Uncertain Supply Chain Management 11 (2023) 1133–1148

Contents lists available at GrowingScience

Uncertain Supply Chain Management

homepage: www.GrowingScience.com/uscm

The effect of knowledge management on firm performance. mediating role of production technology, supply chain integration, and green supply chain

Bryan Young Hartono[a], Hotlan Siagian[a] and Zeplin Jiwa Husada Tarigan[a*]

[a]*School of Business and Management, Petra Christian University, Indonesia*

A B S T R A C T

Article history:
Received November 1, 2022
Received in revised format December 10, 2022
Accepted April 11 2023
Available online April 11 2023

Keywords:
Firm performance
Green supply chain adoption
Knowledge management
Production technology
Supply chain integration

The company's technology implementation is inseparable from employees' ability to operate and use it optimally. Therefore, companies must maintain a developed and adequate process knowledge management according to the latest needs to improve performance while considering environmental impacts. This study investigated the role of knowledge management in adopting production technology, supply chain integration, and green supply chain toward firm performance. The study surveyed the manufacturing industry in East Java that has implemented green supply chain management, with respondents having at least two years of experience working. Respondents have filled in as many as 115 questionnaires considered valid from the 145 questionnaires received. Data processing used the partial least squares software 4.0 version. The result indicated that knowledge management significantly influenced production technology, supply chain integration, and green supply chain adoption. However, knowledge management does not influence firm performance directly. Production technology enables supply chain integration, green supply chain adoption, and firm performance. Furthermore, supply chain integration affects green supply chain adoption and firm performance. Moreover, the result indicated that supply chain adoption directly influences the firm's performance. The practical implication of the results enlightens the managers and top management on the importance of updated technology and knowledge for employees, enabling the adoption of supply chain integration and green supply chain in the pursuit of enhanced firm performance. These results enrich the current research in supply chain management theory.

1. Introduction

In recent years, environmental issues have caused great attention in the industrial sphere. Environmental damage, such as water pollution and global warming, is spreading worldwide. Every country worldwide depends on natural resources, creating waste that can damage the environment (Bag et al., 2020). The inherent threats are due to carbon monoxide emissions, discarded packaging materials, the use of toxic materials, traffic jams, and various other forms of industrial pollution (Chin et al., 2015; Zhang & Wang, 2014). Excessive consumption of natural resources creates conflicts between the environment and economic development (Qi et al., 2021; Guang Shi et al., 2012). The green supply chain is critical to keep paying attention to economic growth, competition, and environmental care (Islam et al., 2017). The current demands for value-creation efforts, namely environmental and industrial sustainability and green and sustainable innovation, have increased attention to the concept of a green supply chain (Jawaad & Zafar, 2020). As a result, the green supply chain has been integrated into the company's innovative strategy to achieve a competitive advantage (Balasubramanian & Shukla, 2017). Deteriorating environments, global climate change, running out of resources, and increasing consumer environmental awareness become sensitive when companies develop their operations (Qi Zhang et al., 2019). According to Huang & Li (2017), today's consumers are not only concerned with quality and price but have also considered the environmental impact. Environmental awareness has also influenced consumer consumption (Qi Zhang et al., 2019). Various factors, such as economic issues, social

* Corresponding author
E-mail address zeplin@petra.ac.id (Z. J. H. Tarigan)

doi: 10.5267/j.uscm.2023.4.009

responsibility, and ethical issues, have left companies with no choice but to be actively involved in considering the impact on the environment (Kazancoglu et al., 2020). Companies have considered the environment in supply chain activities to reduce or eliminate waste (Xie et al., 2022). The production of green products is one example of the world's environmental efforts. Green products are essential to business strategy and improve corporate social responsibility. Consumers are increasingly concerned about the product's social and environmental impact. Companies are increasingly required to the mandatory ecological effects of the products produced. Dubey et al. (2015) show that environmental management improves a company's financial performance through increased revenue and decreased costs. The behavior of producers in producing products has also changed due to the great demands and changes in consumer behavior (Dey et al., 2019; Inman & Green, 2018). Producers must meet consumer needs to maintain competitiveness (Yao & Askin, 2019; Lii & Kuo, 2016). Implementing a green approach to managing resources in the supply chain has become a trend, which has made environmental issues and green supply chain practices important (Abdallah & Al-Ghwayeen, 2020; Guang Shi et al., 2012). The company has implemented a green supply chain to increase its competitive advantage in the global market (Dubey et al., 2015; Doan, 2020). The green supply chain aims to reduce the negative environmental impact of products and services, from the design and purchase stages of environmentally friendly materials to the production and post-consumer waste treatment process (Abdallah & Al-Ghwayeen, 2020).

