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RESEARCH ARTICLE

Investigation of industry 4.0 technologies mediating effect on the supply chain performance and supply chain management practices

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Abstract

The aim of the present article purposefully explores how industry 4.0 may alter conventional methods of administration by performance of supply chain. Nowadays, the business activities/processes have been raised and all are directly associated with industrial revolution. Industry 4.0 acts as a go-between for improved supply chain efficiency and more traditional forms of logistics management. Discovering the transformative effects of industry 4.0 on supply chain management by reading on, however, SCM practices, this study considers the questioner-based data from September 2021 to March 2022 for China economy. Interestingly, the findings of structural equation model (SEM) describe the supportive response of revolution (the fourth industrial revolution) to supply chain management in the previously described field. The consequences of this research argue that the supportive role of technological progress in industrial revolution brings efficient supply chain management. Moreover, the performance indicators under the supply chain work well due to significant progress in industry 4.0. In concluding remarks, such types of advanced technologies serve as an intermediate between the management and practices of supply chain. However, the results provide light on the basic principles behind the success. In addition, these technologies make it possible to significantly improve the performance by allowing process unification, mechanization, and automation and introducing innovative analytic capabilities and supply chain operations including procurement, production, and inventory management, and marketing may work together more efficiently. Some of these processes include marketing, inventory management, and procurement. These improvements are attainable through the implementation of innovative scientific capabilities.

Keywords Industry 4.0 · Supply chain management practices · Supply chain performance · Structural equation model (SEM)

Introduction

The present economic climate, the intensity of competition, the rapidity of technological development, and the operations and supply chain management (SCM) tasks at hand are all factors that companies cannot afford to disregard in the current global market (Chang et al. 2019). The phrase "supply chain management" (SCM) refers to the practices that companies use to coordinate the production, distribution, and consumption of products and related data among all parties involved in the supply chain. A wide variety of interested parties' life can communicate and collaborate more easily thanks to SCM. Increased product quality, reduced uncertainty, increased brand value, and decreased expenses all contribute to better administration of a supply chain (Jiang et al. 2021b). Controlling the flow of supplies and transportation operations are successful when they effectively handle customer demand, product delivery, and information flow across the supply chain (SC) network (Yan et al. 2023). By streamlining operations to better focus on customers, SCM tackles a wide range of strategies.

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Supply chain management (SCM) is more all-encompassing than coordination management because of the interdependence of key business processes, as stated by Haldorai et al. (2022). The referenced study stressed the significance of cooperation between companies as well as within companies (Jiang et al. 2021a). Organizational actions have a framework that includes the execution of basic tasks, value-added tasks, planning and control, and strategic decision metrics. Organizational rivalry in the supply chain is of growing importance to companies, and a thorough analysis of this factor can help lay the groundwork for successful strategic planning (Yi et al. 2023). Everyone involved in SC must do so with the purpose of contributing to an environment that is both dynamic and competitive and conducive to long-term company success (Wang et al. 2022).

Management of the demand, operations, procurement, and transportation processes are all part of what is known as supply chain management, an all-encompassing and comprehensive strategy (Kouhizadeh et al. 2021). This article postulates that in the present economic epoch, three distinct periods of supply chain management have emerged. The three phases are improved operations, increased supply chain coordination and collaboration, and the rise of online marketplaces (Li et al. 2020). Growth is essential for companies at every stage of the production chain; the organizational, administrative, technological, and strategic competencies and capacities are necessary to meet the following four developing requirements: an emphasis on the consumer, the implementation of new technology, the management of existing relationships, and various styles of leadership (Wu et al. 2023). Keep in mind that supply chain management has three levels of coordination: between departments, within departments, and between organizations (Chang et al. 2019). It is recommended that supply chain management follows a sequential process consisting the four phases of supply chain development optimization, material movement planning, and supply chain deal closing.

In essence, industry 4.0 paves the way for the robotic, hand-free manufacturing, distribution, and supply chain management of goods and services. The term "industry 4.0" refers to the current trend towards greater automation in manufacturing, which includes technologies and processes like physical and cyber-physical systems (CPS), the industrial Internet of Things (IIoT), cloud-based cognitive computing, and artificial intelligence (AI). Industrial facilities and transportation vehicles are only two examples of system components that make autonomous, well-informed decisions with little oversight from higher-level supervision (Liu X et al. 2023). A digital manufacturing company is connected, but it also communicates, analyzes, and uses information to drive intelligent behaviors back into the actual world. However, research on the positive and negative impacts of industry 4.0 on SCM is lacking (Benzidia et al. 2021). We typically refer to SCM in the era of industry 4.0 as "SCM 4.0." With SCM 4.0, digital and autonomous relationships between companies are prioritized above the enterprises themselves. Supply chain management (SCM) 4.0 refers to the incorporation and automation of digital technology into the coordination of physical goods, data, and money flows across corporate networks. The vast majority of previous studies on supply chain digitization have zeroed in on one specific technology or application, such as cloud computing or big data analytics (see also (Duong et al. 2022); (Huo et al. 2019); (Benzidia et al. 2021); (Guo et al. 2023). Supply chain digitalization, or "the new connected business system that extends beyond isolated, local, and single-company application to supply chain wide comprehensive smart implementations," is a topic of discussion (Khan et al. 2021b).

The value creation potential of digitalization is predicted to surpass 100 trillion USD by 2025 (Lau et al. 2022), allowing for significant shifts in both internal and external business operations. Consequently, "industry 4.0" has emerged, with many of the world's most valuable corporations participating by adopting digital technology for use in their operations and supply networks. Several researchers have concluded the advantages of digital servitization, which they describe as the "industrial businesses' and their partner ecosystems' transformation in process, capability, and offering to progressively create, deliver, and capture increased service value arising from a broad range of enabling digital technologies" (Fülöp et al. 2022, p. 574). The external linkages and frictions between enterprises (Kovacova and Lăzăroiu 2021);(Han and Trimi 2022);(Guo et al. 2022) are the source of some of the most significant difficulties in digital servitization. Businesses may overcome these obstacles with the use of industry 4.0 technology because they facilitate the implementation of inter-organizational logics, enhance the administration of supply chains, and reform inter-organizational procedures. Therefore, it is crucial to examine how supply chains are impacted by industry 4.0 technologies.

Potential effects of industry 4.0 indirectly influence the rate at which businesses in China region adopt supply chain management (GSM) and supply chain performance. To the authors' knowledge, however, there is no such empirical investigation in the existing literature connecting the impact of SCM, industry 4.0, and supply chain performance. This study addresses the following research topic in order to fill the void in the literature: When it comes to SC management and performance, how does industry technologies of version 4.0 come in? In this analysis, we use a hierarchical, multi-level framework built using structural equation model (SEM) to learn where supply chain management fit well with industry 4.0 developments and performance. The suggested hypotheses were tested using survey answers from Chinese employees who filled out a questionnaire. The goal of this study is to give hard data that supports the developing connection between the two influential paradigms of sustainability in the supply chain and the fourth industrial revolution.

What follows is the outline for the remainder of the paper. In the "Literature reviews and hypothesis development" section, we will examine the existing research papers on GSM, GS performance, and industry 4.0 measures in order to formulate some hypotheses. In the "Methodology" section, we detail our study technique, which is grounded on a structural equation model (SEM) approach. The analysis and presentation of data constitute the "Results and analysis" section. Important interpretations in the "Discussions and conclusions" section provide a summary of the findings, and we present our suggestions for future studies and discuss how our findings contribute to the field.

Literature reviews and hypothesis development

An overview of industry 4.0 and supply chain management

In an effort to lessen the negative effects of business on the environment, sustainable supply chain management (SSCM) (X. Tang 2022) was developed during the last decade—"the management of material, information and capital flows as well as the cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e. economic, environmental and social, into account which are derived from customer and stakeholder requirements" (Guo et al. 2017). As previously said, SSCM places a premium on striking a harmony between these three goals (Siyu et al. 2023). The same vein gave rise to the circular economy model, a method to maintaining the closed-loop cycle of resources and energy. A circular economy is one that prioritizes economic growth and development above the short-term gain from resource extraction and disposal (Yu and Huo 2019). By fusing the concepts of SSCM with the circular economy, the concept of circular supply chain management (CSCM) was born. One of the first investigations into circular supply networks is by Schroeder et al. (2019), which focuses on product recovery management. They also developed a framework for reuse, repair, refurbishment, and recycling which are all possible steps in an integrated supply chain that accepts returns from clients. The literature on circular economy supply chains has continued to focus on closed-loop supply networks and reverse logistics, which explains the meaning of "circular supply chain management" (CSCM) in light of the foregoing as "the configuration and coordination of the organizational functions marketing, sales, R&D, production, logistics, IT, finance, and customer service within and across business units and organizations to close, slow, intensify, narrow, and dematerialize material and energy loops to minimize resource input into and waste and emission leakage out of the system, improve its operative effectiveness and efficiency and generate competitive advantages". A wide range of supply chain participants (e.g., municipal governments, businesses, construction firms, and banks) are urged to place a premium on circular economy principles in order to lessen their negative environmental impacts and make more responsible use of natural resources (Park et al. 2020). Therefore, CSCM is associated with management practices in the sustainable supply chain work to prevent or at least delay negative impacts and environmental effects caused by the whole cradle-to-grave lifecycle of a product (Sarfraz et al. 2022). This fresh approach to the life cycle reveals how garbage may be turned into a profitable resource that helps save the planet.

