
ca_1	2.245	2	1	5	0.554	0.345	0.134	ip_6	2.077	2	1	5	0.906	−0.243	0.405
ca_2	2.288	2	1	5	0.649	0.568	0.202	pi_1	2.269	2	1	5	0.8	−0.359	−0.027
ca_3	2.269	2	1	5	0.587	0.293	0.135	pi_2	2.224	2	1	4	0.697	−0.321	0.039
ca_4	2.293	2	1	5	0.596	0.326	0.145	pi_3	2.288	2	1	5	0.747	0.15	0.161
ca_5	2.256	2	1	5	0.586	0.434	0.146	pi_4	2.274	2	1	5	0.7	0.723	0.398
cc_1	2.272	2	1	5	0.619	0.246	0.122	p_{i5}	2.272	2	1	4	0.714	−0.502	−0.102
cc_2	2.293	2	1	5	0.622	0.435	0.182	ra_1	2.074	2	1	5	0.741	0.28	0.113
cc_3	2.285	2	1	5	0.597	0.414	0.166	ra_2	1.913	2	1	5	0.86	0.225	0.119
cc_4	2.251	2	1	5	0.615	0.233	0.102	ra_3	1.918	2	1	5	0.908	0.133	0.103
cc_5	2.272	2	1	5	0.57	0.234	0.131	ra_4	1.902	2	1	5	0.874	0.202	0.117
co_1	2.198	2	1	4	0.519	0.271	0.135	ra_5	1.908	2	1	5	0.921	0.116	0.102
co_2	2.201	2	1	4	0.526	0.301	0.149	si_1	2.098	2	1	5	0.354	0.194	0.039
co_3	2.219	2	1	5	0.601	0.641	0.221	si_2	2.074	2	1	5	0.411	0.196	0.035
co_4	2.172	2	1	4	0.498	0.278	0.122	si_3	2.084	2	2	5	0.382	0.28	0.051
co_5	2.243	2	1	5	0.603	0.357	0.165	si_4	2.047	2	1	5	0.485	0.104	0.019
er_1	2.222	2	1	5	0.725	0.222	0.084	si_5	2.058	2	1	4	0.336	0.187	0.035
er_2	2.198	2	1	5	0.662	0.416	0.135	$aord_1$	2.467	2	1	5	0.887	0.169	0.464
er_3	2.116	2	1	5	0.826	0.416	0.513	$aord_2$	2.443	2	1	5	0.649	1.051	0.532
er_4	2.172	2	1	5	0.681	0.219	0.088	$aord_3$	2.412	3	1	5	1.037	−0.737	0.024
er_5	2.187	2	1	5	0.74	0.982	0.547	$aord_4$	2.454	2	1	5	0.969	−0.318	0.419
in_1	2.148	2	1	5	1.386	−0.12	1.066	$aprd_5$	2.446	2	1	5	0.901	0.111	0.456
in_2	2.092	2	1	5	1.009	0.506	0.82	va_1	2.765	3	1	5	0.755	0.264	0.678
in_3	2.011	2	1	5	1.237	0.203	1.005	va_2	2.768	3	2	5	0.761	0.089	0.743
in_4	2.148	2	1	5	1.111	0.261	0.888	va_3	2.734	3	1	5	0.822	−0.182	0.758
in_5	1.971	2	1	5	1.231	0.406	1.096	va_4	2.763	3	1	5	0.79	−0.131	0.707
								va_5	2.657	2	1	5	0.824	0.032	0.966

Remark: Mdn means median; SD means standard deviation.

Discriminant validity can be assessed using a two-pronged approach, namely the Fornell–Larcker criterion, and the HTMT ratio of correlations [126]. Fornell and Larcker [126] devised a method to ascertain the reliability of individual items based on the construct reliability, convergent validity, and discriminant validity of the measurement model. To assess discriminant validity, the AVE of a latent variable is compared to the squared correlations between that latent variable and other latent variables in the model. Discriminant validity is achieved if the AVE is greater than the squared correlation between that variable and another variable in the model. All variables in this study satisfied the Fornell–Larcker criterion, as evidenced by the square root of each AVE being higher than the correlations between the other latent variables [127] (see Table A2), which demonstrates adequate discriminant validity for all constructs. Convergent validity was evaluated using AVE, which measures the extent to which a construct gains variance from its items relative to the variance caused by measurement error. The AVE values ranged from 0.568 to 0.886, which exceeded the recommended threshold of 0.500 proposed by Bagozzi and Yi [124] and indicated good convergent validity and reliability [121]. Discriminant validity problems are present when HTMT values exceed 0.900 [128]. Thus, the study did not encounter any discriminant validity issues in the results (please refer to Table A4).

The measurement model is used to assess the reliability and validity of the measures used in the study, while the structural model is used to test the hypotheses between the relationships of each construct. The results of analyzing the structural model are demonstrated in Figure 4 and Table 6, where the path coefficients (refer to Table 6) were derived. The bootstrap resampling method to 5000 subsamples was adopted. The robust statistical approach was taken to test the hypotheses and ensure the validity of the results. Meanwhile, the hypothesis testing results are based on the *p*-values (see Table 6). The hypothesis testing results represent the strength and direction of the relationships as well as the statistical significance of the model.

Table 6. Significant testing results of the structural model path coefficients.

Hypothesis	Sample Mean (M)	Std. Dev. (STDEV)	Path Coeff. (β)	*t* Statistics	*p* Values	f^2	VIF	Total Effects
H_1 (CA→AORD)	0.095	0.044	0.096	2.196	0.028	0.035	1.543	0.096
H_2 (CC→AORD)	0.010	0.048	0.008	0.175	0.861	0.021	1.853	0.008
H_3 (CO→AORD)	0.083	0.044	0.083	1.868	0.062	0.031	1.452	0.083
H_4 (SI→AORD)	−0.041	0.045	−0.047	1.043	0.297	0.023	1.682	−0.047
H_5 (RA→AORD)	−0.157	0.055	−0.155	2.831	0.005	0.044	2.201	−0.155
H_6 (AR→AORD)	0.297	0.074	0.304	4.119	0.000	0.092	2.781	0.304
H_7 (INP→AORD)	0.097	0.043	0.100	2.324	0.020	0.036	1.372	0.100
H_8 (PIP→AORD)	0.129	0.040	0.128	3.164	0.002	0.049	1.215	0.128
H_9 (ER→AORD)	0.195	0.045	0.195	4.368	0.000	0.066	1.781	0.195
H_{10} (VA→AORD)	−0.081	0.041	−0.081	1.995	0.046	0.031	1.252	−0.081
H_{11} (IN→AORD)	−0.380	0.045	−0.379	8.347	0.000	0.230	1.473	−0.379

Remark: R^2 = 0.537, SRMR = 0.072, Q^2 = 0.317.

Further, we evaluated the formative collinearity indicators, which were determined by a variance inflation factor (VIF) evaluating every set of predictors for possible collinearity.

The empirical results indicated that the VIF values corresponding to each hypothesis are H_1 (1.543), H_2 (1.853), H_3 (1.452), H_4 (1.682), H_5 (2.201), H_6 (2.781), H_7 (1.372), H_8 (1.215), H_9 (1.781), H_{10} (1.252), and H_{11} (1.473). Because all of the VIF values are lower than 3 (refer to Table 6), as recommended by Hair et al. [83], there were no collinearity issues among the indicators.

To assess statistical significance and relevance, the nonparametric method of PLS-SEM is widely adopted. SmartPLS 3.2.8 [116] was used to deal with the collected data. The following sections present the descriptive statistics analysis as well as the assessment of measurement and structural models, respectively.

4.3. Structural Model

In the process of evaluating the PLS-SEM results, the structural model is evaluated after the measurement model has been assessed successfully. The structural model can be justified through the reliability test for the measurement model. The PLS-SEM is a non-parametric method; thus, bootstrapping is used to determine statistical significance. The indicator weights were checked by 5000 subsamples. The significance levels of the path coefficients summarized by the primary result of each indicator are presented in Table 6 and Figure 5. This study's hypothesis testing results are inspected by the *p*-values in the evidence against the empirical study's null hypotheses (see Table 6). Becker et al. [129] described the VIF that is used for evaluating this. Because the results did not exceed 3, nonlinear relationships were avoided. Therefore, there is no collinearity issue among the indicators of the constructs. These results are presented in Table 6. In addition, the analysis of variance (ANOVA) test was employed to analyze the gender and age disparities [118] (see Tables 8 and 9).

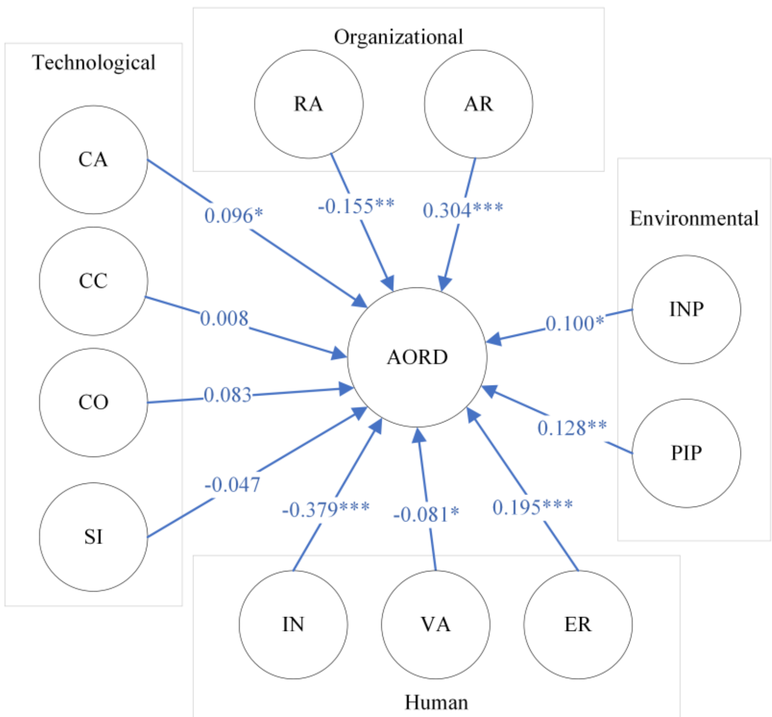

Figure 5. Path analysis results. (Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$).

4.3.1. Collinearity

To assess the collinearity between the latent variables, the variance inflation factor (VIF) was utilized. A higher VIF value indicates a higher level of collinearity. Specifically, if the VIF value exceeds 5.00, it indicates the presence of a collinearity issue between the variables in the structural model. A further recommendation by Kock [130] is to examine common method bias using the collinearity statistics' inner VIFs in the PLS model, and

Kock suggested a value less than 3.3 for each construct in order to examine common method bias. As shown in Table 6, none of the inner VIFs for any of the constructs were greater than 3.3, indicating that the study was free from common method bias.

4.3.2. Coefficient of Determination (R^2)

The coefficient of determination (R^2) is a widely used measure for assessing the predictive power of a structural model in terms of the relationships between dependent and independent variables [99]. According to Chin [90], as well as Becker, Rai, and Rigdon [93], the R^2 is a measure of the model's explanatory power since it is a measurement of the variance that is explained by each of the model's endogenous factors. Ranging from 0 to 1, a higher R^2 value indicates greater accuracy in predicting relationships within the study model. According to Figure 5 and Table 6, the R^2 value of this research result is 0.537, which means moderate explanatory power, as suggested by Hair et al. [131].