Global awareness of the worsening climate crisis has been a significant catalyst for companies forcing them to improve GSCM (Green Supply Chain Management) and environmental performance (Abu Seman et al., 2019; Khan et al., 2021). In recent years, GSCM has evolved as an intra- and inter-enterprise management of the upstream and downstream supply chains, having the ability to minimize the overall environmental impact of forward and backward flows. In addition, according to Santoso et al. (2022), GSCM emerged as an innovative approach to supply chains that pays attention to environmental sustainability in facing the challenges of industrial activity and pollution to the environment. GSCM aims to eliminate or minimize waste, including hazardous chemicals, emissions, energy, and solid waste, in each supply chain, such as product design, procurement, material selection, manufacturing processes, final product delivery, and product end management activities (Chin et al., 2015; Dey et al., 2019; Tarigan et al., 2019). Designed environmental standards can create innovations that can reduce the total cost of a product or increase its value (Buenechea-Elberdin, 2017). The GSCM demonstrates how organizations consider environmental awareness in designing and implementing supply chain practices (Chin et al., 2015). Companies have adopted various green supply chain practices to drive positive environmental impact (Inman & Green, 2018; Tarigan et al., 2021). Abdallah & Al-Ghwayeen (2020) show that companies have begun implementing GSCM practices to meet customer claims for environmentally friendly products and products produced through ecologically sustainable practices and in response to government environmental laws. With increasing pressure on environmental issues, it is expected that companies will need to implement green practices with their customers and suppliers to improve their environmental performance by reducing the environmental impact of their products, services, and operations (Diabat et al., 2013). GSCM is assessed using the following five indicators: green procurement, green manufacturing, green distribution, and green logistics.

Supply chain is a set of collaborative activities and relationships that emerged and was shared by several companies in creating value to provide customers with a valuable mix of services or products (Ali et al., 2016; Amen et al., 2017). It has been suggested that efficient integration of the entire supply chain process could be achieved in collaboration with all partners (Yu et al., 2014; Tarigan et al., 2020). Furthermore, incomplete and evolving conceptualizations have produced inconclusive results about the relationship between GSCM and firm performance (Santoso et al., 2022; Zailani et al., 2012). Exploring the conceptualization of GSCM and its impact on performance, it is necessary to investigate how individual dimensions of GSCM relate to selected dimensions of operational performance (Yu et al., 2014; Famiyeh et al., 2018; Kazancoglu et al., 2020). However, not many companies have integrated GSC practices. Although GSC has been recognized for decades, there are inconsistent arguments and inconclusive findings from existing supply chain literature. Because of these shortcomings, the existing literature fails to understand what constitutes GSC practice (Islam et al., 2017).

Many companies have realized that meeting regulatory requirements is insufficient to survive the competition (Rivera, 2019; Yao & Askin, 2019). Therefore, they have tried to carry out effective and efficient pollution prevention and monitoring. Companies improve their competitiveness through better environmental performance by complying with environmental regulations, addressing customers' concerns, and reducing the environmental impact of production activities (Famiyeh et al., 2018). The pressure exerted under the rules forces the companies to implement green supply chain practices (Diabat et al., 2013; Balasubramanian & Shukla, 2017). The company has adopted green environment programs to eliminate or reduce negative environmental impacts and proactively reduce waste or pollution sources. Another research indicated that companies are increasingly controlling supplier partners to deal with many environmental regulations and the effects of climate change (Lee, 2015).