Many studies have shown that circular supply chain management may benefit from industry 4.0's implementation. Advancements like internet of things and large amounts of data. Saving money and increasing productivity are two major drivers for the widespread use of CS (Meidute-Kavaliauskiene et al. 2021). One of the most important aspects of CSCM is information dissemination along the supply chain (Korhonen et al. 2018); (Yan et al 2021) and the use of accurate forecasting techniques that also help to cut down on waste generation. Because to stakeholder pressures from regulatory agencies, Non-Governmental Organizations (NGOs), supply chain partners, competition, low levels of flexibility, and delayed market entrance, businesses must give equal weight to environmental, social, and economic concerns. (Belhadi et al. 2021). Uncertainty in supply chains is amplified by the interconnected and ever-changing nature of these components (Ercantan and Eyupoglu 2022); (Tu et al. 2020). Industry 4.0 offers answers to these problems by reimagining the supply chain as a platform for digital networks (Yin et al. 2023); (Chen et al. 2022) and stresses the significance of assessing trust, cultures, and behaviors in supply chains and inter-sectoral networks using big data-driven analysis in order to boost sustainability. A smart collection application for garbage management using IoT technology has been presented by academics in the field of municipal logistics. To optimize the transit of scrap metal containers and determine when they are full, the Internet of Things is used in industrial settings. The enhancement was made to a smart waste management platform that, among other things, allows for the monitoring of wastes' distances and offers a suite of analytic services to improve resource allocation and planning in supply chains. Ercantan and Eyupoglu (2022) have looked at sustainability problems in industrial revolution viewpoint on the shipbuilding supply chain. Through their efforts, a connection has been made between 12 key enabling technologies (including the Internet of Things, artificial intelligence, big data, autonomous robots, and cyber-security) and 4 supply chain strategies (including lean, agile, resilient, and green practices). The industrial uses of AI which is the top-ranked strategy for addressing SSCM difficulties include eco-design of goods and life cycle assessment, supply chain digitalization, and implementation of the 6 Rs (recycle, reuse, reduction, refusal, rethink, and repair), as evidenced by the application of the automobile sector's embrace of 4.0 and the circular economy. The food industry may become more environmentally friendly and reduce waste, costs, emissions, and negative social impacts with the use of Internet of Things (IoT) supply chain technologies. Choi et al. (2021) have proposed a web-based framework to track products and their suppliers from beginning to end. In the leather shoe industry, there research confirms that the system has the potential to increase environmental sustainability in the supply chain and is an efficient decision-making tool (Quan et al. 2021).

Recent studies have shown that by using industry 4.0 technologies, businesses and their supply chains may increase their sustainability. They found that, thanks to preventative maintenance measures, scrap metal monitoring could be cut by 20% and scrap metal creation could be cut by 4%. For the practices to be effective, the imperative must first be included into the organization's overarching strategy. Adopting and implementing innovations, such as new technology, programmers, and activities, requires buy-in from upper management. Top-level commitment is required for environmental excellence (Di Vaio and Varriale 2020);(Khan et al. 2021b); (Khan et al. 2018). According to research (Rejeb et al. 2020a), GSCM practices are more likely to be put into action when there is both organizational learning and managerial support. Initial product and process design are where environmental excellence begins, according to the following:

H1. Buying green products has immediate and beneficial effects on industry 4.0.

H2. The recovery of investments has a direct and beneficial effect on industry 4.0.

H3. Reverse logistic directly and positively impacts industry 4.0.

H4. Agile exercise has an immediate and beneficial effect on industry 4.0.

H5. Green exercise has an immediate and beneficial effect on industry 4.0.

H6. The supply chain is a direct target of and beneficiary of industry 4.0.

Supply chain performance and industry 4.0

The literature on supply chain management is rife with difficult topics, and supply chain performance is right up there with them (Rajesh 2020);(Yu and Huo 2019);(Khanfar et al. 2021a, 2021b);(Lu et al. 2023). Performance in the supply chain may be evaluated by looking at how well it handles things like adaptability, dependability, responsiveness, quality, and asset management. Similarly, Novak et al. (2021) think about metrics of performance including adaptability, efficiency, responsiveness, and quality. Alternatively, performance enhancements may be evaluated in terms of options, novelty, timeliness, affordability, and accessibility using a technique based on Hopkins (2021).

When it comes to managing connections and boosting supply chain effectiveness, information exchange is often regarded as a crucial factor. In order to improve supply chain performance via more information sharing, businesses are investing in technology advances to create efficient communication channels and cooperation mechanisms (Costa and Matias 2020). It is widely agreed that the success of a business is dependent on how well its operations are integrated. Therefore, a substantial amount of communication between the various supply chain partners and activities is required to enhance supply chain performance. Supply chain integration is critical for the smooth operation of information flows and the growth of end-to-end business procedures. The cost, quality, diversity, and service level may all benefit from a more integrated system (Gupta et al. 2021). Improvements in supply chain performance may also be attributed to the increased adaptability made possible by integrated and collaborative processes. As we have seen, integration may boost productivity in the workplace by making it easier to share and use data. As a result, operational performance in terms of adaptability and reactivity (Yadav et al. 2020) may be enhanced. Because they provide efficient supply chain risk management, agile and resilient supply chains can have a significant impact on supply chain efficiency. Furthermore, it is widely accepted that increased supply chain visibility and transparency greatly improve operational effectiveness (Çalık 2021). Since supply chain practices cut across functional boundaries, it has been challenging to address the aforementioned challenges and improve supply chain performance. To address this issue, many companies have resorted to information technology (IT) and other forms of technology. Technology may aid supply chain integration by acting as a connecting link between traditionally independent corporate processes, which in turn boosts efficiency (Nica and Stehel 2021); (Belhadi et al. 2022). E-Business solutions are only one way that many companies are using IT to better their operations, while others are seeking to creative and inventive IT to better their process integration and analytical skills. The incorporation of industry 4.0 enabling-technologies into supply chain management is seen as a promising approach to the integration challenge because it is expected that these technologies will revolutionize supply chain management by bringing about high levels of connectivity and comprehensive integration (Belhadi et al. 2021) and thus lead to significant gains in supply chain performance (Hasni et al. 2022).

Yin et al. (2023) is widely credited as the venue where the phrase "industry 4.0" was first used (Pavlínek 2015). Companies may gain from the implementation of industry 4.0 form of linked, adaptable, and diverse production systems that ultimately yield individualized goods (Zhang and Wei 2015). Businesses now have the ability to more efficiently distribute their resources in real time thanks to the tools made available by industry 4.0. The four foundations that support industry 4.0 are manufacturing in the cloud, IoT, additive manufacturing, and cyber-physical systems. The cyber-physical system is a network that combines the internet with physical systems, items, tools, and devices to acquire real-time data for use in making decisions about things like output order priorities, preventative repair schedules, and process optimization (Yang et al. 2020). Data collection and dissemination are simplified by the IoT between various gadgets and inanimate items (Khan et al. 2021c). Technologies like radio-frequency identification (RFID), bar codes, and mobile phones are essential to the functioning of the Internet of Things devices. Information about shared and available production assets is made available via "cloud manufacturing" (Çalık 2021). IoT allows businesses to efficiently gather and analyze massive amounts of data for use in making informed decisions. For instance, there are business apps that aim to lessen the amount of energy used in production and support industries like taxis (Yang et al. 2020); (Huq et al. 2016). Among the many commercial uses of cloud computing are tracking the performance of traffic management systems and determining carbon footprints (Fülöp et al. 2022). Energy management may benefit from AI (Xi et al. 2022); (Fülöp et al. 2022). Companies can save money on production conversion by using IT-enabled quality tools and continuously monitoring their processes (Kovacova and Lăzăroiu 2021);(Chen and Lin 2020). However, some of technology improvement studies with supply chain performance also provide interesting outcomes (Ahmed et al. 2023a, 2023b; Kazmi and Ahmed 2022; Ahmed et al. 2020; Ahmed et al. 2023a, 2023b).

We argue that SCM has become a strategic need because shoppers want products made using processes designed and managed to minimize their impact on the natural world. It is recommended that a product's environmental performance be measured using a matrix that takes into account the whole impact that the supply chain has on the environment. Better economic and environmental results were shown to be associated with the implementation of supply chain practices. A study explains the potential "green multiplier effect" that could arise when environmentally responsible purchasing practices are implemented at all levels of a company's supply chain, not just the first. This effect is driven by the company's ability to build strong partnerships and close cooperation with its suppliers. Some argue that more environmentally friendly purchasing and supply practices will improve overall efficiency (Khokhar et al. 2020). Manufacturing businesses' environmental performance is prioritized when SCM practices are implemented. Improvements in environmental performance are the ultimate aim of eco-friendly practices such as "green buying," "green practices," and "investment recovery." After investigating a variety of variables influencing their adoption, researchers (X. Chen et al. 2022) found that green design improves supply network performance.

H7. The effectiveness of chain of production and the fourth industrial revolution is impacted both directly and indirectly by green purchasing decisions.

H8. Supply networks and manufacturing 4.0 may both benefit immediately from recovering wasted funds.

H9. Does Green actions have immediate, beneficial effects.

H10. Effects of reverse logistics, both immediately and indirectly, are good. How The Impact of Industry 4.0 on Supply Chain Efficiency.

H11. Positive and direct effects of agile practices on logistics in the age of industry 4.0 efficiency.