4.3.3. Predictive Relevance (Q^2)

Stone–Geisser's Q^2 indicator, which is the discrepancy between the expected and observed values of the endogenous constructs [121], was utilized to assess the quality of the evaluation criteria based on the cross-validated predictive relevance of the model. An increase in Q^2 over zero indicates that the model is predictive, whereas a decrease in Q^2 indicates a poor predictive power [121]. Additionally, predictive relevance is categorized as small, medium, and large when below 0.02, equal to 0.15, and above 0.35, respectively. Table 6 presents the Q^2 values for the five endogenous variables, all of which were equal to or greater than 0.317. In addition, the model fit was assessed based on standardized root mean square residuals (SRMR) as a means to measure the discrepancy between the correlation that was observed and the estimated correlation matrix by the model. This was carried out in order to determine how well the model represented the data. In this work, Stone–Geisser's Q^2 is 0.317, while the SRMR is 0.072. Thus, the model is predictive. Meanwhile, SRMR values in the range of 0.05 to 0.08 indicate a fair fit, or that the model captures the data well [132,133].

4.3.4. Effect Size (f^2)

To assess the structural model, an analysis of the f^2 value is crucial. This metric measures the influence of exogenous variables on endogenous variables and aids in determining how the omission of specific exogenous determinants impacts the R^2 value. f^2 values falling below 0.15, between 0.15 and 0.35, and above 0.35 are categorized as indicating small, medium, and large effects, respectively [118]. The results, as depicted in Table 6, highlight that the adoption of RoHS demonstrates the highest f^2 value for EMS providers.

4.4. Hypothesis Testing Results

In light of the findings presented in Table 6, we applied the PLS-SEM [99] to the test in order to confirm the 11 hypotheses outlined in Figure 2. The correlations between the independent variables and the majority of the dependent variables were significant for AORD, except H_2 (CC), H_3 (CO), and H_4 (SI) (see Table 7).

For the hypothesis testing results, examining H_1 showed that CA had a significant effect on AORD (β = 0.096, p = 0.028, $p < 0.05$). Examining H_2 showed that CC had a non-significant result for an effect on AORD (β = −0.008, p = −0.861, $p > 0.05$). Examining H_3 showed that CO had a marginally significant effect on AORD (β = −0.083, p = −0.062, $p > 0.05$). Examining H_4 showed that SI had a non-significant effect on AORD (β = −0.047, p = −0.297, $p > 0.05$). Under the organizational dimension, examining H_5 showed that RA had a significant effect on AORD (β = −0.155, p = 0.005, $p < 0.05$). Examining H_6 showed AR had a positive relationship with the AORD (β = 0.304, p = 0.000, $p < 0.001$). Under the environmental dimension, examining H_7 showed that INP had a positive relationship with AORD (β = 0.100, p = 0.020, $p < 0.05$). Examining H_8 showed that PIP had a positive relationship with AORD (β = 0.128, p = 0.002, $p < 0.05$). Under the human dimension, examining H_9 showed that ER had a negative relationship with AORD ($\beta = -0.195$, $p = 0.000$, $p < 0.001$). Examining H_{10} showed that VA had a negative relationship with AORD ($\beta = -0.081$, $p = 0.046$, $p < 0.05$). Examining H_{11} showed that IN ($\beta = -0.379$, $p = 0.000$, $p < 0.001$) had a negative relationship with AORD. The analytic results are summarized in Table 6. The PLS-SEM results rejected H_2, H_3, and H_4 and supported the other hypotheses: H_1, H_5, H_6, H_7, H_8, H_9, H_{10}, H_{11}.

Table 7. Hypothesis testing results.

Hypotheses	Results
H_1 (CA→AORD)	Supported
H_2 (CC→AORD)	Not Supported
H_3 (CO→AORD)	Not Supported
H_4 (SI→AORD)	Not Supported
H_5 (RA→AORD)	Supported
H_6 (AR→AORD)	Supported
H_7 (INP→AORD)	Supported
H_8 (PIP→AORD)	Supported
H_9 (ER→AORD)	Supported
H_{10} (VA→AORD)	Supported
H_{11} (IN→AORD)	Supported

4.5. Common Method Variance Test

Podsakoff et al. [134] introduced common method variance (CMV) during the 1980s, highlighting that method biases can significantly affect the reliability, validity, and covariation among latent constructs. In social science research, Podsakoff et al. [134] suggested that common measurement methods such as self-reported surveys may be a potential source of bias, which can result in spurious relationships among variables. In addition, CMV can be minimized by a variety of strategies, such as using multiple methods to measure constructs, using multiple sources to collect data, and using statistical techniques, such as partialing out to eliminate the effects of CMV.

Harman's single-factor test is a different technique that can be used to identify CMV [130]. In the single-factor test method developed by Harman, the PCA is applied to a group of test data, and then it is determined whether the first principal component (PC), which refers to the very first factor or component, is considerably larger than any of the remaining components. Using SmartPLS 3.2.8 [99], the test result for CMV was 21.41%, which means that the cumulative variance among measures did not exceed the 50% threshold [135] for common method bias.

4.6. Discussion

In this study, an empirical case is presented to validate the factors that influence the adoption of RoHS by EMS providers. The research results are crucial to protecting the environment, maintaining company competitiveness, and creating competitive advantage for future businesses. In the following subsections, we will discuss the theoretical and practical implications, moderating effects of gender and age, connection with the three pillars of sustainability, and the research limitations and future research possibilities.

4.6.1. Theoretical Implications

The RoHS directive has been implemented in many countries to restrict hazardous substances in EEE. EMS providers play a crucial role in EEE production and assembly. RoHS practices are essential for their products' compliance, safety, and environmental sustainability. Furthermore, it was determined that RoHS practices can help EMS providers reduce their risks and increase their competitive advantage. This section discusses the theoretical implications for EMS providers to adopt RoHS practices based on an empirical study analysis.

Most Related Aspects of RoHS Adoption by EMS Providers

According to the analytic results, the most correlated determinant in the human dimension is innovation (IN). The result is consistent with earlier works by [73,74]. Research conducted by Gupta and Baura [73] elucidates a host of internal challenges faced by manufacturing organizations when they decide to incorporate green innovation. These hurdles range from resource scarcity to financial and personnel restrictions. Ullah and colleagues [74] further substantiate these findings by identifying a shortfall in human resources as a significant barrier to adopting green innovation. This deficit could potentially deter companies from embracing novel practices for meeting regulatory requirements due to extended and expensive payback periods, coupled with anxieties about financial resource allocation.

Adequate resources (AR), an organizational dimension, is the second most correlated determinant, with a correlation coefficient between adequate resources and a firm's adoption of RoHS (AORD) of 0.304 (see Figure 4). In order to adopt RoHS, a firm should consider whether it has the adequate resources to do so. The findings are in line with the findings of Cooper and Slagmuder [39], who proposed that the availability of sufficient resources has a substantial impact on the decisions that a firm makes regarding innovation, investment, and business strategy.

Discussion of Non-Significant Hypotheses

According to the findings of this investigation, the following hypotheses should not be taken seriously as potential explanations. It is also discussed whether the results make sense and whether they are consistent with the findings of past research studies.

Perspective of H_2 (CC$\rightarrow$AORD)

According to the findings of the empirical analysis, the assumption of a positive correlation between complexity (CC) and the adoption of RoHS (H_2) was not supported. The results contradict those of Stacey et al. [136], who argued that complexity positively influenced the adoption of new organizational processes and systems. Their results might be explained by the fact that most of their respondents were staff who served in the business and engineering departments (refer to Table 4). The most difficult aspect of RoHS compliance is finding compatible components of suitable cost, quality, and delivery time. Engineering and business staff are usually responsible for meeting these customer demands and may regard the complexity to be positively correlated with RoHS adoption.

Perspective of H_3 (CO$\rightarrow$AORD)

Based on the analytic results, the third hypothesis (H_3), where compatibility (CO) is positively correlated with the adoption of RoHS, is not significant. According to Yu, Welford, and Hills [137], the declaration of RoHS compliance in terms of raw materials was identified as one of the most significant challenges. Most of the verification and tests of RoHS compliance require supporting documentation and reports to verify full RoHS compliance. In addition to this, because there are only a small number of certification organizations available, and regulators for EMS factories located in the countries that are still developing, such as China, Brazil, and India, the cost for RoHS compliance testing is extremely high [138]. Some confusions may also arise due to insufficient information or ambiguous interpretation of the RoHS regulations by these certification organizations and regulators because they are often confused by the requirements and exemptions [139]. Therefore, the insignificance of the hypothesis is reasonable.

Perspective of H_4 (SI$\rightarrow$AORD)

This study does not support the hypothesis that system integration (SI) and RoHS adoption are positively correlated. The products that EMS providers manufacture include electronic components from thousands of suppliers. Within the supply chain, plenty of bills of materials (BOMs), material composition declarations (MCDs), compliance declarations, and other types of documentation are created on an ongoing basis. The implementation of an SI solution can be costly [103], especially for EMS firms whose complex processes include the upstream and downstream systems consideration. The cost of purchasing hardware and software and hiring experts to implement the system can be a significant barrier for the EMS industry [11]. The integration of different systems can be a complex process, especially if the systems are not designed to work in conjunction with one another [140]. To overcome the barriers of SI, EMS firms should carefully evaluate the need for SI, establish clear goals, and work with experienced partners or SI consultants to assist with the implementation of the SI solution [141].

4.6.2. Discussion of Significant Hypotheses Supported by the Empirical Study Results

According to the findings of the empirical research, the following hypotheses were shown to be significant. Whether or not the findings make sense and whether or not they are consistent with findings from other research investigations is also examined.

Perspective of H_1 (CA→AORD)

The findings of the study support H_1, which identifies that cost (CA) has a significant effect on an EMS's adoption of RoHS. Our findings are consistent with those of Koh, Gunasekaran, and Tseng [142] and Hu and Hsu [143]. This finding is also in agreement with the findings presented by Wang et al. [144] in that cost, from the perspective of the EMS provider, has both theoretical and managerial implications for a firm and its green supply chain management.

Perspective of H_5 (RA→AORD)

The findings of the study demonstrate that there is a negative correlation between relative advantage (RA) and AORD (H_5). The correlation between relative advantage (RA) and the implementation of RoHS is a convoluted one that is highly context dependent. The result is consistent with the findings of Harrington and Ruppel [145] as well as Kremkumar, Ramamurthy, and Nilakanta [146].

Perspective of H_6 (AR→AORD)

Based on our empirical findings, adequate resources (AR) have a significant effect on AORD (H_6). The analytical result is consistent with the works of Johansson and Winroth [147], Zhu et al. [148], Butler [149], and Leonidou et al. [150].

Perspective of H_7 (INP→AORD)

In this research, institutional pressure (INP) has a positive correlation with AORD (H_7). Institutional pressure has a direct impact on the strategies and decisions adopted by a company, according to Liang et al. [67]. This is in line with the findings of Karahanna, Straub, and Chervany [151] and Plouffe, Hulland, and Vandenbosch [152], whose works suggest that institutional pressures may influence the rates at which environmental practices are adopted.

Perspective of H_8 (PIP→AORD)

According to the analytic results, perceived industry pressure (PIP) correlates significantly with an EMS provider's decision to adopt RoHS standards (H_8). As shown in this study, public pressure is a critical factor that corporations and their stakeholders take into consideration when adopting RoHS directives. The finding is consistent with the research of Chien et al. [8], who argue that environmental responsibility is one of the perceived industry pressures that improves a firm's environmentally friendly practices. This finding verifies that public pressure, i.e., the underlying change in the industry environment, has the potential to encourage the adoption of RoHS directives.

Perspective of H_9 (ER→AORD)

According to this research, expert resources (ERs) have a positive correlation with AORD (H_9). This result is consistent with past work and real-world practices. Bohlouli et al. [153] argue that the expert resources can provide a firm with the exact technology for keeping the firm's competence above that of others.