Another study indicated that the company that had implemented a green supply chain to meet customer demand requests and enforce environmental regulations improved the company's sustainability (Tzokas et al., 2015). Stringent regulations increased global competitiveness, and stakeholder pressure has obliged companies to consider environmental issues in supply chain flows (Rivera, 2019). Nevertheless, the green supply chain implemented by the company is essential to achieve the company's profit and market share goals by reducing risks and environmental impacts (Balasubramanian & Shukla, 2017). Each company has different pressures, including scarcity of resources, stricter regulations, and increased pressure on society

and consumers (Tan & Cross, 2012). Therefore, companies need to effectively integrate environmental issues into operational and strategic planning programs to gain and maintain competitive advantage and minimize the impact of environmental problems (Diabat et al., 2013). Supply chain integration can be achieved by adopting appropriate technology in the production area (Kraus et al., 2020; Pirmanta et al., 2021). The technology adoption addresses external changes, including changes in suppliers, customers, and competitors, with environmental uncertainty (Martinez-Sanchez et al., 2019; Di Vaio & Varriale, 2020; Basana et al., 2022b). Corporate awareness of protecting the environment is growing globally, and the green movement to conserve the earth's resources is gaining momentum, thus putting pressure on businesses to adhere to environmentally friendly practices (Chuang and Huang, 2018). The company has shown increased concern for preserving the environment (Singh & Teng, 2016) and is part of a long-term competitive strategy (Kalyar et al., 2019). Green supply chain to minimize or eliminate the negative effects that supply chain flows have on the environment (Govindan et al., 2014).

The gradual growth of environmental concern has been ingrained in the company's thinking to formulate and align appropriate strategies (Kalyar et al., 2019). Increased pressure from governments and environmental regulatory agencies means companies are under pressure to pay attention to the environment (Kalyar et al., 2019). Implementing a complete, adequate, and integrated management system must meet criteria such as speed, production with high capacity, high quality, low cost, and inventory (Pickle et al., 2017; Dey et al., 2019). Knowledge Management can change with the innovation carried out by the company and can be a shaper of company competitiveness (Ali et al., 2023; Abbas & Sağsan, 2019). Customer awareness of green environmental aspects and consumption of products and services has increased. The global economic environment focused on firm performance has changed from a focus on wealth creation through superior economic performance in the success of assets, market forces, and liabilities to a focus on environmental performance while achieving high financial performance to achieve a sustainable level of performance (Chin et al., 2015).

Supply chain collaboration has been identified as one of the leading game-changing trends for supply chains (Tarigan et al., 2020). Companies evaluate supply chains in response to environmental challenges, such as global environmental regulations, green consumerism, and climate change (Lee, 2015). Companies may face various ecological risks associated with their supply chains (Lee, 2015; Siagian et al., 2022b). The company seeks to make changes toward a greener supply chain by implementing environmental audits and certification plans, providing environmental support to suppliers, and promoting ecological cooperation (Abdallah & Al-Ghwayeen, 2020). A systematic approach to reducing an adverse environmental impact, resource consumption, and waste ultimately contributes to quality improvement. Supply chain integration is a series of activities related to coordinating product flows between supply chain partners, including transactions, material movements, procedures, and optimization processes, considering the underlying information flow (Basana et al., 2022b; Siagian et al., 2022b). Information exchange refers to the coordination of information transfer and communication (Genovese et al., 2017; Huo et al., 2015; Pirmanta et al., 2021).

In contrast, operational integration involves developing joint activities, collaborative work processes, and coordinated decision-making among supply chain partners (Famiyeh et al., 2018). Based on the explanation above, four big goals can be set, namely first, getting the magnitude of the influence of knowledge management on production technology, supply chain integration, green supply chain adoption, and firm performance. Second, production technology impacts supply chain integration, green supply chain adoption, and firm performance. The third is obtaining supply chain integration, which affects green supply chain adoption and firm performance. Finally, fifth, green supply chain adoption affects firm performance.

2. Literature Review

The supply chain is a collection of companies that move materials together. A supply chain is a network of organizations involved in activity relationships that generate value from finished products or services delivered to customers (Nabila et al., 2021). According to Doan (2020), a supply chain is a network between participants to distribute a product or service. The supply chain consists of all stages directly or indirectly in satisfying customer needs. Tarigan et al., (2019) defines a supply chain as a group of manufacturers, suppliers, distributors, retailers, and other transport providers, information, and logistics management services that provide goods to consumers. The supply chain includes external and internal counterparties for the company (Tarigan et al., 2021).