Theoretical background

Supply chain management's foundational assumptions and performance theories, however, need to be discussed to clear the theme to the reader. However, under the specified terms, there are five different forms of SCM. The major focus of RBV is on acquiring another firm's core skills for the purpose of gaining superiority over one's rivals. The assets of a corporation are its resources and expertise, according to RBV. When it comes to SCM, or supply chain management, RBV is a popular theory. In theory of stakeholders (ST), in addition to shareholders, stakeholders are a focus of stakeholder theory. Stakeholder value creation is the main emphasis. Several business choices, such as supplier strategy, outsourcing strategy, and make-or-buy decision, are informed by this notion. There is a direct connection between SCM and ST in terms of decision-making. In theory of institutions (IT), formal structure of an organization may be heavily influenced by institutional pressure and legitimacy. Technical efficiency has withstood the test of time in a competitive market which may be guaranteed by a well-structured organization. The way we think about SCM and related topics may need to change in light of this notion. The purpose of transaction cost theory (TCT) is to shed light on why businesses of a certain kind are necessary. Specifically with the field of SCM (supply chain management), TCT seeks to lessen the financial burden of making a make-or-buy decision. Three characteristics of a company affect whether consumers decide to make or purchase from it. Transaction frequency, asset specificity, and transaction uncertainty are the three main factors. To prevent supply chain enterprises from engaging in exploitative behavior during outsourcing, TCT advocates the use of a variety of control and governance methods. According to RDT, a company needs access to a wide variety of resources in order to function well. It is possible that a company does not have the resources to handle everything fairly. Because of this, it has the potential to form bonds with other beings. According to RDT, businesses need to build social exchanges to get access to complementary and diverse resources. While supply chain performance is crucial for every business, the growing digital age operation complexity has made it harder to achieve. "The efficient and effective execution of supply chain tasks" is what is meant by "supply chain performance" (He and Ortiz 2021). Business logistics and supply chain management reveal that a lot of effort has been made to better understand supply chain performance behaviors (Yu and Huo 2019)(Lu et al. 2010)(Czernek 2013) and (Purwandari et al. 2022). Several researchers have observed the influence of correlations among supply chain efficiency and several other aspects. The boundary between service providers and customers is considered, as well as the relationship between logistics innovation and performance, and the connection between knowledge sharing and logistics innovation (Zachariadis et al. 2019).

Methodology

Due to the inductive and exploratory nature of the study's goals, a survey research strategy was used. To that end, a well-organized survey was created for this research. The first part of the questionnaire is dedicated to gathering general information about the respondents and their organizations. The next tasks include data collection on the different notions required to establish causal links. The survey was created only in English and uses a five-point Likert scale. The constructs were measured using tools borrowed from other research and modified to fit the present investigation. The variables used in this analysis include green purchasing (the practice of requiring suppliers to meet specific environmental standards for the goods they provide), investment recovery, and reverse logistics, also known as reuse (Lv et al. 2020)(Khan et al. 2021c). As this field continues to develop, there is still significant uncertainty and gaps in the established scale on industry 4.0 (Ghadimi et al. 2019). Tools for smart manufacturing are from Novak et al. (2021), Hopkins (2021), and Gupta et al. (2021). Participants were asked to rate the growth or decline of their organization's supply chain performance over the last several years. To evaluate SC effectiveness, we used a scale derived from.

Data collection

Furthermore, to follow the case studies of Çalık (2021), this study has made an effort to clear all the ambiguity regarding the structural equation model. During the period of September 2021 to March 2022, the present study gathered observational data from a variety of manufacturing companies located throughout India. In the present investigation, a survey was conducted using a standard questionnaire that was primarily made up with no room for interpretation. According to a five-point Likert scale, ranging from "no" application (1) to full execution (5), respondents ranked the topics (5). A preliminary exam will be administered to academics and professionals to ensure the findings are accurate and consistent. In order to keep the study at a high level of quality and strategy, some adjustments were made as a result of their recommendations. The complete collection of all seven structures is reflected across the final instrument's 23 pieces, which together make up the finished instrument. There are four components to the construct of green purchasing. Just as there are three parts to investment recovery, there are four subparts that make up each of these: methods for managing the supply chain, supply chain management outcomes, reverse logistics, and industries entering the fourth industrial revolution. After that, 700 employees in India's industrial sector were sent new questionnaires with cover sheets explaining the study's goals, data security, and ethical considerations. A question was posed to the interviewees, asking them to identify the degree to which their organizations have put these technologies into use. We obtained a total of 485 respondents to the survey. However, after thorough examination, it was determined that sixty of the submissions were lacking important information. In the end, a total of 425 responses that were considered legitimate were utilized for further research. The percentage of people who responded was approximately 52%. The demographic information for 425 manufacturing professionals from across India is presented in Table 1. In terms of the age distribution, the majority of respondents fall into the bracket of 31–40 years

Table 1 Characteristics of sample (sample size = 425)

Gender	425	Age		Educational level	
Male	75.76%	20–30	30%	Under graduate	54.5%
Female	24.24%	31–40	42.87%	Post graduate	35.37%
Years of experience		41–50	12.83%	PhD	10.13
0–5	19.48%	51–60	4%		
5–10	32.29%	61–70	9.3%		
10–15	25.87%	Above 70	1%		
15–20	22.36%				

old. In a similar manner, there are 322 male respondents while there are only 103 female respondents when looking at the gender distribution. Regarding their level of schooling, the vast majority of respondents hold bachelor's degrees or higher. According to the categorization that is based on experience, the majority have between 5 and 10 years of experience. Table 1 should be consulted in order to obtain further information.

Structural equation model

However, the current study tries well to follow-up the recent studies that have employed very interesting methodology such as Ahmed et al. (2021) and Qazi et al. (2021). The "complex" associations between measured and unmeasured (latent) variables, as well as the relationships between two or more latent variables, may be tested by SEM. It incorporates both factor analysis and multiple regressions. SEM is an efficient strategy for taking into account the unreliability of survey answer, and it is also a helpful tool for dealing with multicollinearity. When one of your dependents has to be treated like an independent in your analysis, SEM may be a helpful method (Babajide et al. 2021). When analyzing the impact of SCM competitive advantage, for instance, factors such as advanced IT-based automated ordering to suppliers and cutting-edge IT throughout the supply chain are first seen as dependent variables.

Evaluation of the model

Four criteria, item reliability, internal consistency, a measurement model's convergent validity, and discriminate validity, were tested in this research.

Dependability of items

The reliability of survey questions was evaluated by looking at their item loadings on some underlying latent variable. All of the items' standardized loadings must be more than 0.70 (Chen and Yang 2021). Items with loadings greater than 0.7 in Table 2 were considered acceptable.

Validity that converges

This criterion looks at how closely connected survey questions really were in the field. In order to establish convergent validity, we looked at the concepts' internal consistency and the average variance (AVE) (Fornell & Larcker, 1981).

Composite reliability was used to determine whether or not a particular latent component was internally consistent. The overall trustworthiness of a model must be greater than 0.70 for it to be considered internally consistent. That is according to a study (Nunnally, 1978).

AVE takes into consideration the effects of measurement error by contrasting the amount of variation that a latent construct obtains from its indicators with the amount of variation that may be attributed to measurement errors. If the adjusted variance equivalent (AVE) is at least 0.50, then it is possible to account for at least half of the variation in the indicators. The average variance estimates (AVEs) of the latent constructs in the research model are shown to be more than 0.5 in Table 3.

Validity for discrimination

Examining (a) whether the square root of the AVE, i.e., for each latent construct, exceeds its association coefficients with

Table 2 Means, median, standard deviations, Cronbach's alpha value, average variance extracted, and composite reliability

Variables	Mean	Median	Std. dev.	Cronbach's alpha	AVE	CR
SCP	5.276	4.976	0.873	0.947	0.827	0.921
I4.0	1.471	1.387	1.094	0.873	0.729	0.956
GP	3.173	2.989	0.976	0.956	0.976	0.878
IR	9.537	9.438	1.563	0.832	0.742	0.812
RL	3.658	3.546	0.845	0.865	0.839	0.935
AP	0.325	0.216	0.765	0.921	0.759	0.841
GRP	1.153	0.965	0.945	0.865	0.943	0.906

SCP supply chain management, *I4.0* industry 4.0, *GP* green purchasing, *IR* investment recovery, *RL* reverse logistic, *AP* agile practices, *GRP* green practices

Table 3 Discriminant validity

Variables	SCP	I4.0	GP	IR	RL	AP	GRP
SCP	0.954						
I4.0	0.176*	0.913					
GP	0.472**	0.327*	0.854				
IR	0.276*	0.248*	0.621*	0.945			
RL	0.037**	0.538**	0.137**	0.643*	0.876		
AP	0.547*	0.643**	0.057*	0.155**	0.076*	0.923	
GRP	0.525*	0.417*	0.215**	0.629*	0.397**	0.096*	0.841

*, ** and *** means 10%, 5% and 1 level of significance

other latent constructs (Menkeh 2021) and (b) whether the survey items load a greater amount on the latent constructs than on other latent constructs (Gefen and Straub 2004) are common ways for researchers to evaluate the discriminant power of their research model (Centobelli et al. 2019).