Perspective of H_{10} (VA→AORD)

Based on the analytic results, the hypothesis of the negative correlation between verification ability (VA) and the adoption of RoHS (H_{10}) is supported. The result is consistent with earlier works (e.g., [154,155]). The process of executing environmental audits may carry significant costs [154]. Additionally, the findings of such audits may impact a company in more ways than just its financial standing. There can be non-financial implications, such as a tarnished corporate image, especially in cases where the company is found to be in violation of environmental laws and regulations [155].

Perspective of H_{11} (IN→AORD)

Based on the analytic results, the hypothesis of a negative correlation between innovation (IN) in green compliance and the adoption of RoHS (H_{11}) is supported. Since the first proposal of RoHS by the EU two decades ago, novel directives such as RoHS 2, the RoHS 2 Amendment, and RoHS 3 have been proposed. To comply with these innovations in green compliance, EMS providers need to continually invest in changing internal processes, equipment, and IS as well as to recruit new experts or certification organizations. The findings of Gupta and Baura [73], who also argue that various internal difficulties will emerge, are compatible with the hypothesis, and it shows that the hypothesis is correct when manufacturing organizations adopt green innovations. Thus, the negative correlation between innovation capability and the adoption of RoHS (H_{11}) is reasonable.

4.6.3. Practical Implications

Adopting RoHS practices is crucial for EMS providers to ensure compliance with regulatory requirements and meet the growing demand for environmentally friendly and safe electronic products. The empirical results have several practical implications for EMS providers. This section outlines some key areas of focus for EMS providers when adopting RoHS practices.

Most Related Aspects of RoHS Adoption by EMS Providers

According to the analytic results, the most correlated determinant in the human dimension is innovation (IN). The correlation coefficient is -0.379. As EMS providers may be required to adjust their manufacturing processes and recruit experts to ensure compliance with RoHS, an EMS provider may fail to adopt the innovative RoHS practice due to the possible need to increase its resources and investments [156]. To solve the problem, EMS providers can work closely with their suppliers to develop RoHS-compliant components and materials to reduce the human effect on non-compliant product return and reworks [157]; the potential benefit is that it could save audit resources and expenses [155]. By implementing these strategies, EMS providers can improve their RoHS compliance and minimize any impact on their competitiveness.

To achieve compliance, EMS providers may have to invest in new equipment and technologies that are RoHS compliant, implement robust quality control systems, and hire experts to manage compliance-related activities [158]. Expert resources (ERs) are ranked as the third most related factor in RoHS adoption (AORD) (0.195). This empirical result is in agreement with the findings of Lin and colleagues [159], who argued that expert resources (ERs) are the most relevant competence required for RoHS adoption. With ERs, a firm can acquire a specific strength, and any existing knowledge gaps can be identified and filled. The establishment of RoHS training programs by official education institutes can help provide sufficient experts to bridge the gap in human resources.

Non-Significant Hypotheses

From the aspect of complexity (H_2, CC→AORD)), it is possible for brand-name IT companies (e.g., Apple, HP, and Dell) to consider simplifying the design of their products by using fewer components, introducing the design for manufacturability and assembly (DFMA) techniques [160], reducing the total amount of materials employed and reducing the total amount of solder joints [161]. Such measures can reduce the complexity of the manufacturing processes of EMS providers, thus facilitating RoHS compliance.

From the perspective of compatibility (H_3, CO→AORD), to fulfil the RoHS requirement, EMS providers should be capable of managing their manufacturing systems in a manner that is consistent with the requirements set out by the RoHS directive. This includes understanding the environmental and social impacts of their supply chain and developing strategies to reduce these impacts. EMS providers must also develop the following sustainable supply chain strategies to retain their competitiveness in the industry: (1) conduct a comprehensive material analysis of all of the components that go into an EMS's product to determine whether any of the materials contain restricted substances; (2) ensure that their materials contain no restricted substances by regularly testing products; (3) consult regulatory authorities and certification organizations to clear up any confusion over RoHS regulations; and (4) analyze IT and IS comprehensively to identify gaps in ensuring compliance [68] and enhance corresponding competences. By taking these steps, firms can improve their ability to obtain accurate and up-to-date Declarations of Conformity (DoCs) and ensure that their products are RoHS compliant.

Discussion of Significant Hypotheses Supported by the Empirical Study Results

According to the findings of the empirical research, the following hypotheses were shown to be significant. Whether or not the findings make sense and whether or not they are consistent with findings from other research investigations is also examined.

Perspective of H_1 (CA→AORD)

EMS providers often face pressure from their brand-name customers to minimize their BOMs in order to achieve the target cost and increase the profitability of the brand-name IT customers. In addition to being expected to deliver high-quality products to customers on time and at a lower cost, EMS providers are always trying to further reduce costs through strategies such as value engineering, which involves re-evaluating product design, materials, and manufacturing processes. EMS providers also cooperate closely with suppliers to negotiate better prices, while remaining in compliance with RoHS certification.

Perspective of H_5 (RA→AORD)

When these brand-name IT customers are price-sensitive and unwilling to pay extra for environmentally friendly products, it can result in higher production costs for EMS providers [144]. Moreover, if competitors in the industry do not adopt RoHS measures or prioritize environmental regulations, the EMS providers that do chose to comply may face a competitive disadvantage. Through national government regulations, tax incentives, and the support of customers, the relative advantage for EMS providers to adopt RoHS measures can be increased.

Perspective of H_6 (AR→AORD)

It is imperative that EMS providers assess their compliance needs and identify the resources necessary to meet those needs prior to adopting RoHS. Essential to accomplishing this is developing a detailed project plan, identifying key milestones and timelines, and allocating resources accordingly. Ensuring that employees are aware of and capable of implementing RoHS compliance may require additional staffing and training. Therefore, the correlation is reasonable.

Perspective of H_7 (INP→AORD)

The analytic results indicating that institutional pressure positively impacts on an EMS provider's attitude toward RoHS decisions is highly reasonable. Accordingly, INP can be a vital strategy for encouraging an EMS provider to adopt the RoHS directive. The different types of institutional pressure that impact a firm's decision regarding the adoption of RoHS directives include coercive, normative, and mimetic pressure [162].

Perspective of H_8 (PIP→AORD)

Since industry pressure can be an important motivator for EMS providers to adopt RoHS regulations and RoHS compliance is expected or required by many industries, EMS providers tend to feel the pressure to adopt the regulation in order to remain competitive and meet customer expectations [163]. Such pressure possibly originates from industry associations, trade organizations, or other stakeholders who are concerned about the environmental impact of electronics and equipment [66].

Perspective of H_9 (ER→AORD)

Organizations can also mitigate the risk of non-compliance with RoHS directives by utilizing the expertise of companies such as SGS, an industry leader in compliance testing [108]. Thus, the availability of experts (of RoHS) is a dominant factor in the adoption of RoHS [164].

Perspective of H_{10} (VA→AORD)

To ensure that products or services comply with established standards, an EMS provider needs to have the ability to verify its products to ensure that they comply with RoHS and other regulations related to safety and quality. However, the need to verify hundreds or thousands of components has become a barrier for EMS providers, since either adopting their own resources of verification or engaging the services of third parties is costly. Moreover, EMS providers typically face the time pressure of launching their products and having to receive a variety of country-specific approvals; thus, selecting and deciding on the verification ability that meets established standards has become a dominant issue for EMS providers [43]. As such, the negative correlation between the verification ability and the adoption of RoHS is highly reasonable. EMS providers can increase their ability to verify compliance with RoHS directives by conducting comprehensive risk assessments of their manufacturing processes to determine potential sources of hazardous substances. This approach will enable EMS providers to develop appropriate verification procedures and controls for detecting and eliminating these substances from the products.

Perspective of H_{11} (IN→AORD)

Encouraging firms to adopt RoHS practice and overcome the barriers being identified in these aspects of IN, RA, and VA is key to the EMS provider's adoption of RoHS. EMS providers should continue to invest in the changes mentioned above and regularly assess and update their internal processes to optimize efficiency, reduce costs, and improve quality. This may involve implementing lean manufacturing principles, streamlining workflows, and adopting new process improvement methodologies, appropriate definitions of policy instruments, and regulations by leading economies such as those of mainland China, Japan, and the US. The regulations for brand-name IT companies of electronic products (e.g., Apple, HP, Dell, etc.) will force these firms to regulate their EMS providers. Moreover, the establishment of government tax incentives in places where the factories of EMS providers are located can further encourage these firms to adopt innovative RoHS practices.

4.6.4. Moderating Effect Analysis of Gender and Age

This study aimed to explore potential variations in EMS providers' intentions to adopt the RoHS regulation based on two demographic factors: gender and age. To investigate this, moderator effects were analyzed using *t*-tests and ANOVA with the assistance of SPSS 22 [117] software. Specifically, the independent sample *t*-test was conducted to examine the disparities between male and female employees in terms of adopting the RoHS practice. The findings, as presented in Table 8, suggest that, apart from the variables, SI, PIP, and IN, the remaining eight variables exhibit a significant difference ($p > 0.05$) in relation to RoHS adoption and decision making. Consequently, it can be concluded that gender influenced the intentions of EMS providers to adopt the RoHS regulation.

Table 8. Results of testing gender differences in RoHS adoption using a *t*-test.

Variable	**Male**		**Female**		***t*-Value**	***p*-Value**
	Mean	**Std**	**Mean**	**Std**		
CA	1.425	0.567	2.078	0.896	5.733	0.000
CC	2.001	0.250	3.073	1.171	13.955	0.000
CO	3.327	0.464	3.611	0.733	3.054	0.045
SI	3.371	0.292	3.592	0.652	3.479	0.076
RA	2.188	0.209	3.356	1.196	15.833	0.000
AR	4.163	0.231	3.807	0.787	−6.022	0.019
INP	1.429	0.229	2.578	1.390	13.603	0.000
PIP	4.304	0.286	4.350	0.548	0.775	0.651
ER	1.803	0.294	2.625	1.140	10.183	0.000
VA	4.381	0.516	3.778	0.850	−5.774	0.001
IN	3.760	0.501	3.587	0.643	−1.774	0.077

Based on the age moderator effect analysis, differences were observed in the subjective CA (t-value = 5.733, $p = 0.000$, $p < 0.05$), CC (t-value = 13.955, $p = 0.000$, $p < 0.05$), CO (t-value = 3.054, $p = 0.045$, $p < 0.05$), RA (t-value = 15.833, $p = 0.000$, $p < 0.05$), AR (t-value = −6.022, $p = 0.019$, $p < 0.05$), INP (t-value = 13.603, $p = 0.000$, $p < 0.05$), ER (t-value = 10.183, $p = 0.000$, $p < 0.05$), and VA (t-value = −5.774, $p = 0.001$, $p < 0.05$), respectively.

In an investigation into the influences of age, the authors employed the statistical software SPSS 22 [117] to analyze the data and examine the impact of age on the adoption of RoHS standards. A *t*-test was conducted, and the results are presented in Table 8. The findings indicated that age played a less significant role as a moderating factor in the study, influencing the factors that affected the intentions of EMS providers to adopt RoHS standards.

The study revealed that age influenced two key aspects (see Table 9): verification ability (VA) and the adoption of RoHS among EMS providers. Specifically, a negative correlation was observed between verification ability (VA) and the adoption of RoHS. This implies that as the verification ability decreases, the likelihood of adopting RoHS standards also decreases. Remarkably, this negative correlation held true across all age groups or levels of participation within the EMS provider sample.

Table 9. Results of testing age differences in RoHS adoption using a *t*-test.