2.1. Knowledge Management

Knowledge Management is an approach that can be applied by flexible organizational management and gives rise to competitiveness in the future, being progressive towards new products and services, conquering new markets and creating new markets, and retaining knowledge (Shakerian et al., 2016). Knowledge is an intangible asset (Ilvonen et al., 2018). It is a source of competitiveness for organizations and individuals that competitors find difficult to replicate (Lim et al., 2017). Knowledge can be accumulated to achieve company performance and maintain a competitive advantage (Pham & Pham, 2021; Doan, 2020). The company always utilizes and manages knowledge to be shared among members of the company to produce better work synergies (Agyabeng-Mensah et al., 2022). Knowledge management systems are applied in acquiring, transferring, and using knowledge (Abbas & Sağsan, 2019; Pérez-Luño et al., 2019). Knowledge management can bridge information sharing as a learning process to improve company performance (Attia & Eldin, 2018; Suprapto et al., 2017).

Knowledge management involves the technical capabilities of managers and workers and social networks to design, modify and execute workflows to allow the circulation of knowledge in internal and external processes (Chen et al., 2018). Knowledge sharing can form interactive connections to transfer, combine, and enhance knowledge (Pihlajamaa et al., 2019). Knowledge management is related to supply chain management in providing and managing large amounts of data generated. Indicators of knowledge management are adopted from (Pham & Pham, 2021; Li et al., 2012). The indicators are the company has reliable, knowledgeable human resources (KM1), the company has experts on the environment (KM2), the company transfers knowledge between staff about the environment (KM3), the company has environmentally friendly technology (KM4), and the company has a department that is responsible for the environment (KM5).

2.2. Production Technology

Production Technology is a process, material, and planning to focus on manufacturing processes used with metals and polymers, materials used in engineering, and production planning and cost accounting (Huo et al., 2015). The technology used by the company is changing rapidly by following the changes and developments in finding technology in the production and packaging process of products (Di Vaio & Varriale, 2020). Indicators used in research by paying attention to rapid technological changes with an approach that adopts the research of Martinez-Sanchez et al. (2019), namely: the company uses technology to produce products (PT1), the company adjusts the technology according to the characteristics of the product produced (PT2), the company chooses technology that suits the needs of the current company (PT3), the company provides adequate training to staff in the use of technology (PT4).

2.3. Supply Chain Integration (SCI)

Supply chain integration is a strategic step to increase organizational productivity (Kotzab et al., 2023). Supply chain integration to the extent to which manufacturers strategically collaborate with their supply chain partners and manage intra- and inter-organizational processes (Chen et al., 2018; Yu et al., 2014). The goal is to achieve an effective and efficient flow of products and services, information, money, and decisions, to provide maximum value to customers at low cost and high speed (Khanuja & Jain, 2022). Supply chain integration is a research variable with a multi-dimensional form (Nabila et al., 2021; Tarigan et al., 2019). Supply chain integration considers three perspectives: strategic, tactical, and operational. Second, supply chain integration refers to forming a network that includes elements of the supply chain: suppliers, customers, and companies involved (Tseng & Liao (2015; Siagian et al., 2022a). Third, supply chain integration is a relationship between participants in the supply chain flow (Singh & Teng, 2016). The SCI variable indicator is namely the company shares information with external partners (SCI1), the company coordinates with partners in fulfilling orders (SCI2), the company has an integration between adequate internal functions (SCI3) and the company builds strategic collaboration with external partners (SCI4) (Siagian et al., 2022b; Nabila et al., 202; Pirmanta et al., 2021).

2.4. Green Supply Chain Adoption

The green supply chain is essential in improving company performance and competitiveness. Current customer demand is pressing companies to be able to strive for value creation, namely environmental and industrial sustainability, and green and sustainable innovation (Davenport et al., 2019). The green supply chain is the company's innovative strategy to achieve a competitive advantage (Doan, 2020). Green supply chain adoption is an innovation that environmental thinking can incorporate into all phases of the supply chain (Carvalho et al., 2020; Govindan et al., 2014). Innovations are used in companies by designing products, procurement, environmentally friendly manufacturing processes, delivery of the final product to consumers, and end-of-life management (Xie et al., 2022; Suprapto et al., 2017). Green supply chains aim to minimize the detrimental environmental impacts of operational activities and processes, including atmospheric emissions, excessive resource consumption, waste generation, and improper disposal of products (Famiyeh et al., 2018; Zhang & Wang, 2014). Green supply chains have been used as holistic innovations (Balasubramanian & Shukla, 2017) to incorporate environmental issues into supply chains and help companies improve their sustainability (Carvalho et al., 2020; Davenport et al., 2019; Rivera, 2019). Green supply chain practices have five main elements embedded in the supply chain phase: eco-design, eco-friendly purchasing, internal environmental management, customer cooperation on environmental issues, and investment recovery (Xie et al., 2022). A green supply chain is a systematic approach to transparently integrate supply chain actors and activities to achieve overall economic goals and strongly emphasize environmental performance (Genovese et al., 2017; Govindan et al., 2014). The indicators of the green supply chain were adopted from the research of Xie et al. (2022), which are companies involved externally in implementing environmentally friendly (GSCA1), companies use reliable green technology (GSCA2), companies use ecologically friendly materials (GSCA3). In addition, companies control waste to comply with applicable regulations or regulations (GSCA4).