Results and analysis

Summary statistics

In the present investigation, the reliability of the model, as well as its ability to discriminate between groups, is assessed using generally accepted normative criteria. Table 2 summarizes these findings for your perusal. First, we carry out the reliability analysis in order to calculate the values of Cronbach's alpha, which are then appraised for the structures. Cronbach's alpha should have a number that is greater than 0.70 for the dependability to be considered exceptional (Li et al. 2021a, 2021b)(Chen et al. 2021). Table 2 presents the average variance recovered (Gunasekaran et al. 2004), as well as the mean, median, composite reliability, standard deviation, and Cronbach's alpha (CR) of the final constructs. According to the findings of this research, the calculated reliability analysis varied from 0.832 to 0.956, "which is greater than 0.7," the threshold as suggested by Khan et al. (2021a, 2021b, 2021c) and Li et al. (2021b).

Discriminant validity

The Fornell-Larcker criterion was applied to each and every construct in order to determine whether or not they met the requirements for discriminant validity. The concept is likely suboptimal if its overall variance is lower than the mean variance of all constructs. Discriminant validity results from the research are shown in Table 3. If the AVE's square root is greater than the correlation values on all constructs, then the AVE has discriminant validity (Oliveira et al. 2017). The off-diagonal values revealed the relationships between the different structures, whereas the diagonal ones reflected the square root of the AVE. Overall, the square component AVE values were higher than the correlation coefficients at the construct level, as seen in Table 3. This demonstrated the discriminating potential of the latent variables. It was shown through the research that the buildings are autonomous from one another. The findings and conclusions of the convergent and discriminant validity analyses are presented in Tables 2 and 3, respectively. The evidence points to good convergent and discriminant validity on the whole. Since each of the seven constructs has been shown to be uni-dimensional, and since the activity of one construct is related to that of the others, we can be confident that the measures function as intended. As a consequence, we are able to conduct structural equation modeling in order to generate accurate findings. Table 3 shows the discriminant validity.

The heterotrait-monotrait (HTMT) ratio, which provides estimates of the true correlations across components, is another sign of discriminating validity (Haldorai et al. 2022). Discriminant validity is present if the HTMT score is less than 0.90. Table 4 demonstrates that most estimates fell well short of the target of 0.90.

In the SEM fit, CMIN(X^2)/df is one of the widely used estimates of the study model fit, as stated by Hair and colleagues. Model fits with CMIN(X^2)/df numbers between 3 and 1 are demonstrated to be satisfactory. When the CFI is close to 1, it indicates that the two models are a good fit (Khan et al. 2021a); (Ahmed and Omar 2019). Very excellent model fit is indicated by normed fit index (NFI) values near 1, incremental fit index (IFI) values near 1, and Tucker-Lewis index (TLI) values near 1. This model has a very good fit, with a root mean square error of approximation (RMSEA) of less than 0.08. Because of this, the model's secret ingredients are now concurrently valid across different populations. The ideal and actual model fit values are shown in Table 4. However, the given Table 5 based on the one tail test and chi-square can be considered as evidence.

Path analysis of a hypothetical model

The results, including the computed route variables, are shown in Table 6 after we have analyzed the probabilities of each possible event. The SEM results show that hypotheses H2, H3, and H5 are supported at the *p* 0.05 level, whereas hypotheses H1,

Table 4 Heterotrait-monotrait (HTMT) ratio for discriminant validity

Variables	SCP	I4.0	GP	IR	RL	AP	GRP
SCP	0.623						
I4.0	0.512	0.527					
GP	0.556	0.429	0.567				
IR	0.562	0.176	0.527	0.325			
RL	0.428	0.472	0.436	0.261	0.337		
AP	0.187	0.563	0.266	0.421	0.218	0.478	
GRP	0.426	0.435	0.369	0.634	0.509	0.267	0.462

Table 5 Model fit suggested value and observed value

Fit indices	CMIN(X^2)/df	CFI	NFI	IFI	TLI	RMSEA
Suggested values	<3	≥ 0.95	>0.9	>0.9	>0.9	≤ 0.07
Actual values	2.873	0.934	0.976	0.952	0.993	0.059

TLI Tucker-Lewis index, *RMSEA* mean square error of approximation, *CFI* comparative fit index, *NFI* normed fit index, X^2 chi-square

Table 6 Hypothesis outcomes for the SEM

Hypothesis	Coefficient	Std. dev.	*T*-statistics	*p*-value
H1 GP→I4.0	0.215*	0.069	1.763	0.000
H2 IR→I4.0	0.128**	0.165	1.298	0.034
H3 RL→I4.0	0.273	0.128	2.139	0.115
H4 AP→I4.0	0.387	0.147	2.738	0.268
H5 GRP→I4.0	0.178*	0.421	1.865	0.003
H6 I4.0→SCP	0.356*	0.216	1.912	0.000

*, ** and *** means 10%, 5% and 1 level of significance

Table 7 The results of the mediation effect

Relationship	Coefficient	Std. dev.	*T*-statistics	*p*-values
GP→I4.0→SCP	0.556**	0.326	2.873	0.054
IR→I4.0→SCP	0.176**	1.065	3.326	0.023
GRP→I4.0→SCP	0.246*	0.715	2.767	0.005
RL→I4.0→SCP	0.386**	0.873	2.278	0.047
AP→I4.0→SCP	0.233**	0.369	5.287	0.017

*, ** and *** means 10%, 5% and 1 level of significance

H4, and H6 are supported at the *p* 0.001 level. According to the study's findings, customers that place a high value on environmental responsibility are more inclined to buy into industry 4.0 solutions (= 0.215, *p* 0.000) (H1). There is a strong correlation between use growth and ecologically responsible buying practices and a company's chance of effectively adopting industry 4.0 technologies, with a rise of 0.215% in the former and 1% in the latter. Similarly, the outcomes demonstrate the limits of what is now possible with agile industry 4.0 technology (= 0.387, *p*-value 0.000) (H3), investment recovery has a significant impact (= 0.128, *p*-value 0.034) (H2), and reverse logistics has a significant impact (= 0.273, *p*-value 0.015) (H2). In addition, increasing the prevalence of these practices by just one percent increases 0.128%, 0.273%, and 0.387% more likely that industry 4.0 technology will be effectively deployed. Based on the evidence presented, it was determined that hypothesis H5—that there are strong ties between GRP and industry 4.0 technologies—is false (= 0.178, *p*-value 0.003). The findings show that with every 1% increase in GRP installations, increased likelihood of industry 4.0 technology being successfully adopted is 0.178%. It was hypothesized (H6) that there are significant positive connections between the impact of industry 4.0 on supply chain efficiency, which is quite similar to H5 (= 0.356, $p = 0.000$). It also demonstrates that for every 1% improvement in industry 4.0 technology, supply chain efficiency may be enhanced by 0.356%.

Mediation analysis

In this investigation, we utilized mediation analysis to explore how the spread of industry 4.0 technology modifies the relationship between SCM best practices and the idea of SCM KPIs. The study's primary goal is to get a better understanding of how supply chain metrics in industry 4.0 compare to more traditional methods. Table 7 shows the investigation's findings. According to the data in the RL-I4.0-SCP, interaction occurred. The other four instances, however, had no repercussions at all.

Discussions and conclusions

The other activities in the supply chain will continue to operate in the same manner, in spite of the fact that "industry 4.0" technologies will have a significant effect on the sales processes, specifically on interactions with consumers. Because smart data tools and smartphone applications have the most significant influence on the logistics behind supply chain organization, we will be sure to include both of these in the documentation of our investigation. Intelligent data tools necessitate a particular level of understanding on the part of the individuals working within an organization. When it comes to recruiting new employees, leading businesses will shift their focus from understanding supply chains to requiring knowledge of subjects such as quantitative and statistical analysis and the development of algorithms (Zhao et al. 2023). This expertise will be required all along the supply chain in order to evaluate the vast amounts of data that are currently accessible and to put in place tools and analyses that make use of smart data. The distribution of a digital value proposition to the consumer is considered to be even more important (Li et al. 2020a, 2020b), despite the fact that tangible transportation operations are increasingly being digitized. By using applications for mobile phones, it may be possible to provide a rapid reaction with tailored advertising to environmental and societal patterns that are mentioned on social networks (Li et al. 2020a, 2020b). This presents a possibility for the creation of brand-new business strategies as well as the acquisition of new consumers in a variety of marketplaces (Rejeb et al. 2020a, 2020b). This connection to social networks, which is made possible by the IoT, establishes an interaction with numerous other devices (such as computers, databases, notebooks, tablets, or mobile phones), and it raises consciousness regarding problems relating to information technology (Khanfar et al. 2021a, 2021b). As a result, isolated systems that previously functioned on their own are now connected to a variety of other devices and networks (Yu et al. 2022). These make it possible to incorporate people into the manufacturing, transportation, and customer service operations (Rejeb et al. 2020a, 2020b). It is possible to use applications on a mobile device to control not only individual pieces of machinery but also large portions of the production facilities themselves while the manufacturing process is in progress.

The following themes are used to describe the study's findings: (i) six hypotheses labeled H1, H2, H3, H4, H5, and H6 summarize directly how industry 4.0 connects to the state of the art in supply chain management (SCM), with the undeniable connection between technology progress and supply chain efficiency brought on by the fourth industrial revolution (4.0). (ii) Industry 4.0 technologies' middleman status is between established supply chain practices and suggested efficiency indicators. The findings show that industry 4.0 tools may be developed using SCP best practices. The link between green practices and supply chain KPIs only holds when using industry 4.0 technologies. To begin, this study bridges a gap in the existing literature by providing hard data to support the claim that certain supply chain management tactics are in fact linked to the use of industry 4.0 tools. Second, this study investigates potential connections between industry 4.0 tools and supply chain performance metrics. Similarly, technology has been shown to improve supply chain management's adherence and key performance metrics in specified regions. This article begins with a brief introduction to the issue before delving further into the ways in which it builds upon, modifies, and otherwise interacts with the aforementioned works. Both a positive (H3) and a negligible (H4) impact of agile practices on industry 4.0 are shown.