Variable	**Under 30**		**30–40**		**40–50**		**Over 50**		***t*-Value**	***p*-Value**
	Mean	**Std**	**Mean**	**Std**	**Mean**	**Std**	**Mean**	**Std**		
CA	1.466	0.548	1.459	0.528	1.540	0.743	1.432	0.740	0.174	0.862
CC	2.124	0.621	2.000	0.234	2.208	0.711	2.111	0.444	1.406	0.161
CO	3.483	0.519	3.311	0.480	3.354	0.513	3.315	0.469	−1.255	0.210
SI	3.418	0.376	3.369	0.291	3.397	0.375	3.403	0.371	0.106	0.915
RA	2.382	0.656	2.189	0.208	2.395	0.682	2.250	0.521	0.224	0.823
AR	4.193	0.339	4.138	0.234	4.060	0.467	4.200	0.209	−0.634	0.527
INP	1.643	0.659	1.425	0.228	1.600	0.803	1.543	0.482	0.322	0.748
PIP	4.254	0.275	4.316	0.289	4.307	0.371	4.338	0.319	1.136	0.256
ER	2.017	0.652	1.781	0.284	1.928	0.607	1.875	0.442	−0.248	0.804
VA	4.425	0.523	4.386	0.483	4.192	0.702	4.321	0.593	−2.013	0.045
IN	3.828	0.520	3.733	0.495	3.701	0.552	3.782	0.504	−0.579	0.563

These results shed light on the importance of considering age as a factor when examining the factors that influence EMS providers' intentions to adopt RoHS standards. The findings suggest that individuals within the EMS industry may face challenges in terms of their verification ability, which, in turn, impacts their willingness to adopt RoHS standards. By identifying this age-related influence, the study contributes to a deeper understanding of the dynamics surrounding RoHS adoption within the EMS provider context.

4.6.5. Connection with the Three Pillars of Sustainability

OEMs receive a range of services from EMS providers, including product design, assembly, testing, and distribution. These businesses are indispensable to the global electronics supply chain. The adoption of the RoHS directive by EMS companies can have a beneficial effect on the three pillars that support sustainable development, as follows:

Environmental sustainability: EMS providers that comply with RoHS standards reduce the environmental impact [165] of their products significantly. RoHS compliance reduces the amount of hazardous waste [166] sent to landfills and manufacturing-related pollution. This contributes to improved air, water, and soil quality, which benefits ecosystem health and biodiversity. The directive also encourages these companies to seek out environmentally favorable substitutes for banned substances, which may lead to advancements in material science and green technologies.

Economic sustainability: Despite the initial cost of engaging in RoHS compliance being substantial for some EMS companies [167], the economic benefits in the long run can be significant. RoHS-compliant businesses can obtain a competitive advantage in markets where consumers value eco-friendly products. In addition, the use of fewer hazardous materials can reduce potential future liabilities associated with environmental remediation or health issues, and by being compelled to re-evaluate their manufacturing processes, businesses frequently discover opportunities for enhancing efficiency and reducing costs.

The social impact of RoHS adoption by EMS providers is the promotion of healthier workplaces and communities. By reducing the consumption of hazardous substances, these companies safeguard their employees and the communities where their products are manufactured, utilized, and discarded. This promotes social justice, health, and well-being. In addition, businesses that are viewed as proactive in addressing environmental and health issues can strengthen their social license to operate, improve their corporate reputation, and develop stronger relationships with their stakeholders.

In conclusion, the adoption of RoHS by EMS companies is a step in the direction of more sustainable practices. It is consistent with the objective of developing electronics that are not only high-performing, but also environmentally favorable, economically viable, and socially responsible.

4.6.6. Research Limitations and Future Research Possibilities

This work examined the effects of key aspects on EMS providers' decisions to adopt RoHS. There are several limitations that should be discussed here. Firstly, we will discuss the non-significant hypotheses, which are possible topics of future research. Moreover, cross-country comparisons are potential topics for future research. The implications for RoHS adoption in other fields and industries will also be discussed. RoHS adoptions in new products and other fields also warrant further investigation.

According to Johnson [131], the non-significant results are worthy of further analysis. Carver [168] mentioned that researchers can continue to explore non-significant results by introducing more datasets to increase the number of respondents, thus resolving the statistically insignificant hypothesis results. In some circumstances, hypothesis testing for tentative statistical models can be considered. According to Allen and Mehler [169], the adoption of multilevel data may help mitigate issues concerning statistical power.

Moreover, an examination of the factors that affect RoHS adoption across different regions and countries would be beneficial. Van Ark, O'Mahoney, and Timmer [170] and Mante Meijer et al. [171] claim that studying the adoption of RoHS in other countries could reveal some discrepancies between countries.

The composition of the respondents in our recent study reflects the demographic realities of the Asian electronics and, more specifically, the Electronic Manufacturing Services (EMS) industry. We see a male dominance due to the traditional role allocation in these industries, where female employees often handle rudimentary tasks, limiting their representation in departments such as engineering and management, as detailed in Table 4.

This gender distribution is not a peculiarity of our study, but mirrors the industry's prevailing structure. Additionally, a Taiwanese government report has indicated that approximately 78% of employees within science and technology parks, which host many EMS firms, are under 45 years old. This demographic detail explains the higher representation of younger participants in our study, which is a reflection of the workforce demographics rather than an inherent bias in our research design.

However, it is crucial to acknowledge the limitation that our sample may not entirely reflect the perceptions of female and older employees. To provide a more comprehensive understanding of RoHS adoption attitudes and related subjects, future investigations would benefit significantly from specifically targeting these underrepresented groups. This approach would afford us insights into the gender and age-related nuances within the EMS industry.

Finally, according to Koruza et al. [172], new technological advances are exempted from the RoHS directive. However, such exemptions may be re-evaluated and amended in the future. Thus, new technologies and materials that are safer, eco-friendly, and more sustainable should be explored.

5. Conclusions

The RoHS regulation, a green practice for EMS providers, mandates lead-free solders and components in electronic manufacturing, reducing toxic substances and heavy metal poisoning among workers. This improves workers' health, especially in developing countries and e-waste recycling factories, where most waste is processed. Compliance benefits EMS providers by improving product reliability and customer satisfaction. Brand-name IT companies prefer partnering with RoHS-compliant EMS providers, preventing potential legal, reputational, and financial risks.

Despite the significance of RoHS adoption, few studies have explored its determinants. This study fills this gap by applying the TOE-HOT fit model. Key findings revealed that expert resources, adequate resources, perceived industrial and institutional pressure, and cost were positively associated with RoHS adoption. Barriers included innovation, relative advantage, and verification ability, with human dimension innovation being crucial. Government regulations, tax incentives, support from IT customers, comprehensive material analyses, regular product testing, and regulatory consultation can increase RoHS compliance. These findings provide a framework for EMS providers to enhance RoHS adoption, boosting their green capabilities. The analytic framework used in this study can also aid firms in investigating factors affecting the implementation of sustainable practices.

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Appendix A

Table A1. Measurement validation.

LVs	Items	Factor Loading	Cronbach's α	ρ_A	CR	AVE	RDN
AR			0.942	0.943	0.955	0.811	N.A
	ar_1	0.907					
	ar_2	0.940					
	ar_3	0.908					
	ar_4	0.927					
	ar_5	0.815					
CC			0.957	0.945	0.967	0.854	N.A
	cc_1	0.930					
	cc_2	0.979					
	cc_3	0.907					
	cc_4	0.875					
	cc_5	0.926					
CO			0.957	0.946	0.967	0.853	N.A
	co_1	0.932					
	co_2	0.941					
	co_3	0.948					
	co_4	0.905					
	co_5	0.890					
CA			0.965	0.948	0.973	0.877	N.A
	ca_1	0.950					
	ca_2	0.970					
	ca_3	0.928					
	ca_4	0.929					
	ca_5	0.904					
ER			0.819	0.846	0.870	0.576	N.A
	er_1	0.852					
	er_2	0.869					
	er_3	0.754					
	er_4	0.719					
	er_5	0.726					
IN			0.829	0.869	0.876	0.568	N.A
	in_1	0.748					
	in_2	0.828					
	in_3	0.753					
	in_4	0.761					
	in_5	0.733					
IP			0.973	0.948	0.978	0.882	N.A
	ip_1	0.938					
	ip_2	0.970					
	ip_3	0.927					
	ip_4	0.948					
	ip_5	0.929					
	ip_6	0.922					
PI			0.968	0.947	0.975	0.886	N.A
	pi_1	0.938					
	pi_2	0.915					
	pi_3	0.980					
	pi_4	0.898					
	pi_5	0.973					

Table A1. *Cont.*

LVs	Items	Factor Loading	Cronbach's α	ρ_A	CR	AVE	RDN
RA			0.907	0.914	0.937	0.754	N.A
	ra_1	0.932					
	ra_2	0.956					
	ra_3	0.925					
	ra_4	0.933					
	ra_5	0.919					
SI			0.916	0.934	0.937	0.750	N.A
	si_1	0.872					
	si_2	0.892					
	si_3	0.956					
	si_4	0.779					
	si_5	0.822					
AORD			0.842	0.845	0.888	0.615	0.316
	$aord_1$	0.830					0.323
	$aord_2$	0.707					0.259
	$aord_3$	0.808					0.390
	$aord_4$	0.746					0.317
	$aord_5$	0.822					0.291
VA			0.926	0.930	0.944	0.772	N.A
	va_1	0.857					
	va_2	0.890					
	va_3	0.907					
	va_4	0.879					
	va_5	0.860					

Remark: LVs means latent variables; Cronbach's α means Cronbach's alpha; ρ_A means Dijkstra–Henseler's rho; RDN means redundancy; N.A means not applicable.

Table A2. Discriminant validity: Fornell–Larcker criterion.

LVs	AR	CO	CC	CA	ER	IN	IP	PIP	RA	SI	AORD	VA
AR	**0.900**											
CO	0.466	**0.924**										
CC	0.675	0.280	**0.924**									
CA	0.491	0.336	0.343	**0.937**								
ER	0.414	0.340	0.279	0.274	**0.759**							
IN	−0.040	−0.150	−0.032	0.053	−0.317	**0.765**						
IP	0.281	0.227	0.225	0.277	0.395	−0.312	**0.939**					
PI	0.189	0.146	0.128	0.166	0.281	−0.282	0.281	**0.941**				
RA	0.604	0.488	0.425	0.485	0.564	−0.113	0.333	0.225	**0.868**			
SI	0.509	0.375	0.336	0.425	0.447	−0.117	0.358	0.306	0.451	**0.866**		
AORD	0.439	0.344	0.300	0.267	0.483	−0.538	0.410	0.366	0.328	0.336	**0.784**	
VA	−0.160	−0.168	−0.087	−0.049	−0.231	0.404	−0.175	−0.138	−0.187	−0.210	−0.344	**0.879**

Remark: LVs means latent variables.

Table A3. Discriminant validity—Loading and cross-loading criterion.