2.5. Firm Performance (FP)

Firm Performance is a broad concept that covers various dimensions of operations, management, and competitive advantages of the company (Li et al., 2019). Company performance consists of financial and non-financial performance (Siagian and Tarigan, 2021). For example, the company's performance in providing customer satisfaction and market performance is non-

financial (Tseng & Liao, 2015). Company performance is a display of the situation for the company over a certain period. It can also be expressed as results or achievements that are influenced by the company's operational activities in utilizing the resources owned (Kazancoglu et al., 2020). Attia & Eldin (2018) defines firm performance as showing how good a process's activities are in a company by producing the output of a strategy to achieve goals. The company's operational performance includes marketing, logistics, and financial performance (Basana et al., 2022a). Company performance is the company's achievement in producing operational and business performance in a certain period (Alsadi & Aloulou, 2021; Bag et al., 2020). The firm performance is measured using Alsadi & Aloulou (2021) indicators. The indicators include the company reducing the delivery cycle time (FP1), the company responding to customer requests quickly (FP2), the company delivering products appropriately (FP3), 4) the company producing volume demand (FP4), and the company reducing production costs on an ongoing basis (FP5).

3. Relationship Between Research Concepts

3.1. Knowledge Management and Production Technology

The fundamental driving force in promoting modern and high-quality development impacts product quality and efficiency and improves the production environment (Adnan et al., 2019; Kushwaha & Sharma, 2016). The use of digitalization technology can help more efficient work routines in an industry supported by knowledge management (Wilkesmann & Wilkesmann, 2017). An adequate digitization system in organizations is closely related to applying good knowledge management (Ilvonen et al., 2018). Organizations can take advantage of the role of their resources, the process of transferring knowledge between employees, and the utilization of technology that meets the company's needs (Pérez-Luño et al., 2019). The company can take advantage of the transfer of knowledge from the company's external parties to the company's internal parties to overcome gaps in the supply chain and implement appropriate technology (Lee & Ha, 2018; Ali et al., 2023). Therefore, investments made by organizations need to be focused on knowledge that is specific to companies and digital technology. Based on this explanation, the research hypothesis can be determined as follows:

Hypothesis 1: *Knowledge management affects production technology.*

3.2. Knowledge Management and Supply Chain Integration

Companies can use knowledge management to coordinate internally and externally (Tan & Cross, 2012; Kotzab et al., 2023). The company's ability to use knowledge management can be a strategy to integrate partners in the supply chain flow (Ali et al., 2023; Pihlajamaa et al., 2019). Companies can practically use knowledge management to collaborate with partners and produce supply chain integration in the manufacturing industry (Li et al., 2012). The mechanism for knowledge integration has a structure and process in a company, including the use of adequate documentation, discussions as a form of information sharing, project analysis, project review, and the use of consultants, analysis, interpretation, and combination of knowledge in a company. Knowledge management capabilities are formed from infrastructure and processes that lead to knowledge integration (Pihlajamaa et al., 2019; Shakerian et al., 2016). The company always strives to practice knowledge management with partners through supply chain integration to increase efficiency and effectiveness continuously (Wong et al., 2020; Yu et al., 2014). Based on the above description, a hypothesis is determined as follows.