The implementation of "an environmentally conscious purchasing practice that reduces sources of waste and promotes recycling and reclamation of purchased materials without adversely affecting the performance requirements of such materials" has been referred to as "green purchasing management," and it has been described as "an environmentally conscious purchasing practice". Increasingly stringent laws for environmentally responsible corporate practices have inspired a growing movement towards "green supply chain management," and it is necessary to apply environmental standards in the selection and requirements of suppliers. It complies with certain minimum requirements regarding its environmental management and performance. GSCM stands for "green supply chain management." In order to examine the connection between environmental spending management and firm performance, Gonzales-Benito et al. (2016) conduct an observational study on a representative sample of 100 Portuguese businesses. This study focuses on a cross-section of Portuguese businesses. The authors look at the ways in which strategic inclusion of the buying function and the development of long-term partnerships with suppliers might alleviate these problems. Green procurement management has been shown to boost procurement efficiency, an impact that is amplified when businesses foster ongoing exchanges with their primary providers. It makes it easier to study how incorporating environmental responsibility affects businesses, as well as how to find sustainable suppliers. It shows that using these practices improves procurement departments' operational performance and that this improvement is amplified when businesses forge long-term ties with their suppliers. However, such interesting arguments are in coherence with the findings of Raza and Khan (2022).

This aids businesses in greening the "process" by taking into account product life cycle features, surplus inventory or resources, and waste or faulty product recycling at the same time during the planning and design stage. Recycling also helps businesses learn more about the properties of materials and finished goods, which may inform future decisions about material selection and design. As a result, the growth of investment recovery will encourage green procurement and ecological design in businesses. In conclusion, "green input" will make it easier to make "green products" via a "green process." Companies, and even the whole supply chain as a whole, will benefit from the rising environmental consciousness of the general public, which will boost product demand, market share, and profits. It follows that corporate green management has a beneficial effect on organizations' financial performance, corroborating the results of prior research (Chen et al. 2022)(Nureen et al. 2022)(Ali et al. 2020). Sustainable construction practices guarantee that present resource demands are addressed in a way that will not deplete them in the future. Ethical and long-term success in business is guaranteed by preserving natural ecosystems and eliminating harmful waste via recycling and processing. Management buy-in for adopting ethical business practices is crucial to the success of this plan, and supply chain integration improves communication about resource use and waste production at all levels (Kazancoglu et al. 2018). Cleaner manufacturing practices are critical to the long-term health of the environment and businesses, according to previous studies. When it comes to developing enterprises in an ethical and sustainable manner, industry 4.0 may be at the bottom of the list of researched practices, but that does not mean it is without worth.

In order to better understand the influence, this study presents the results of a literature review on the effects of industry 4.0 on SCM and published results. The purpose of this examination is to illuminate ongoing trends, new findings, and unanswered issues out in the open. The results of this study's analysis of relevant prior research indicate that the concept of "industry 4.0" is widely regarded as playing an essential role in the SC. If the concept was put into practice, there would be less need for human involvement, and businesses would experience higher levels of productivity. Researchers and managers alike will benefit from the book's in-depth analysis of the current level of research on industry 4.0 in the realm of supply chain management and the accompanying, developing trends in both academia and industry. The paper claims that logistics, production, and transportation would all be affected by the introduction of industry 4.0. Three new aspects have been introduced: (a) experimental vs (b) evidence, (c) qualitative versus (d) quantitative, and (e) management level versus (f) processor or technology level has given researchers access to a broader choice of issues to investigate. Researchers wishing to better their work in these areas and engineering administrators looking to begin implementing industry 4.0 may both benefit from grounding in these subjects. These are potentially significant areas for research in the future and call for additional investigation. However, there are not a lot of professionals out there who are knowledgeable about industry 4.0, which is one of the factors that impede progress in research and conversation regarding this topic.

This article set out to empirically examine how Chinese businesses might benefit from industry 4.0 by adopting GSC practices and how such practices can in turn improve their GSC performance. The study was inspired by the paucity of literature on how industry 4.0 and SCM overlap. The research found that the key objective, the adoption of SCM practices in Chinese enterprises, will benefit from the deployment of industry 4.0 technology. Evidence that industry 4.0 technology will help businesses migrate to sustainable development may be found in the positive effects they will have on GSC performance metrics (Xie et al. 2023; Xu et al. 2023). The findings also show that the green performance of automotive supply chains will improve as a consequence of industry 4.0's impact on GSC practices (Pakseresht et al. 2020).

Policy implications

From a management standpoint, the research shows that there are measurable advantages to applying SCM and industry 4.0 inside supply chains, even if the implementation varies by organization size and SC area of operation. The findings of this research highlight the need for the creation of empirically based, technology-centric models of industry 4.0 maturity. If the link between GSC practices and industry 4.0 technology can be shown experimentally, practitioners may feel more comfortable implementing these two together to boost firm performance. This study also provides a comprehensive analysis of the potential direct and indirect effects of industry 4.0 technologies on the operational effectiveness of GSCs. These insights will assist early adopters in their understanding of the relationship between intelligent production systems (driven by integrated technologies that are part of industry 4.0) and the solutions that are used to address safety, control, and other operational challenges. Understanding the structural relationship between key industry 4.0 technologies and GSC practices will help supply chain managers choose which technologies/practices to implement first to boost supply chain performance. This study's results will encourage corporate decision-makers to look at the impact of the fourth industrial revolution on supply chain sustainability.

Our findings will be useful for professionals driving projects related to digitization, supply networks, or industry 4.0, such as chief technology officers, digital managers, and supply-chain managers. Get familiar with the technologies at the heart of industry 4.0, as well as the potential advantages, dangers, and success factors associated with adopting them. With these 11 foundational technologies at their disposal, business leaders can tailor their supply chains to match the specific needs of their operations. The above framework can be used by businesses as they race to build complex digital supply networks to evaluate the relative merits of core companies, coordinate their individual investment strategies, and outline the necessary steps at each stage of the process. Some examples include weighing the pros and cons of several significant technologies in light of business demands and supply chain constraints.

Furthermore, managers may utilize the proposed framework to examine the drawbacks of the enterprise's current legacy systems and the ways in which they might be improved by implementing technology relevant to industry 4.0 (Li et al. 2023). Architectural models (Li Z et al. 2021c),(Huang et al. 2021),(Cugno et al. 2022),(Tang et al. 2022) for and reference to digital or smart supply networks can also be developed using such a structure. As a result, the suggested descriptive framework has the potential to serve as a directing instrument for managers in the process of selecting and integrating supply chain efficiency thanks to the aid of industry 4.0 tools. Considering the remote possibility that digitalization will ever go away and because the fourth industrial revolution is compelling an increasing number of companies in the digitalization of production and distribution networks, our study has the potential to potentially motivate a great deal of more research on this pertinent subject. Finally, "supply chain 4.0," also known as "industry 4.0," has the potential to be part of, and significantly impact, many ongoing trends, including digital servitization, automation, robotics, and new business models like carpooling and ridesharing. Current trends in this approach include digital servitization, the sharing economy, the circular economy, and electricity. Our results can help researchers in these fields to conceptualize and plan for effective digital transformation of supplier networks.

At the moment, the majority of large corporations are recruiting engineering managers for a variety of different managerial positions. Managers in the field of engineering must oversee many projects at once, come up with all-encompassing plans for reaching goals, and take the helm when it comes to integrating technical processes. In addition to analyzing relevant technologies and determining whether or not projects are viable, engineering managers' responsibilities include developing, testing, launching, maintaining, and repairing new and better building and equipment innovations. Other responsibilities of an engineering manager include evaluating the viability of projects. Because the gravity of the task in industry 4.0 is being adopted at the same time, it will be an enormous commitment on their part. Therefore, it is crucial that they understand the idea so that they can perform their duties effectively. By studying the results of this survey, managers in the engineering field would do well to learn as much as they can about industry 4.0. As part of the industry 4.0 learning process, they are exposed to various smart workplace networks. In the following article, the authors show how engineering managers can use the industry 4.0 infrastructure to your advantage to increase the output, accountability, openness, and efficiency of production systems. In engineering management, these problems are known as "grand challenges." Focusing more on the academic elements of industry 4.0, this overview aims to help engineering managers understand its strengths and weaknesses, as well as its current status in support efforts, which provides better parameters for decision-making as industry 4.0 and automation are implemented. They are likely to be well versed in the strategies companies use to adopt digital thinking and integrate "4.0" in the industrial sector. The number of businesses prepared to try out and implement industry 4.0 technologies is very low. Reasons for this include the large initial investment required and the time it takes to recoup the investment. For this reason, managers must have a solid understanding of technology in order to make informed decisions throughout the execution process.

We propose that manufacturing organizations must use SCM practices in conjunction with suppliers and customers to ensure environmental sustainability, and we give data to support this claim. Managers in the manufacturing sector need not only the standard managerial competencies but also those specific to SCM. Managers in the manufacturing industry can no longer discount the significance of the supply chain to the company as a whole. It cannot be overstated how important it is for companies to adopt SCM strategies and work towards improving the procedures that apply throughout the whole supply chain and provide superior service to supply chain end-users. However, in the real world, manufacturing managers are held accountable for their companies' results. Management teams will shift their focus to the supply chain if they see that doing so improves organizational effectiveness. We set out to learn whether SCM practices stressing supplier and customer engagement increased environmental performance, which in turn boosted business results.