	AR	CO	CC	CA	ER	IN	IP	PI	RA	SI	AORD	VA
ar_1	**0.907**	0.658	0.406	0.419	0.341	−0.006	0.205	0.186	0.543	0.452	0.338	−0.122
ar_2	**0.940**	0.594	0.449	0.485	0.405	−0.070	0.311	0.174	0.590	0.478	0.477	−0.187
ar_3	**0.908**	0.662	0.418	0.409	0.338	0.013	0.180	0.184	0.533	0.451	0.339	−0.101
ar_4	**0.927**	0.630	0.444	0.505	0.422	−0.049	0.326	0.156	0.584	0.480	0.462	−0.173
ar_5	**0.815**	0.501	0.366	0.358	0.333	−0.052	0.193	0.159	0.445	0.427	0.305	−0.112

Table A3. *Cont.*

	AR	CO	CC	CA	ER	IN	IP	PI	RA	SI	AORD	VA
co_1	0.380	**0.932**	0.202	0.255	0.273	−0.122	0.162	0.090	0.403	0.277	0.267	−0.146
co_2	0.404	**0.941**	0.225	0.287	0.268	−0.153	0.166	0.109	0.423	0.296	0.282	−0.157
co_3	0.563	**0.948**	0.380	0.424	0.441	−0.146	0.307	0.190	0.582	0.476	0.425	−0.176
co_4	0.278	**0.905**	0.165	0.216	0.234	−0.081	0.157	0.080	0.350	0.207	0.221	−0.101
co_5	0.429	**0.890**	0.241	0.296	0.279	−0.170	0.195	0.163	0.415	0.377	0.317	−0.173
cc_1	0.651	0.261	**0.930**	0.323	0.277	−0.046	0.222	0.154	0.401	0.383	0.291	−0.085
cc_2	0.749	0.323	**0.979**	0.398	0.335	−0.051	0.259	0.162	0.489	0.391	0.353	−0.108
cc_3	0.579	0.202	**0.907**	0.273	0.192	−0.011	0.181	0.078	0.358	0.194	0.236	−0.092
cc_4	0.521	0.253	**0.875**	0.278	0.265	0.002	0.209	0.086	0.325	0.284	0.214	−0.048
cc_5	0.564	0.233	**0.926**	0.280	0.190	−0.024	0.150	0.084	0.352	0.256	0.256	−0.058
ca_1	0.411	0.260	0.310	**0.950**	0.222	0.105	0.262	0.161	0.407	0.362	0.232	−0.006
ca_2	0.582	0.388	0.410	**0.970**	0.362	0.033	0.325	0.183	0.559	0.477	0.343	−0.072
ca_3	0.428	0.286	0.283	**0.928**	0.221	0.049	0.213	0.170	0.416	0.330	0.216	−0.026
ca_4	0.438	0.304	0.287	**0.929**	0.202	0.011	0.218	0.123	0.441	0.380	0.226	−0.081
ca_5	0.372	0.306	0.264	**0.904**	0.216	0.060	0.248	0.126	0.390	0.413	0.178	−0.025
er_1	0.448	0.358	0.303	0.330	**0.852**	−0.223	0.337	0.187	0.502	0.419	0.443	−0.200
er_2	0.478	0.367	0.341	0.346	**0.869**	−0.207	0.394	0.212	0.547	0.447	0.442	−0.154
er_3	0.158	0.150	0.088	0.063	**0.654**	−0.410	0.234	0.236	0.354	0.227	0.362	−0.202
er_4	0.212	0.175	0.131	0.118	**0.719**	−0.172	0.257	0.224	0.373	0.285	0.273	−0.158
er_5	0.152	0.162	0.105	0.070	**0.672**	−0.186	0.237	0.241	0.295	0.260	0.242	−0.167
in_1	0.058	−0.100	0.046	0.107	−0.229	**0.748**	−0.251	−0.185	−0.073	−0.007	−0.346	0.284
in_2	−0.135	−0.179	−0.096	0.004	−0.321	**0.828**	−0.335	−0.332	−0.188	−0.122	−0.574	0.357
in_3	0.025	−0.027	0.000	0.014	−0.216	**0.753**	−0.125	−0.140	−0.015	−0.117	−0.315	0.271
in_4	−0.043	−0.174	−0.021	0.082	−0.221	**0.761**	−0.279	−0.207	−0.072	−0.080	−0.418	0.345
in_5	0.024	−0.023	0.001	0.007	−0.183	**0.733**	−0.116	−0.131	−0.008	−0.113	−0.293	0.255
ip_1	0.291	0.199	0.232	0.247	0.363	−0.268	**0.938**	0.273	0.344	0.355	0.381	−0.145
ip_2	0.275	0.232	0.216	0.277	0.398	−0.318	**0.970**	0.269	0.314	0.342	0.418	−0.174
ip_3	0.300	0.199	0.221	0.256	0.358	−0.265	**0.927**	0.271	0.341	0.350	0.379	−0.148
ip_4	0.239	0.188	0.196	0.264	0.366	−0.303	**0.948**	0.245	0.287	0.319	0.359	−0.168
ip_5	0.238	0.244	0.215	0.252	0.377	−0.320	**0.929**	0.275	0.309	0.327	0.398	−0.183
ip_6	0.238	0.211	0.185	0.266	0.359	−0.282	**0.922**	0.249	0.278	0.326	0.369	−0.166
pi_1	0.167	0.099	0.096	0.145	0.262	−0.275	0.238	**0.938**	0.187	0.258	0.342	−0.118
pi_2	0.178	0.137	0.130	0.153	0.241	−0.245	0.251	**0.915**	0.195	0.280	0.326	−0.142
pi_3	0.186	0.155	0.113	0.148	0.276	−0.282	0.263	**0.980**	0.219	0.291	0.366	−0.138
pi_4	0.190	0.155	0.128	0.184	0.282	−0.251	0.291	**0.898**	0.264	0.338	0.325	−0.119
pi_5	0.170	0.143	0.135	0.155	0.263	−0.272	0.280	**0.973**	0.201	0.277	0.363	−0.134
ra_1	0.489	0.819	0.346	0.373	0.316	0.020	0.243	0.100	**0.532**	0.391	0.256	−0.109
ra_2	0.568	0.360	0.382	0.439	0.556	−0.119	0.289	0.222	**0.956**	0.405	0.292	−0.194
ra_3	0.498	0.318	0.379	0.420	0.524	−0.149	0.320	0.203	**0.925**	0.376	0.278	−0.170
ra_4	0.508	0.329	0.378	0.446	0.487	−0.112	0.304	0.230	**0.933**	0.387	0.305	−0.172
ra_5	0.533	0.317	0.342	0.399	0.526	−0.116	0.270	0.204	**0.919**	0.380	0.276	−0.152
si_1	0.468	0.324	0.283	0.378	0.358	−0.140	0.307	0.255	0.379	**0.872**	0.306	−0.234
si_2	0.379	0.321	0.263	0.317	0.381	−0.082	0.290	0.261	0.367	**0.892**	0.255	−0.139
si_3	0.543	0.403	0.377	0.464	0.504	−0.129	0.399	0.310	0.514	**0.956**	0.386	−0.218
si_4	0.452	0.310	0.300	0.324	0.363	−0.026	0.277	0.206	0.388	**0.779**	0.232	−0.156
si_5	0.321	0.235	0.199	0.321	0.286	−0.106	0.243	0.283	0.253	**0.822**	0.233	−0.137
$aord_1$	0.421	0.320	0.270	0.322	0.350	−0.373	0.294	0.305	0.312	0.299	**0.830**	−0.237
$aord_2$	0.247	0.186	0.210	0.029	0.312	−0.435	0.322	0.254	0.088	0.163	**0.707**	−0.248
$aord_3$	0.335	0.281	0.229	0.184	0.443	−0.494	0.318	0.316	0.246	0.296	**0.808**	−0.339
$aord_4$	0.293	0.237	0.188	0.180	0.439	−0.451	0.394	0.273	0.317	0.249	**0.746**	−0.297
$aord_5$	0.419	0.318	0.279	0.324	0.337	−0.346	0.278	0.282	0.311	0.299	**0.822**	−0.217

Table A3. *Cont.*

	AR	CO	CC	CA	ER	IN	IP	PI	RA	SI	AORD	VA
va_1	−0.162	−0.151	−0.069	−0.096	−0.151	0.382	−0.167	−0.104	−0.157	−0.188	−0.344	**0.857**
va_2	−0.153	−0.158	−0.078	−0.030	−0.211	0.374	−0.135	−0.162	−0.208	−0.218	−0.301	**0.890**
va_3	−0.145	−0.152	−0.103	−0.030	−0.217	0.328	−0.118	−0.140	−0.158	−0.177	−0.295	**0.907**
va_4	−0.133	−0.165	−0.063	−0.071	−0.237	0.335	−0.170	−0.112	−0.203	−0.200	−0.266	**0.879**
va_5	−0.106	−0.111	−0.071	0.020	−0.208	0.346	−0.177	−0.088	−0.098	−0.138	−0.292	**0.860**

Table A4. Discriminant validity of HTMT.

LVs	AR	CO	CC	CA	ER	IN	IP	PIP	RA	SI	AORD	VA
AR												
CO	0.465											
CC	0.700	0.270										
CA	0.491	0.326	0.338									
ER	0.426	0.341	0.280	0.260								
IN	0.087	0.147	0.059	0.077	0.365							
IP	0.281	0.221	0.229	0.279	0.429	0.319						
PI	0.200	0.142	0.127	0.169	0.325	0.288	0.290					
RA	0.651	0.520	0.450	0.507	0.632	0.123	0.356	0.241				
SI	0.538	0.371	0.341	0.437	0.487	0.140	0.371	0.324	0.486			
AORD	0.478	0.363	0.326	0.293	0.554	0.602	0.452	0.404	0.375	0.369		
VA	0.164	0.173	0.090	0.061	0.269	0.446	0.184	0.146	0.205	0.222	0.384	

Remark: LVs means latent variables.

References

1. Mihai, F.-C.; Gnoni, M.-G.; Meidiana, C.; Ezeah, C.; Elia, V. Waste electrical and electronic equipment (WEEE): Flows, quantities, and management—A global scenario. In *Electronic Waste Management and Treatment Technology*; Prasad, M.N.V., Vithanage, M., Eds.; Butterworth-Heinemann: Oxford, UK, 2019; pp. 1–34.
2. Peet, R.; Robbins, P.; Watts, M. *Global Political Ecology*; Routledge: Oxfordshire, UK, 2010.
3. Tortorella, G.L.; Fettermann, D.; Fogliatto, F.S.; Kumar, M.; Jurburg, D. Analysing the influence of organisational culture and leadership styles on the implementation of lean manufacturing. *Prod. Plan. Control.* **2021**, *32*, 1282–1294. [CrossRef]
4. Rehman Khan, S.A.; Yu, Z. Assessing the eco-environmental performance: An PLS-SEM approach with practice-based view. *Int. J. Logist. Res.* **2021**, *24*, 303–321. [CrossRef]
5. Li, G.; Li, L.; Choi, T.M.; Sethi, S.P. Green supply chain management in Chinese firms: Innovative measures and the moderating role of quick response technology. *J. Oper. Manag.* **2020**, *66*, 958–988. [CrossRef]
6. Hwang, B.N.; Huang, C.Y.; Wu, C.H. A TOE approach to establish a green supply chain adoption decision model in the semiconductor industry. *Sustainability* **2016**, *8*, 168. [CrossRef]
7. Yadegaridehkordi, E.; Nilashi, M.; Nasir, M.H.N.B.M.; Ibrahim, O. Predicting determinants of hotel success and development using Structural Equation Modelling (SEM)-ANFIS method. *Tour. Manag.* **2018**, *66*, 364–386. [CrossRef]
8. Chien, M.-K.; Shih, L.-H. Relationship between management practice and organisation performance under European Union directives such as RoHS: A case-study of the electrical and electronic industry in Taiwan. *Afr. J. Environ. Sci.* **2007**, *1*, 37–48.
9. Clemons, E.K. Information systems for sustainable competitive advantage. *Inf. Manag. Decis.* **1986**, *11*, 131–136. [CrossRef]
10. Van Liemt, G. *Subcontracting in Electronics: From Contract Manufacturers to Providers of Electronic Manufacturing Services (EMS)*; International Labour Office: Geneva, Switzerland, 2007.
11. Barnes, E.; Dai, J.; Deng, S.; Down, D.; Goh, M.; Lau, H.C.; Sharafali, M. *Electronics Manufacturing Service Industry*; Georgia Institute of Technology: Atlanta, GA, USA, 2000.
12. Gencer, C.; Gürpinar, D. Analytic network process in supplier selection: A case study in an electronic firm. *Appl. Math. Model.* **2007**, *31*, 2475–2486. [CrossRef]
13. Randall, S. *The Worldwide Electronics Manufacturing Services Market*; New Venture Research Corp.: Nevada City, CA, USA, 2022; Volume 2023.
14. Ecer, F. Multi-criteria decision making for green supplier selection using interval type-2 fuzzy AHP: A case study of a home appliance manufacturer. *Oper. Res.* **2022**, *22*, 199–233.
15. Rajput, S.P.; Datta, S. Sustainable and green manufacturing–A narrative literature review. *Mater. Today* **2020**, *26*, 2515–2520. [CrossRef]
16. Rehman, M.A.; Shrivastava, R. Green manufacturing (GM): Past, present and future (a state of art review). *World Rev. Sci. Technol. Sustain. Dev.* **2013**, *10*, 17–55. [CrossRef]

17. Dornfeld, D.A. *Green Manufacturing: Fundamentals and Applications*; Springer Science & Business Media: New York, NY, USA, 2012.
18. Deif, A.M. A system model for green manufacturing. *J. Clean. Prod.* **2011**, *19*, 1553–1559. [CrossRef]
19. Stark, J. *Product Lifecycle Management (PLM)*; Springer: New York, NY, USA, 2020; pp. 1–33.
20. ElMaraghy, W.; ElMaraghy, H.; Tomiyama, T.; Monostori, L. Complexity in engineering design and manufacturing. *CIRP Ann* **2012**, *61*, 793–814. [CrossRef]
21. Fromme, H.; Körner, W.; Shahin, N.; Wanner, A.; Albrecht, M.; Boehmer, S.; Parlar, H.; Mayer, R.; Liebl, B.; Bolte, G. Human exposure to polybrominated diphenyl ethers (PBDE), as evidenced by data from a duplicate diet study, indoor air, house dust, and biomonitoring in Germany. *Environ. Int.* **2009**, *35*, 1125–1135. [CrossRef] [PubMed]
22. George, E.; Pecht, M. RoHS compliance in safety and reliability critical electronics. *J. Mater. Sci. Mater. Electron.* **2016**, *65*, 1–7. [CrossRef]
23. Danso, A.; Adomako, S.; Amankwah-Amoah, J.; Owusu-Agyei, S.; Konadu, R. Environmental sustainability orientation, competitive strategy and financial performance. *Bus. Strategy Environ.* **2019**, *28*, 885–895. [CrossRef]
24. Ghazilla, R.A.R.; Sakundarini, N.; Abdul-Rashid, S.H.; Ayub, N.S.; Olugu, E.U.; Musa, S.N. Drivers and barriers analysis for green manufacturing practices in Malaysian SMEs: A preliminary findings. *Procedia CIRP* **2015**, *26*, 658–663. [CrossRef]
25. Althaf, S.; Babbitt, C.W.; Chen, R. The evolution of consumer electronic waste in the United States. *J. Ind. Ecol.* **2021**, *25*, 693–706. [CrossRef]
26. Tornatzky, L.G.; Fleischer, M.; Chakrabarti, A.K. *Processes of Technological Innovation*; Lexington Books: Lanham, MD, USA, 1990.
27. Malik, S.; Chadhar, M.; Vatanasakdakul, S.; Chetty, M. Factors affecting the organizational adoption of blockchain technology: Extending the technology–organization–environment (TOE) framework in the Australian context. *Sustainability* **2021**, *13*, 9404. [CrossRef]
28. Baker, J. The technology–organization–environment framework. In *Information Systems Theory*; Dwivedi, Y., Wade, M., Schneberger, S., Eds.; Springer: New York, NY, USA, 2012; pp. 231–245.
29. Yusof, M.M.; Kuljis, J.; Papazafeiropoulou, A.; Stergioulas, L.K. An evaluation framework for Health Information Systems: Human, organization and technology-fit factors (HOT-fit). *Int. J. Med. Inform.* **2008**, *77*, 386–398. [CrossRef]
30. Hapsari, W.P.; Labib, U.A.; Haryanto, H.; Safitri, D.W. A Literature Review of Human, Organization, Technology (HOT)–Fit Evaluation Model. In *6th International Seminar on Science Education (ISSE 2020)*; Atlantis Press: Amsterdam, The Netherlands, 2021; pp. 876–883.
31. Feng, B.; Hu, X.; Orji, I.J. Multi-tier supply chain sustainability in the pulp and paper industry: A framework and evaluation methodology. *Int. J. Prod. Res.* **2023**, *61*, 4657–4683. [CrossRef]
32. Bsharat, M.; Ibrahim, O. Quality of service acceptance in cloud service utilization: An empirical study in Palestinian higher education institutions. *Educ. Inf. Technol.* **2020**, *25*, 863–888. [CrossRef]
33. Lindermann, C.; Jahnke, U.; Moi, M.; Koch, R. Analyzing product lifecycle costs for a better understanding of cost drivers in additive manufacturing. In *2012 International Solid Freeform Fabrication Symposium*; University of Texas at Austin: Austin, TX, USA, 2012.
34. Sharif, A.M.; Irani, Z. Applying a fuzzy-morphological approach to complexity within management decision making. *Manag. Decis.* **2006**, *44*, 930–961. [CrossRef]
35. Grady, J.O. *System Integration*; CRC Press: Boca Raton, FL, USA, 1994.
36. Henningsson, S.; Yetton, P.W.; Wynne, P.J. A review of information system integration in mergers and acquisitions. *J. Inf. Technol.* **2018**, *33*, 255–303. [CrossRef]
37. Gong, D.-C.; Hsiao, W.-C.; Ho, P.-S. Information integration architecture of risk management for RoHS. In Proceedings of the 2008 International Conference on Computer Science and Software Engineering, Wuhan, China, 12–14 December 2008; pp. 512–515.
38. Rogers, E.M. *Diffusion of Innovations*, 3rd ed.; Simon and Schuster: New York, NY, USA, 1983.
39. Cooper, R.G.; Kleinschmidt, E.J. Benchmarking the firm's critical success factors in new product development. *J. Prod. Innov. Manag. Int. Publ. Prod. Dev. Manag. Assoc.* **1995**, *12*, 374–391. [CrossRef]
40. Pattanayak, D.; Koilakuntla, M.; Punyatoya, P. Investigating the Influence of TQM, Service Quality and Market Orientation on Customer Satisfaction and Loyalty in the Indian Banking Sector. *Int. J. Qual. Reliab. Manag.* **2017**, *34*, 362–377. [CrossRef]
41. Wang, S.; Li, J.; Zhao, D. Institutional pressures and environmental management practices: The moderating effects of environmental commitment and resource availability. *Bus. Strategy Environ.* **2018**, *27*, 52–69. [CrossRef]
42. Torres-Coronas, T. *Social E-Enterprise: Value Creation through ICT: Value Creation through ICT*; Information Science Reference: Hershey, PA, USA, 2012.
43. Griffith, E.E.; Hammersley, J.S.; Kadous, K. Audits of complex estimates as verification of management numbers: How institutional pressures shape practice. *Contemp. Account. Res.* **2015**, *32*, 833–863. [CrossRef]
44. Laursen, K.; Foss, N.J. New human resource management practices, complementarities and the impact on innovation performance. *Camb. J. Econ.* **2003**, *27*, 243–263. [CrossRef]
45. Li, X.; Wang, B.; Peng, T.; Xu, X. Greentelligence: Smart manufacturing for a greener future. *Chin. J. Mech.* **2021**, *34*, 116. [CrossRef]
46. Wu, C.-C. A Derivation of Key Success Factors for Influencing the Adoption of RoHS Process Materials by Mobile Phone Manufacturers. Master's Thesis, National Taiwan Normal University, Taipei, Taiwan, 2018.
47. Grinstein, A.; Goldman, A. Characterizing the technology firm: An exploratory study. *Res. Policy.* **2006**, *35*, 121–143. [CrossRef]
48. Stacey, R.D. *Complexity and Creativity in Organizations*; Berrett-Koehler Publishers: San Francisco, CA, USA, 1996; 312p.

49. Rounaghi, M.M.; Jarrar, H.; Dana, L.-P. Implementation of strategic cost management in manufacturing companies: Overcoming costs stickiness and increasing corporate sustainability. *Future Bus. J.* **2021**, *7*, 31. [CrossRef]
50. Cooper, R. *Supply Chain Development for the Lean Enterprise: Interorganizational Cost Management*; Routledge: Oxfordshire, UK, 2017.
51. Huang, C.-M.; Raj, A.; Osterman, M.; Pecht, M. Assembly options and challenges for electronic products with lead-free exemption. *IEEE Access* **2020**, *8*, 134194–134208. [CrossRef]
52. Hobday, M. Product complexity, innovation and industrial organisation. *Res. Policy.* **1998**, *26*, 689–710. [CrossRef]
53. Amini, M.; Javid, N.J. A Multi-Perspective Framework Established on Diffusion of Innovation (DOI) Theory and Technology, Organization and Environment (TOE) Framework Toward Supply Chain Management System Based on Cloud Computing Technology for Small and Medium Enterprises. *Int. J. Inf. Technol. Innov. Adop.* **2023**, *11*, 1217–1234.
54. Cenci, M.P.; Scarazzato, T.; Munchen, D.D.; Dartora, P.C.; Veit, H.M.; Bernardes, A.M.; Dias, P.R. Eco-friendly electronics—A comprehensive review. *Adv. Mater. Technol.* **2022**, *7*, 2001263. [CrossRef]
55. Paez, O.; Dewees, J.; Genaidy, A.; Tuncel, S.; Karwowski, W.; Zurada, J. The lean manufacturing enterprise: An emerging sociotechnological system integration. *Hum. Factors Ergon. Manuf.* **2004**, *14*, 285–306. [CrossRef]
56. Pellinen, J.; Teittinen, H.; Järvenpää, M. Performance measurement system in the situation of simultaneous vertical and horizontal integration. *Int. J. Oper. Prod. Manag.* **2016**, *36*, 1182–1200. [CrossRef]
57. Rajaguru, R.; Matanda, M.J. Effects of inter-organizational compatibility on supply chain capabilities: Exploring the mediating role of inter-organizational information systems (IOIS) integration. *Ind. Mark. Manag.* **2013**, *42*, 620–632.
58. Wang, C.-H. How organizational green culture influences green performance and competitive advantage: The mediating role of green innovation. *J. Manuf. Technol. Manag.* **2019**, *30*, 666–683. [CrossRef]
59. Gold, S.; Seuring, S.; Beske, P. Sustainable supply chain management and inter-organizational resources: A literature review. *Corp. Soc. Responsib. Environ.* **2010**, *17*, 230–245.
60. Fishbein, M.; Ajzen, I. *Belief, Attitude, Intention, and Behavior: An Introduction to Theory and Research*; Addison-Wesley: Reading, MA, USA, 1975.
61. Davis, F.D. Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Q.* **1989**, *13*, 319–340. [CrossRef]
62. Jain, S.; Singhal, S.; Jain, N.K.; Bhaskar, K. Construction and demolition waste recycling: Investigating the role of theory of planned behavior, institutional pressures and environmental consciousness. *J. Clean. Prod.* **2020**, *263*, 121405.
63. Baah, C.; Opoku-Agyeman, D.; Acquah, I.S.K.; Agyabeng-Mensah, Y.; Afum, E.; Faibil, D.; Abdoulaye, F.A.M. Examining the correlations between stakeholder pressures, green production practices, firm reputation, environmental and financial performance: Evidence from manufacturing SMEs. *Sustain. Prod. Consum.* **2021**, *27*, 100–114.
64. Liu, H.; Ke, W.; Wei, K.K.; Gu, J.; Chen, H. The role of institutional pressures and organizational culture in the firm's intention to adopt internet-enabled supply chain management systems. *J. Oper. Manag.* **2010**, *28*, 372–384. [CrossRef]
65. Yong, J.Y.; Yusliza, M.Y.; Ramayah, T.; Seles, B.M.R.P. Testing the stakeholder pressure, relative advantage, top management commitment and green human resource management linkage. *Corp. Soc. Responsib. Environ.* **2022**, *29*, 1283–1299. [CrossRef]
66. Betts, T.K.; Wiengarten, F.; Tadisina, S.K. Exploring the impact of stakeholder pressure on environmental management strategies at the plant level: What does industry have to do with it? *J. Clean. Prod.* **2015**, *92*, 282–294.
67. Liang, H.; Saraf, N.; Hu, Q.; Xue, Y. Assimilation of enterprise systems: The effect of institutional pressures and the mediating role of top management. *MIS Q.* **2007**, *31*, 59–87. [CrossRef]
68. Cahyono, D.; Suryani, E. The Suitability Evaluation of Procurement Information Systems to the Needs of Users and Management Using Human, Organization, Technology-Fit (HOT-Fit) Framework. *IPTEK J. Technol. Sci.* **2020**, *31*, 101–110. [CrossRef]
69. Xu, J.; Lu, W. Developing a human-organization-technology fit model for information technology adoption in organizations. *Technol. Soc.* **2022**, *70*, 102010. [CrossRef]
70. Akman, I.; Mishra, A. Green information technology practices among IT professionals: Theory of planned behavior perspective. *Probl. Ekorozwoju* **2014**, *9*, 47–54.
71. Riess, A.; Lepmets, M.; McKechnie, S.; Walker, A. Verification of the effectiveness of risk management in the medical device industry. In *European Conference on Software Process Improvement*; Springer: Berlin/Heidelberg, Germany, 2018; pp. 380–386.
72. Esmaeilian, B.; Sarkis, J.; Lewis, K.; Behdad, S. Blockchain for the future of sustainable supply chain management in Industry 4.0. *Resour. Conserv. Recycl.* **2020**, *163*, 105064. [CrossRef]
73. Gupta, H.; Barua, M.K. Evaluation of manufacturing organizations ability to overcome internal barriers to green innovations. In *Strategic Decision Making for Sustainable Management of Industrial Networks*; Rezaei, J., Ed.; Springer: Cham, Switzerland, 2021; pp. 139–160.
74. Ullah, S.; Ahmad, N.; Khan, F.U.; Badulescu, A.; Badulescu, D. Mapping interactions among green innovations barriers in manufacturing industry using hybrid methodology: Insights from a developing country. *Int. J. Environ. Res. Public Health* **2021**, *18*, 7885. [PubMed]
75. Kanapathy, K.; Yee, G.W.; Zailani, S.; Aghapour, A.H. An intra-regional comparison on RoHS practices for green purchasing management among electrical and electronics SMEs in Southeast Asia. *Int. J. Procure. Manag.* **2016**, *9*, 249–271. [CrossRef]
76. Pumpinyo, S.; Nitivattananon, V. Investigation of barriers and factors affecting the reverse logistics of waste management practice: A case study in Thailand. *Sustainability* **2014**, *6*, 7048–7062.