Green buying and investment recovery are often implemented more effectively by manufacturers that are under more regulatory scrutiny. Manufacturers in China are improving their environmental performance via green procurement in response to existing regulatory requirements. Nonetheless, regulatory stress dampens economic performance and slows investment recovery. In light of our subsequent finding, regulatory policymakers should encourage environmentally responsible purchases while also assisting businesses in implementing investment recovery strategies including benchmarking, knowledge sharing, and system development. It is important to make production managers aware of the necessity to use SCM practices in instances when regulatory demand is high.

Limitations and future research

We present and evaluate a whole performance model for SCM practices. We think the main value of this research is in the whole model itself, rather than in analyzing its constituent parts. However, this method pushes the limitations of the sample size. Given the disparity between the number of constructs and the size of the sample, we opted to test the boundaries of structural equation modeling to determine whether or not the complete model fit the data really well. Given the breadth of industry 4.0's uses, further research in related fields (such aircraft and locomotive) may lend credence to the generalization of the established relationship mentioned in this work. It would be fascinating to see how factors like business in the context of Industry 4.0, factors such as size, level of expertise, and other moderators SCM in future studies, since this might have a bearing on the linkages between the two paradigms. The following are some potential topics for further study: There is a need for further research on the effects of emerging ICT technologies on supply chains across sectors. Applying joint research with businesses would help ease the implementation challenges of new supply chain technology. Second, a variety of new business models have emerged with the help of technological advancements. It is crucial for businesses to discover methods that can speed up the creation of innovative business models that take advantage of new technology and boost their efficiency. It is now essential to strengthen developing business models' supply chain resilience, in particular in light of the post-epidemic norm. Third, the development of new technologies and the discipline of smart supply chain engineering, which places an emphasis on the technical components and infrastructure of supply chains, both play crucial roles in the implementation of smart SC. It is also important to investigate how various national policies and research initiatives affect the diffusion of innovative technology through supply chains.

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Data availability The data can be made available on request.

Declarations

Ethical approval and consent to participate We declare that we have no human participants, human data, or human tissues.

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References

Ahmed M, Guo Q, Qureshi MA, Raza SA, Khan KA, Salam J (2021) Do green HR practices enhance green motivation and proactive environmental management maturity in hotel industry? Int J Hospital Manag 94:102852

Ahmed W, Islam N, Qureshi HN (2023a) Understanding the acceptability of block-chain technology in the supply chain; case of a developing country. J Sci Technol Policy Manag

Ahmed, W., Khan, M. A., Najmi, A., & Khan, S. A. (2023b). Strategizing risk information sharing framework among supply chain partners for financial performance. In Supply Chain Forum: An International Journal (24, 2, pp. 233-250). Taylor & Francis.

Ahmed W, Najmi A, Ikram M (2020) Steering firm performance through innovative capabilities: a contingency approach to innovation management. Technol Soc 63:101385

Ahmed W, Omar M (2019) Drivers of supply chain transparency and its effects on performance measures in the automotive industry: case of a developing country. Int J Serv Oper Manag 33(2). https://doi.org/10.1504/IJSOM.2019.100291

Ali Y, Saad TB, Sabir M, Muhammad N, Salman A, Zeb K (2020) Integration of green supply chain management practices in construction supply chain of CPEC. Manag Environ Qual 31(1):185–200. https://doi.org/10.1108/MEQ-12-2018-0211

Babajide A, Osabuohien E, Tunji-Olayeni P, Falola H, Amodu L, Olokoyo F, Adegboye F, Ehikioya B (2021) Financial literacy, financial capabilities, and sustainable business model practice among small business owners in Nigeria. J Sustain Finance Invest:1–23. https://doi.org/10.1080/20430795.2021.1962663

Belhadi A, Kamble SS, Chiappetta Jabbour CJ, Mani V, Khan SAR, Touriki FE (2022) A self-assessment tool for evaluating the integration of circular economy and industry 4.0 principles in closed-loop supply chains. Int J Prod Econ 245:108372. https://doi.org/10.1016/J.IJPE.2021.108372

Belhadi A, Kamble SS, Chiappetta Jabbour CJ, Mani V, Rehman Khan SA, Touriki FE (2021) A self-assessment tool for evaluating the integration of circular economy and industry 4.0 principles in closed-loop supply chains. Int J Prod Econ:108372. https://doi.org/10.1016/j.ijpe.2021.108372

Benzidia S, Makaoui N, Subramanian N (2021) Impact of ambidexterity of blockchain technology and social factors on new product development: a supply chain and industry 4.0 perspective. Technol Forecast Soc Chang 169:120819. https://doi.org/10.1016/j.techfore.2021.120819

Çalık A (2021) A novel Pythagorean fuzzy AHP and fuzzy TOPSIS methodology for green supplier selection in the industry 4.0 era. Soft Comput 25(3):2253–2265. https://doi.org/10.1007/S00500-020-05294-9/TABLES/11

Centobelli P, Cerchione R, Singh R (2019) Int J Prod Econ 212:111–124. https://doi.org/10.1016/j.ijpe.2019.02.011

Chang SE, Chen Y-C, Lu M-F (2019) Supply chain re-engineering using blockchain technology: a case of smart contract based tracking process. Technol Forecast Soc Chang 144:1–11. https://doi.org/10.1016/j.techfore.2019.03.015

Chen N, Yang Y (2021) The impact of customer experience on consumer purchase intention in cross-border E-commerce——taking network structural embeddedness as mediator variable. J Retail Consum Serv 59:102344. https://doi.org/10.1016/j.jretconser.2020.102344

Chen W, Jafarzadeh S, Thakur M, Ólafsdóttir G, Mehta S, Bogason S, Holden NM (2021) Environmental impacts of animal-based food supply chains with market characteristics. Sci Total Environ 783:147077. https://doi.org/10.1016/j.scitotenv.2021.147077