77. Byrnes, J.P.; Miller, D.C.; Schafer, W.D. Gender differences in risk taking: A meta-analysis. *Psychol. Bull.* **1999**, *125*, 367. [CrossRef]
78. Tripathi, S. Moderating effects of age and experience on the factors influencing the actual usage of cloud computing. *J. Int. Technol. Inf. Manage* **2018**, *27*, 121–158.
79. Zhu, J.; Zhu, C.; Lu, D.; Wang, G.G.; Zheng, X.; Cao, J.; Zhang, J. Regeneration and succession: A 50-year gap dynamic in temperate secondary forests, Northeast China. *For. Ecol. Manage* **2021**, *484*, 118943.
80. Tsai, J.-F.; Wu, S.-C.; Pham, T.K.L.; Lin, M.-H. Analysis of key factors for green supplier selection: A case study of the electronics industry in Vietnam. *Sustainability* **2023**, *15*, 7885. [CrossRef]
81. Hasson, F.; Keeney, S.; McKenna, H. Research guidelines for the Delphi survey technique. *J. Adv. Nurs.* **2000**, *32*, 1008–1015.
82. Wold, H. Path models with latent variables: The NIPALS approach. In *Quantitative Sociology*; Blalock, H.M., Ed.; Elsevier: Amsterdam, The Netherlands, 1975; pp. 307–357.
83. Hair, J.; Hollingsworth, C.L.; Randolph, A.B.; Chong, A.Y.L. An updated and expanded assessment of PLS-SEM in information systems research. *Ind. Manage. Data Syst.* **2017**, *117*, 442–458. [CrossRef]
84. Hair, J.F., Jr.; Hult, G.T.M.; Ringle, C.M.; Sarstedt, M.; Danks, N.P.; Ray, S. *Partial Least Squares Structural Equation Modeling (PLS-SEM) Using R: A Workbook*; Springer Nature: London, UK, 2021.
85. Ali, F.; Rasoolimanesh, S.M.; Sarstedt, M.; Ringle, C.M.; Ryu, K. An assessment of the use of partial least squares structural equation modeling (PLS-SEM) in hospitality research. *Int. J. Contemp. Hosp. Manage* **2018**, *30*, 514–538. [CrossRef]
86. Hair, J.F., Jr.; Hult, G.T.M.; Ringle, C.M.; Sarstedt, M. *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)*, 3rd ed.; Sage Publications: Thousand Oaks, CA, USA, 2021; ISBN 9781544396422.
87. Wold, H. Soft modelling: The basic design and some extensions. In *Systems under Indirect Observation, Part II*; North-Holland: Amsterdam, The Netherlands, 1982; pp. 36–37.
88. Lohmöller, J.-B. Predictive vs. Structural Modeling: PLS vs. ML. In *Latent Variable Path Modeling with Partial Least Squares*; Physica: Heidelberg, Germany, 1989; pp. 199–226.
89. Sarstedt, M.; Ringle, C.M.; Hair, J.F. Partial least squares structural equation modeling. In *Handbook of Market Research*; Homburg, C., Klarmann, M., Vomberg, A., Eds.; Springer: Cham, Switzerland, 2021; pp. 587–632.
90. Chin, W.W. The partial least squares approach to structural equation modeling. In *Modern Methods for Business Research*; Marcoulides, G.A., Ed.; Lawrence Erlbaurn Associates, Inc.: Mahwah, NJ, USA, 1998; pp. 295–336.
91. Tenenhaus, M.; Vinzi, V.E.; Chatelin, Y.-M.; Lauro, C. PLS path modeling. *Comput. Stat. Data Anal.* **2005**, *48*, 159–205. [CrossRef]
92. Noonan, R.; Wold, H. PLS path modeling with indirectly observed variables: A comparison of alternative estimates for the latent variable. In *Systems under Indirect Observations: Part II*; Jöreskog, K.G., Wold, H.O.A., Eds.; North-Holland: Amsterdam, The Netherlands, 1982; pp. 75–94.
93. Becker, J.-M.; Rai, A.; Rigdon, E. Predictive validity and formative measurement in structural equation modeling: Embracing practical relevance. In Proceedings of the International Conference on Information Systems, Milano, Italy, 15–18 December 2013.
94. Henseler, J. On the convergence of the partial least squares path modeling algorithm. *Comput. Stat.* **2010**, *25*, 107–120. [CrossRef]
95. Russo, D.; Stol, K.-J. PLS-SEM for software engineering research: An introduction and survey. *ACM Comput. Surv.* **2021**, *54*, 78.
96. Uraon, R.S.; Gupta, M. Do HRD practices affect perceived market performance through operational performance? Evidence from software industry. *Int. J. Prod. Perform. Manag.* **2020**, *69*, 85–108. [CrossRef]
97. Hair, J.F., Jr.; Matthews, L.M.; Matthews, R.L.; Marko, S. PLS-SEM or CB-SEM: Updated guidelines on which method to use. *Int. J. Multivar. Data Anal.* **2017**, *1*, 107–123. [CrossRef]
98. Dash, G.; Paul, J. CB-SEM vs PLS-SEM methods for research in social sciences and technology forecasting. *Technol. Forecast. Soc. Change* **2021**, *173*, 121092. [CrossRef]
99. Hair, J.F., Jr.; Hult, G.T.M.; Ringle, C.; Sarstedt, M. *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)*, 2nd ed.; Sage Publications: Thousand Oaks, CA, USA, 2016; ISBN 9781483377452.
100. Chen, X.; Yu, H.; Yu, F. What is the optimal number of response alternatives for rating scales? From an information processing perspective. *J. Mark. Anal.* **2015**, *3*, 69–78. [CrossRef]
101. Weijters, B.; Cabooter, E.; Schillewaert, N. The effect of rating scale format on response styles: The number of response categories and response category labels. *Int. J. Res. Mark.* **2010**, *27*, 236–247.
102. George, B.; Harris, A.; Mitchell, A. Cost-effectiveness analysis and the consistency of decision making. *Pharmacoeconomics* **2001**, *19*, 1103–1109. [CrossRef] [PubMed]
103. Martens, B.; Teuteberg, F. Decision-making in cloud computing environments: A cost and risk based approach. *Inf. Syst. Front.* **2012**, *14*, 871–893. [CrossRef]
104. Stacey, R.D. *Strategic Management and Organisational Dynamics: The Challenge of Complexity to Ways of Thinking about Organisations*, 6th ed.; Pearson Education: London, UK, 2011.
105. Teisman, G.R. Complexity and management of improvement programmes: An evolutionary approach. *Public Manag. Rev.* **2008**, *10*, 341–359. [CrossRef]
106. Giachetti, R.E. A decision support system for material and manufacturing process selection. *J. Intell. Manuf.* **1998**, *9*, 265–276. [CrossRef]
107. Lee, J.-C.; Shiue, Y.-C.; Chen, C.-Y. Examining the impacts of organizational culture and top management support of knowledge sharing on the success of software process improvement. *Comput. Hum. Behav.* **2016**, *54*, 462–474. [CrossRef]