Chen X, Lin B (2020) Energy and CO_2 emission performance: a regional comparison of China's non-ferrous metals industry. J Clean Prod 274. https://doi.org/10.1016/j.jclepro.2020.123168
Chen X, Wang C, Li S (2022) The impact of supply chain finance on corporate social responsibility and creating shared value: a case from the emerging economy. Supply Chain Manag Int J. https://doi.org/10.1108/scm-10-2021-0478
Chen Z, Zhu W, Feng H, Luo H (2022) Changes in Corporate Social Responsibility Efficiency in Chinese Food Industry Brought by COVID-19 Pandemic—A Study With the Super-Efficiency DEA-Malmquist-Tobit Model. Front Public Health, 10. https://doi.org/10.3389/fpubh.2022.875030
Choi W, Kim J, Lee S, Park E (2021) Smart home and internet of things: a bibliometric study. J Clean Prod 301:126908. https://doi.org/10.1016/j.jclepro.2021.126908
Costa J, Matias JCO (2020) Open innovation 4.0 as an enhancer of sustainable innovation ecosystems. Sustainability 12(19):8112. https://doi.org/10.3390/SU12198112
Cugno M, Castagnoli R, Büchi G, Pini M (2022) Industry 4.0 and production recovery in the covid era. Technovation 114:102443. https://doi.org/10.1016/J.TECHNOVATION.2021.102443
Czernek K (2013) Determinants of cooperation in a tourist region. Ann Tour Res 40(1):83–104. https://doi.org/10.1016/j.annals.2012.09.003
Di Vaio A, Varriale L (2020) Blockchain technology in supply chain management for sustainable performance: evidence from the airport industry. Int J Inf Manag 52:102014. https://doi.org/10.1016/j.ijinfomgt.2019.09.010
Duong ATB, Vo VX, Carvalho MDS, Sampaio P, Truong HQ (2022) Risks and supply chain performance: globalization and COVID-19 perspectives. Int J Prod Perform Manag. https://doi.org/10.1108/IJPPM-03-2021-0179
Ercantan O, Eyupoglu S (2022) How do green human resource management practices encourage employees to engage in green behavior? Perceptions of university students as prospective employees. Sustainability 14(3):1718. https://doi.org/10.3390/SU14031718
Fornell C, Larcker DF (1981) Structural equation models with unobservable variables and measurement error: Algebra and statistics. 382–388
Fülöp MT, Topor DI, Ionescu CA, Căpușneanu S, Breaz TO, Stanescu SG (2022) Fintech accounting and industry 4.0: future-proofing or threats to the accounting profession? J Bus Econ Manag 23(5):997–1015–1997–1015. https://doi.org/10.3846/JBEM.2022.17695
Gefen D, Straub DW (2004) Consumer trust in B2C e-Commerce and the importance of social presence: experiments in e-products and e-services. Omega 32(6):407–424. https://doi.org/10.1016/j.omega.2004.01.006
Ghadimi P, Wang C, Lim MK, Heavey C (2019) Intelligent sustainable supplier selection using multi-agent technology: theory and application for industry 4.0 supply chains. Comput Ind Eng 127:588–600. https://doi.org/10.1016/j.cie.2018.10.050
Gonzales-Benito ME, Kremer C, Ibáñez MA, Martin C (2016) Effect of antioxidants on the genetic stability of cryopreserved mint shoot tips by encapsulation-dehydration, Plant Cell Tiss. Cult 127:359–368
Gunasekaran A, Patel C, McGaughey RE (2004) A framework for supply chain performance measurement. Int J Prod Econ 87(3):333–347. https://doi.org/10.1016/j.ijpe.2003.08.003
Guo LL, Qu Y, Tseng ML (2017) The interaction effects of environmental regulation and technological innovation on regional green growth performance. J Clean Prod 162:894–902. https://doi.org/10.1016/j.jclepro.2017.05.210
Guo B, Wang Y, Feng Y, Liang C, Tang L, Yao X, Hu F (2022) The effects of environmental tax reform on urban air pollution: A quasi-natural experiment based on the Environmental Protection Tax Law. Front Public Health, 10, 967524. https://doi.org/10.3389/fpubh.2022.967524
Guo B, Wang Y, Zhang H, Liang C, Feng Y, ... Hu F (2023) Impact of the digital economy on high-quality urban economic development: Evidence from Chinese cities. Econ Model, 120, 106194. https://doi.org/10.1016/j.econmod.2023.106194
Gupta H, Kumar A, Wasan P (2021) Industry 4.0, cleaner production and circular economy: an integrative framework for evaluating ethical and sustainable business performance of manufacturing organizations. J Clean Prod 295:126253. https://doi.org/10.1016/j.jclepro.2021.126253
Haldorai K, Kim WG, Garcia RLF (2022) Top management green commitment and green intellectual capital as enablers of hotel environmental performance: the mediating role of green human resource management. Tour Manag 88:104431. https://doi.org/10.1016/j.tourman.2021.104431
Han H, Trimi S (2022) Towards a data science platform for improving SME collaboration through industry 4.0 technologies. Technol Forecast Soc Chang 174:121242. https://doi.org/10.1016/j.techfore.2021.121242
Hasni MJS, Farah MF, Adeel I (2022) The technology acceptance model revisited: empirical evidence from the tourism industry in Pakistan. J Tour Futures. https://doi.org/10.1108/JTF-09-2021-0220/FULL/PDF
He J, Ortiz J (2021) Sustainable business modeling: the need for innovative design thinking. J Clean Prod 298:126751. https://doi.org/10.1016/j.jclepro.2021.126751
Hopkins JL (2021) An investigation into emerging industry 4.0 technologies as drivers of supply chain innovation in Australia. Comput Ind 125:103323. https://doi.org/10.1016/j.compind.2020.103323
Huang X, Huang S, Shui A (2021) Government spending and intergenerational income mobility: Evidence from China. J Econ Behav Organ 191:387–414. https://doi.org/10.1016/j.jebo.2021.09.005
Huo B, Gu M, Wang Z (2019) Green or lean? A supply chain approach to sustainable performance. J Clean Prod 216:152–166. https://doi.org/10.1016/j.jclepro.2019.01.141
Huq FA, Chowdhury IN, Klassen RD (2016) Social management capabilities of multinational buying firms and their emerging market suppliers: an exploratory study of the clothing industry. J Oper Manag 46:19–37. https://doi.org/10.1016/j.jom.2016.07.005
Jiang P, Van Fan Y, Klemeš JJ (2021a) Impacts of COVID-19 on energy demand and consumption: challenges, lessons and emerging opportunities. Appl Energy 285. https://doi.org/10.1016/j.apenergy.2021.116441
Jiang X, Shen JH, Lee CC, Chen C (2021b) Supply-side structural reform and dynamic capital structure adjustment: evidence from Chinese-listed firms. Pac Basin Financ J 65. https://doi.org/10.1016/J.PACFIN.2020.101482
Kazancoglu Y, Kazancoglu I, Sagnak M (2018) A new holistic conceptual framework for green supply chain management performance assessment based on circular economy. J Clean Prod 195:1282–1299. https://doi.org/10.1016/J.JCLEPRO.2018.06.015
Kazmi SW, Ahmed W (2022) Understanding dynamic distribution capabilities to enhance supply chain performance: a dynamic capability view. BIJ 29(9):2822–2841
Khan S, Haleem A, Khan MI, Abidi MH, Al-Ahmari A (2018) Implementing traceability systems in specific supply chain management (SCM) through critical success factors (CSFs). Sustainability 10(1). https://doi.org/10.3390/su10010204
Khan SAR, Godil DI, Jabbour CJC, Shujaat S, Razzaq A, Yu Z (2021a) Green data analytics, blockchain technology for sustainable development, and sustainable supply chain practices: evidence from small and medium enterprises. Ann Oper Res:1–25. https://doi.org/10.1007/s10479-021-04275-x

Khan SAR, Mathew M, Dominic PDD, Umar M (2021b) Evaluation and selection strategy for green supply chain using interval-valued q-rung orthopair fuzzy combinative distance-based assessment. Environ Dev Sustain 24:1–33. https://doi.org/10.1007/s10668-021-01876-1
Khan SAR, Razzaq A, Yu Z, Miller S (2021c) Industry 4.0 and circular economy practices: a new era business strategies for environmental sustainability. Bus Strateg Environ 30(8):4001–4014. https://doi.org/10.1002/BSE.2853
Khanfar AAA, Iranmanesh M, Ghobakhloo M, Senali MG, Fathi M (2021a) Applications of blockchain technology in sustainable manufacturing and supply chain management: a systematic review. Sustainability 13(14). https://doi.org/10.3390/su13147870
Khanfar AAA, Iranmanesh M, Ghobakhloo M, Senali MG, Fathi M (2021b) Applications of blockchain technology in sustainable manufacturing and supply chain management: a systematic review. Sustainability 13(14):7870. https://doi.org/10.3390/SU13147870
Khokhar M, Iqbal W, Hou Y, Abbas M, Fatima A (2020) Assessing supply chain performance from the perspective of Pakistan's manufacturing industry through social sustainability. Processes 8(9). https://doi.org/10.3390/pr8091064
Korhonen J, Nuur C, Feldmann A, Birkie SE (2018) Circular economy as an essentially contested concept. J Clean Prod 175:544–552. https://doi.org/10.1016/j.jclepro.2017.12.111
Kouhizadeh M, Saberi S, Sarkis J (2021) Blockchain technology and the sustainable supply chain: theoretically exploring adoption barriers. Int J Prod Econ 231:107831. https://doi.org/10.1016/j.ijpe.2020.107831
Kovacova M, Lăzăroiu G (2021) Sustainable organizational performance, cyber-physical production networks, and deep learning-assisted smart process planning in industry 4.0-based manufacturing systems. Econ Manag Finan Markets 16(3):41–54. https://doi.org/10.22381/emfm16320212
Lau YY, Dulebenets MA, Yip HT, Tang YM (2022) Healthcare supply chain management under COVID-19 settings: the existing practices in Hong Kong and the United States. Healthcare 10(8):1549. https://doi.org/10.3390/HEALTHCARE10081549
Lv Z, Chen D, Lou R, Song H (2020) Industrial security solution for virtual reality. IEEE Internet of Things Journal 8(8):6273–6281. https://doi.org/10.1109/JIOT.2020.3004469
Li G, Wu H, Sethi SP, Zhang X (2021a) Contracting green product supply chains considering marketing efforts in the circular economy era. Int J Prod Econ 234:108041. https://doi.org/10.1016/J.IJPE.2021.108041
Li G, Wu H, Sethi SP, Zhang X (2021b) Contracting green product supply chains considering marketing efforts in the circular economy era. Int J Prod Econ 234:108041. https://doi.org/10.1016/J.IJPE.2021.108041
Li QK, Lin H, Tan X, Du S (2020) H∞ consensus for multiagent-based supply chain systems under switching topology and uncertain demands. IEEE Trans Syst Man Cybern Syst Hum 50(12):4905–4918. https://doi.org/10.1109/TSMC.2018.2884510
Li J, Yang X, Shi V, Cai GG (2023) Partial centralization in a durable-good supply chain. Prod Oper Manag 32(9):2775–2787. https://doi.org/10.1111/poms.14006
Li Y, Dai J, Cui L (2020a) The impact of digital technologies on economic and environmental performance in the context of industry 4.0: a moderated mediation model. Int J Prod Econ 229:107777. https://doi.org/10.1016/J.IJPE.2020.107777
Li Y, Dai J, Cui L (2020b) The impact of digital technologies on economic and environmental performance in the context of industry 4.0: a moderated mediation model. Int J Prod Econ 229:107777. https://doi.org/10.1016/J.IJPE.2020.107777
Li Z, Zhou X, Huang S (2021c) Managing skill certification in online outsourcing platforms: A perspective of buyer-determined reverse auctions. Int J Prod Econ, 238, 108166. https://doi.org/10.1016/j.ijpe.2021.108166
Liu X, Shi T, Zhou G, Liu M, Yin Z, Yin L, ... Zheng W (2023) Emotion classification for short texts: an improved multi-label method. Humanities and Social Sciences Communications 10(1):306. https://doi.org/10.1057/s41599-023-01816-6
Lu Y, Zhao L, Wang B (2010) From virtual community members to C2C e-commerce buyers: trust in virtual communities and its effect on consumers' purchase intention. Electron Commer Res Appl 9(4):346–360. https://doi.org/10.1016/j.elerap.2009.07.003
Lu S, Liu M, Yin L, Yin Z, Liu X, Zheng W, ... Kong X (2023) The multi-modal fusion in visual question answering: a review of attention mechanisms. PeerJ Computer Science, 9, e1400. https://doi.org/10.7717/peerj-cs.1400
Meidute-Kavaliauskiene I, Yıldız B, Çiğdem Ş, Činčikaitė R (2021) An integrated impact of blockchain on supply. Logistics 5(2):33
Menkeh, M. I. (2021). The impact of financial inclusion on agricultural development in Ngoketunjia division, North West Cameroon.
Nica E, Stehel V (2021) Internet of things sensing networks, artificial intelligence-based decision-making algorithms, and real-time process monitoring in sustainable industry 4.0. J Self-Govern Manag Econ 9(3):35–47. https://doi.org/10.22381/jsme9320213
Novak A, Bennett D, Kliestik T (2021) Product decision-making information systems, real-time sensor networks, and artificial intelligence-driven big data analytics in sustainable industry 4.0. Econ Manag Finan Markets 16(2):62. https://doi.org/10.22381/emfm16220213
Nunnally JC (1978) An overview of psychological measurement. A handbook, Clinical diagnosis of mental disorders, pp 97–146
Nureen N, Liu D, Ahmad B, Irfan M (2022) Exploring the technical and behavioral dimensions of green supply chain management: a roadmap toward environmental sustainability. Environ Sci Pollut Res:1–14. https://doi.org/10.1007/s11356-022-20352-5
Oliveira T, Alhinho M, Rita P, Dhillon G (2017) Modelling and testing consumer trust dimensions in e-commerce. Comput Human Behav 71:153–164. https://doi.org/10.1016/j.chb.2017.01.050
Pakseresht M, Shirazi B, Mahdavi I, Mahdavi-Amiri N (2020) Toward sustainable optimization with Stackelberg game between green product family and downstream supply chain. Sustain Prod Consum 23:198–211. https://doi.org/10.1016/j.spc.2020.04.009
Park G, Shin SR, Choy M (2020) Early mover (dis)advantages and knowledge spillover effects on blockchain startups' funding and innovation performance. J Bus Res 109:64–75. https://doi.org/10.1016/j.jbusres.2019.11.068
Pavlínek P (2015) The impact of the 2008–2009 crisis on the automotive industry: global trends and firm-level effects in Central Europe. Eur Urban Reg Stud 22(1):20–40. https://doi.org/10.1177/0969776412460534
Purwandari B, Suriazdin SA, Hidayanto AN, Setiawan S, Phusavat K, Maulida M (2022) Factors affecting switching intention from cash on delivery to E-payment services in C2C E-commerce transactions: COVID-19, transaction, and technology perspectives. Emerg Sci J 6:136–150. https://doi.org/10.28991/esj-2022-sper-010
Qazi W, Qureshi JA, Raza SA, Khan KA, Qureshi MA (2021) Impact of personality traits and university green entrepreneurial support on students' green entrepreneurial intentions: the moderating role of environmental values. J Appl Res High Educ 13(4):1154–1180. https://doi.org/10.1108/JARHE-05-2020-0130
Quan F, Mingming Z, Hu S, Yuhang C (2021) Research on data fusion scheme of power internet of things based on cloud and NFV. Procedia Comput Sci 183:115–119. https://doi.org/10.1016/j.procs.2021.02.038