108. Bon, A.T.; Zaid, A.A.; Jaaron, A. Green human resource management, Green supply chain management practices and Sustainable performance. In Proceedings of the 8th International Conference on Industrial Engineering and Operations Management (IEOM), Bandung, Indonesia, 6–8 March 2018; pp. 6–8.
109. Boxall, P.; Purcell, J. *Strategy and Human Resource Management*; Macmillan International Higher Education: New York, NY, USA, 2011.
110. Thong, J.Y.; Yap, C.-S.; Raman, K. Top management support, external expertise and information systems implementation in small businesses. *Inf. Syst. Res.* **1996**, *7*, 248–267. [CrossRef]
111. Lado, A.A.; Zhang, M.J. Expert systems, knowledge development and utilization, and sustained competitive advantage: A resource-based model. *J. Inf. Syst.* **1998**, *24*, 489–509.
112. Takala, J.; Bhufhai, A.; Phusavat, K. Proposed verification method for the content suitability of the customer satisfaction survey. *Ind. Manag. Data Syst.* **2006**, *106*, 841–854. [CrossRef]
113. Gupta, A.K.; Tesluk, P.E.; Taylor, M.S. Innovation at and across multiple levels of analysis. *Organ. Sci.* **2007**, *18*, 885–897. [CrossRef]
114. Goodland, R. The concept of environmental sustainability. *Annu. Rev. Ecol. Evol. Syst.* **1995**, *26*, 1–24. [CrossRef]
115. Armstrong, J.S.; Overton, T.S. Estimating nonresponse bias in mail surveys. *J. Mark. Res.* **1977**, *14*, 396–402. [CrossRef]
116. Ringle, C.M.; Wende, S.; Becker, J.-M. *SmartPLS 3. Boenningstedt*; SmartPLS GmbH: Hamburg, Germany, 2015.
117. Wagner, W.E., III. *Using IBM®SPSS®Statistics for Research Methods And Social Science Statistics*; Sage Publications: Los Angeles, CA, USA, 2019.
118. Wijaya, T.T.; Jiang, P.; Mailizar, M.; Habibi, A. Predicting Factors Influencing Preservice Teachers' Behavior Intention in the Implementation of STEM Education Using Partial Least Squares Approach. *Sustainability* **2022**, *14*, 9925. [CrossRef]
119. McKinney, V.; Yoon, K.; Zahedi, F.M. The measurement of web-customer satisfaction: An expectation and disconfirmation approach. *Inf. Syst. Res.* **2002**, *13*, 296–315. [CrossRef]
120. Hair, J.F.; Sarstedt, M.; Ringle, C.M.; Mena, J.A. An assessment of the use of partial least squares structural equation modeling in marketing research. *J. Acad. Mark. Sci.* **2012**, *40*, 414–433. [CrossRef]
121. Huang, C.-Y.; Wang, H.-Y.; Yang, C.-L.; Shiau, S.J. A derivation of factors influencing the diffusion and adoption of an open source learning platform. *Sustainability* **2020**, *12*, 7532. [CrossRef]
122. Smirnov, N.V. On the estimation of the discrepancy between empirical curves of distribution for two independent samples. *Bull. Math. Univ.* **1939**, *2*, 3–14.
123. Kim, H.-Y. Statistical notes for clinical researchers: Assessing normal distribution (2) using skewness and kurtosis. *Restor. Dent. Endod.* **2013**, *38*, 52–54. [CrossRef]
124. Bagozzi, R.P.; Yi, Y. On the evaluation of structural equation models. *J. Acad. Mark. Sci.* **1988**, *16*, 74–94. [CrossRef]
125. Jöreskog, K.G. Structural analysis of covariance and correlation matrices. *Psychometrika* **1978**, *43*, 443–477. [CrossRef]
126. Fornell, C.; Larcker, D.F. *Structural Equation Models with Unobservable Variables and Measurement Error: Algebra and Statistics*; Sage Publications: Los Angeles, CA, USA, 1981.
127. Ali, Z.; Sun, H.; Ali, M. The impact of managerial and adaptive capabilities to stimulate organizational innovation in SMEs: A complementary PLS–SEM approach. *Sustainability* **2017**, *9*, 2157. [CrossRef]
128. Henseler, J.; Ringle, C.M.; Sarstedt, M. A new criterion for assessing discriminant validity in variance-based structural equation modeling. *J. Acad. Mark. Sci.* **2015**, *43*, 115–135. [CrossRef]
129. Becker, J.-M.; Ringle, C.M.; Sarstedt, M.; Völckner, F. How collinearity affects mixture regression results. *Mark. Lett.* **2015**, *26*, 643–659. [CrossRef]
130. Kock, N. Common method bias in PLS-SEM: A full collinearity assessment approach. *Int. J. e-Collab.* **2015**, *11*, 1–10.
131. Johnson, D.H. The insignificance of statistical significance testing. *J. Wildl. Manag.* **1999**, *63*, 763–772. [CrossRef]
132. Browen, M.; Cudeck, R. Alternative ways of assessing model fit. In *Testing Structural Equation Models*; Bollen, K.A., Long, J.S., Eds.; Sage: Thousand Oaks, CA, USA, 1993.
133. Hu, L.t.; Bentler, P.M. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Struct. Equ. Model.* **1999**, *6*, 1–55. [CrossRef]
134. Podsakoff, P.M.; MacKenzie, S.B.; Moorman, R.H.; Fetter, R. Transformational leader behaviors and their effects on followers' trust in leader, satisfaction, and organizational citizenship behaviors. *Leadersh Q* **1990**, *1*, 107–142. [CrossRef]
135. Chang, S.-J.; Van Witteloostuijn, A.; Eden, L. *Common Method Variance in International Business Research*; Springer: New York, NY, USA, 2020; pp. 385–398.
136. Stacey, R.D.; Griffin, D.; Shaw, P. *Complexity and Management: Fad or Radical Challenge to Systems Thinking?* Roudedge: New York, NY, USA, 2000.
137. Yu, J.; Welford, R.; Hills, P. Industry responses to EU WEEE and ROHS Directives: Perspectives from China. *Corp. Soc. Responsib. Environ.* **2006**, *13*, 286–299. [CrossRef]
138. Lau, J.H. *Reliability of RoHS-compliant 2D and 3D IC Interconnects*; McGraw-Hill Education: New York, NY, USA, 2011.
139. Veleva, V.; Sethi, S. The electronics industry in a new regulatory climate: Protecting the environment and shareholder value. *Corp. Environ. Strategy* **2004**, *11*, 207–224.
140. Zhou, C.H.; Shi, H.; Wang, X.N. Study on RoHS data integration system based on Optical Character Recognition. *Appl. Mech. Mater.* **2012**, *220*, 2083–2086. [CrossRef]

141. Bernardo, M.; Casadesus, M.; Karapetrovic, S.; Heras, I. Do integration difficulties influence management system integration levels? *J. Clean. Prod.* **2012**, *21*, 23–33. [CrossRef]
142. Koh, S.C.; Gunasekaran, A.; Tseng, C. Cross-tier ripple and indirect effects of directives WEEE and RoHS on greening a supply chain. *Int. J. Prod. Econ.* **2012**, *140*, 305–317. [CrossRef]
143. Hu, A.H.; Hsu, C.W. Critical factors for implementing green supply chain management practice: An empirical study of electrical and electronics industries in Taiwan. *Manag. Res. Rev.* **2010**, *33*, 586–608. [CrossRef]
144. Wang, Z.; Wang, Q.; Zhang, S.; Zhao, X. Effects of customer and cost drivers on green supply chain management practices and environmental performance. *J. Clean. Prod.* **2018**, *189*, 673–682. [CrossRef]
145. Harrington, S.J.; Ruppel, C.P. Telecommuting: A test of trust, competing values, and relative advantage. *IEEE Trans. Commun.* **1999**, *42*, 223–239. [CrossRef]
146. Premkumar, G.; Ramamurthy, K.; Nilakanta, S. Implementation of electronic data interchange: An innovation diffusion perspective. *J. Inf. Syst.* **1994**, *11*, 157–186. [CrossRef]
147. Johansson, G.; Winroth, M. Introducing environmental concern in manufacturing strategies. *Manag. Res. Rev.* **2010**, *33*, 877–899. [CrossRef]
148. Zhu, K.; Kraemer, K.; Xu, S. Electronic business adoption by European firms: A cross-country assessment of the facilitators and inhibitors. *Eur. J. Inf. Syst.* **2003**, *12*, 251–268. [CrossRef]
149. Butler, T. Compliance with institutional imperatives on environmental sustainability: Building theory on the role of Green IS. *J. Strateg. Inf. Syst.* **2011**, *20*, 6–26. [CrossRef]
150. Leonidou, L.C.; Christodoulides, P.; Kyrgidou, L.P.; Palihawadana, D. Internal drivers and performance consequences of small firm green business strategy: The moderating role of external forces. *J. Bus. Ethics.* **2017**, *140*, 585–606. [CrossRef]
151. Karahanna, E.; Straub, D.W.; Chervany, N.L. Information technology adoption across time: A cross-sectional comparison of pre-adoption and post-adoption beliefs. *MIS Q.* **1999**, *23*, 183–213. [CrossRef]
152. Plouffe, C.R.; Hulland, J.S.; Vandenbosch, M. Richness versus Parsimony in Modeling Technology Adoption Decisions—Understanding Merchant Adoption of a Smart Card-Based Payment System. *Inf. Syst. Res.* **2001**, *12*, 208–222. [CrossRef]
153. Bohlouli, M.; Mittas, N.; Kakarontzas, G.; Theodosiou, T.; Angelis, L.; Fathi, M. Competence assessment as an expert system for human resource management: A mathematical approach. *Expert Syst. Appl.* **2017**, *70*, 83–102. [CrossRef]
154. Bae, S.; Seol, I. An exploratory empirical investigation of environmental audit programs in S&P 500 companies. *Manag. Res. News* **2006**, *29*, 573–579.
155. Laura-Diana, R. The impact of auditing on green information and communication technologies. *Financ. Audit.* **2016**, *14*, 217.
156. Puttlitz, K.J.; Galyon, G.T. Impact of the ROHS directive on high-performance electronic systems. In *Lead-Free Electronic Solders*; Springer: Berlin/Heidelberg, Germany, 2006; pp. 347–365.
157. Song, W.; Yu, H.; Xu, H. Effects of green human resource management and managerial environmental concern on green innovation. *Eur. J. Innov.* **2020**, *24*, 951–967. [CrossRef]
158. Grant, D.; Yeo, B. A global perspective on tech investment, financing, and ICT on manufacturing and service industry performance. *Int. J. Inf. Manag.* **2018**, *43*, 130–145. [CrossRef]
159. Lin, Y.-H.; Lee, P.-C.; Chang, T.-P. Practical expert diagnosis model based on the grey relational analysis technique. *Expert Syst. Appl.* **2009**, *36*, 1523–1528. [CrossRef]
160. Mesa, J.; Maury, H.; Arrieta, R.; Corredor, L.; Bris, J. A novel approach to include sustainability concepts in classical DFMA methodology for sheet metal enclosure devices. *Res. Eng. Des.* **2018**, *29*, 227–244. [CrossRef]
161. Menon, S.; George, E.; Osterman, M.; Pecht, M. High lead solder (over 85%) solder in the electronics industry: RoHS exemptions and alternatives. *J. Mater. Sci. Mater. Electron.* **2015**, *26*, 4021–4030. [CrossRef]
162. Latif, B.; Mahmood, Z.; Tze San, O.; Mohd Said, R.; Bakhsh, A. Coercive, normative and mimetic pressures as drivers of environmental management accounting adoption. *Sustainability* **2020**, *12*, 4506. [CrossRef]
163. Wing-Hung Lo, C.; Fryxell, G.E.; Tang, S.-Y. Stakeholder pressures from perceived environmental impacts and the effect on corporate environmental management programmes in China. *Environ. Politics* **2010**, *19*, 888–909. [CrossRef]
164. Song, M.; Wang, S.; Zhang, H. Could environmental regulation and R&D tax incentives affect green product innovation? *J. Clean. Prod.* **2020**, *258*, 120849.
165. Business & Legal Reports, Inc. *Global Environmental Challenge for U.S. Business: Are you Ready?* Business & Legal Reports, Inc.: Old Saybrook, CT, USA, 2009.
166. Goodship, V.; Stevels, A.; Huisman, J. *Waste Electrical and Electronic Equipment (WEEE) Handbook*; Elsevier Science: Amsterdam, The Netherlands, 2019.
167. Pecht, M.; Fukuda, Y.; Rajagopal, S. The impact of lead-free legislation exemptions on the electronics industry. *IEEE Trans. Compon. Packag. Manuf. Technol.* **2004**, *27*, 221–232. [CrossRef]
168. Carver, R. The case against statistical significance testing. *Harv. Educ. Rev.* **1978**, *48*, 378–399. [CrossRef]
169. Allen, C.; Mehler, D.M. Open science challenges, benefits and tips in early career and beyond. *PLoS Biol.* **2019**, *17*, e3000246.
170. Van Ark, B.; O'Mahoney, M.; Timmer, M.P. The Productivity Gap between Europe and the United States: Trends and Causes. *J. Econ. Perspect.* **2008**, *22*, 25–44. [CrossRef]

171. Mante-Meijer, E.; Haddon, L.; Concejero, P.; Klamer, L.; Heres, J.; Ling, R.; Thomas, F.; Smoreda, Z.; Vrieling, I. *Checking It Out with the People–ICT Markets and Users in Europe*; EURESCOM: Heidelberg, Germany, 2001.
172. Koruza, J.; Bell, A.J.; Frömling, T.; Webber, K.G.; Wang, K.; Rödel, J. Requirements for the transfer of lead-free piezoceramics into application. *J. Mater.* **2018**, *4*, 13–26. [CrossRef]