Rajesh R (2020) Exploring the sustainability performances of firms using environmental, social, and governance scores. J Clean Prod 247:119600. https://doi.org/10.1016/j.jclepro.2019.119600
Raza SA, Khan KA (2022) Impact of green human resource practices on hotel environmental performance: the moderating effect of environmental knowledge and individual green values. Int J Contemp Hosp Manag 34(6):2154–2175
Rejeb A, Simske S, Rejeb K, Treiblmaier H, Zailani S (2020a) Internet of things research in supply chain management and logistics: a bibliometric analysis. Internet of Things 12:100318. https://doi.org/10.1016/J.IOT.2020.100318
Rejeb A, Simske S, Rejeb K, Treiblmaier H, Zailani S (2020b) Internet of things research in supply chain management and logistics: a bibliometric analysis. Internet of Things 12:100318. https://doi.org/10.1016/J.IOT.2020.100318
Siyu Lu, Ding Y, Yin Z, Liu M, Liu X, Zheng W, Yin L (2023) Improved Blending Attention Mechanism in Visual Question Answering. Comput Syst Sci Eng 47(1):1149–1161. https://doi.org/10.32604/csse.2023.038598
Sarfraz M, Ivascu L, Abdullah MI, Ozturk I, Tariq J (2022) Exploring a pathway to sustainable performance in manufacturing firms: the interplay between innovation capabilities, green process, product innovations and digital leadership. Sustainability 14(10):5945. https://doi.org/10.3390/SU14105945
Schroeder P, Anggraeni K, Weber U (2019) The relevance of circular economy practices to the sustainable development goals. J Ind Ecol 23(1):77–95. https://doi.org/10.1111/jiec.12732
Tang, X. (2022). Innovation and sustainability w e i v re In w e i v re.
Tang YM, Chau KY, Fatima A, Waqas M (2022) Industry 4.0 technology and circular economy practices: business management strategies for environmental sustainability. Environ Sci Pollut Res:0123456789. https://doi.org/10.1007/s11356-022-19081-6
Tu Y, Han Y, Ma R, Gong J (2020) Work analysis and the future reform of HRM for China's judicial system: a comparative study from the perspective of post system between China and the US. Journal of Chinese Human Resources Management 11(1):34–49. https://doi.org/10.47297/wspchrmWSP2040-800503.20201101
Wang H, Wu Z, Chen J, Chen L (2022) Evaluation of road traffic noise exposure considering differential crowd characteristics. Transportation Research Part D: Transport and Environment, 105, 103250. https://doi.org/10.1016/j.trd.2022.103250
Wu B, Gu Q, Liu Z, Liu J (2023) Clustered institutional investors, shared ESG preferences and low-carbon innovation in family firm. Technological Forecasting and Social Change, 194, 122676. https://doi.org/10.1016/j.techfore.2023.122676
Xie X, Jin X, Wei G, Chang C (2023) Monitoring and Early Warning of SMEs' Shutdown Risk under the Impact of Global Pandemic Shock. Systems 11(5):260. https://doi.org/10.3390/systems11050260
Xi X, Xi B, Miao C, Yu R, Xie J, Xiang R, Hu F (2022) Factors influencing technological innovation efficiency in the Chinese video game industry: applying the meta-frontier approach. Technol Forecast Soc Chang 178:121574. https://doi.org/10.1016/J.TECHFORE.2022.121574
Xu J, Yang Z, Wang Z, Li J, Zhang X (2023) Flexible sensing enabled packaging performance optimization system (FS-PPOS) for lamb loss reduction control in E-commerce supply chain. Food Control, 145, 109394. https://doi.org/10.1016/j.foodcont.2022.109394
Yadav G, Luthra S, Jakhar SK, Mangla SK, Rai DP (2020) A framework to overcome sustainable supply chain challenges through solution measures of industry 4.0 and circular economy: an automotive case. J Clean Prod. https://doi.org/10.1016/j.jclepro.2020.120112
Yan L, Yin-He S, Qian Y, Zhi-Yu S, Chun-Zi W, ... Zi-Yun L (2021) Method of Reaching Consensus on Probability of Food Safety Based on the Integration of Finite Credible Data on Block Chain. IEEE access, 9, 123764-123776. https://doi.org/10.1109/ACCESS.2021.3108178
Yan X, Wu Z, Wang H (2023) Network noise control under speed limit strategies using an improved bilevel programming model. Transportation Research Part D: Transport and Environment, 121, 103805. https://doi.org/10.1016/j.trd.2023.103805
Yang J, Cheng J, Huang S (2020) CO_2 emissions performance and reduction potential in China's manufacturing industry: a multi-hierarchy meta-frontier approach. J Clean Prod 255. https://doi.org/10.1016/j.jclepro.2020.120226
Yi H, Meng X, Linghu Y, Zhang Z (2023) Can financial capability improve entrepreneurial performance? Evidence from rural China. https://doi.org/10.1080/1331677X.2022.2091631
Yin J, Song H (2023) Does the perception of smart governance enhance commercial investments? Evidence from Beijing, Shanghai, Guangzhou, and Hangzhou. Heliyon 9(8):e19024. https://doi.org/10.1016/j.heliyon.2023.e19024
Yu Y, Huo B (2019) The impact of environmental orientation on supplier green management and financial performance: the moderating role of relational capital. J Clean Prod 211:628–639. https://doi.org/10.1016/j.jclepro.2018.11.198
Yu Z, Khan SAR, Umar M (2022) Circular economy practices and industry 4.0 technologies: a strategic move of automobile industry. Bus Strategy Environ 31(3):796–809. https://doi.org/10.1002/bse.2918
Zachariadis M, Hileman G, Scott SV (2019) Governance and control in distributed ledgers: understanding the challenges facing blockchain technology in financial services. Inf Organ 29(2):105–117. https://doi.org/10.1016/j.infoandorg.2019.03.001
Zhang N, Wei X (2015) Dynamic total factor carbon emissions performance changes in the Chinese transportation industry. Appl Energy 146:409–420. https://doi.org/10.1016/j.apenergy.2015.01.072
Zhao S, Zhang L, An H, Peng L, Zhou H, ... Hu F (2023) Has China's low-carbon strategy pushed forward the digital transformation of manufacturing enterprises? Evidence from the low-carbon city pilot policy. Environ Impact Assess Rev, 102, 107184. https://doi.org/10.1016/j.eiar.2023.107184