Hypothesis 2: *Knowledge management affects supply chain integration.*

3.3. Knowledge Management and Firm Performance

The company's ability to practice knowledge management is defined as a planned and organized effort to impact firm performance through upgraded knowledge regarding customer service and performance (Shahzad et al., 2020). Organizations can improve performance and build competitive advantage through adequate managerial arrangements of resources and specialized knowledge capabilities (Tseng & Lee, 2014; Ilvonen et al., 2018). In addition, organizations must enhance their knowledge and practices to improve innovation and performance (Kianto et al., 2017). Knowledge contribution to firm performance is increasing productivity and competitiveness, decision-making, responsiveness, innovation, product, or service quality, learning curve, flexibility, and cost efficiency (Wong et al., 2020; Buenechea-Elberdin, 2017: Khanuja & Jain, 2021). Various industrial sectors also show that companies that implement knowledge management achieve real improvements in firm performance. Multiple benefits and values can be obtained from organizational efforts in improving proactive knowledge management capabilities (Agyabeng-Mensah et al., 2022). Therefore, knowledge management significantly influences firm performance (Lim et al., 2017). This argument proposes a hypothesis as follows.

Hypothesis 3: *Knowledge management affects firm performance.*

3.4. Knowledge Management and Green Supply Chain Adoption

Companies can share knowledge and cooperate in improving the creation and development of green products (Agyabeng-Mensah et al., 2022). Knowledge sharing is built by organizations with partners as one of the strategies for improving green

innovation by exploring new things and maintaining sustainable performance (Lim et al., 2017; Guo et al., 2020; Jawaad & Zafar, 2020). Knowledge management is owned by the organization using adequate employee knowledge and competence. Knowledge management increases when top management invests in environmentally friendly and green resources to develop innovation in the green supply chain (Pérez-Luño et al., 2019). Learning in organizations that emphasize combining corporate strategy with knowledge management strategy so that green innovation goals can be achieved (Buenechea-Elberdin, 2017; Davenport et al., 2019; Attia & Eldin, 2018). Knowledge sharing significantly impacts green innovation and success (Carvalho et al., 2020). Knowledge management that is better organized and planned can improve green innovation (Abbas & Sağsan, 2019). The above argument leads to a hypothesis as follows.

Hypothesis 4: *Knowledge management affects green supply chain adoption.*

3.5. Production Technology and Supply Chain Integration

Technology owned by organizations is an essential and valuable asset (Huo et al., 2015; Siagian and Tarigan, 2021). Technology can help organizations to build unique and competitive capabilities by improving supply chain integration internally and externally (Pirmanta et al., 2021). The rapid development of technology has fundamentally changed companies' production and operation modes to be optimized to accelerate the implementation of supply chain integration (Huo, 2012; Kushwaha & Sharma, 2016). Technology has become an indispensable tool for supply chain integration (Pirmanta et al., 2021). Technology enables systemic network integration that facilitates information sharing with suppliers and customers (Suprapto et al., 2017). This technology can help suppliers improve their forecasting to supply parts and components on time, allowing customers to provide constructive feedback (Yu et al., 2021; Siagian et al., 2022a). Supply chain integration can mediate the use of technology and communication between organizations to improve supply chain performance (Basana et al., 2022b). Supply chain integration can overcome transaction uncertainty and reduce opportunistic behavior by using technology that meets organizational needs resulting from systems and personnel (Yu et al., 2021). Supply chain integration is obtained from the organization's efforts to implement intra- and inter-technology and communication (Nabila et al., 2021). Based on this description, a hypothesis is formulated.

Hypothesis 5: Production technology affects supply chain integration.

3.6. Production Technology and Firm Performance

Adopting technology in the supply chain allows companies to collect information as a form of knowledge about customers, suppliers, and market demands, which in turn floats the company's processes to improve firm performance (Tseng & Liao, 2015; Siagian et al., 2022a). The critical role of technology as one of the strategic orientations is to build organizational capabilities and enhance firm performance (Alsadi & Aloulou, 2021). The application of technology can reduce complexity and allow companies to optimize global supply chain strategies to maximize company performance (Tseng & Liao, 2015; Siagian and Tarigan, 2021). The use of technology in the process in manufacturing companies can impact manufacturing performance by reducing costs, improving quality and delivery accuracy, and increasing flexibility (Schrettle et al., 2014; Khanuja & Jain, 2021). Adopting technology as a system implementation in companies can improve performance (Ali et al., 2016). Using a high level of technology can maintain superior performance to increase organizational competitiveness (Aloulou, 2019; Tzokas et al., 2015). An empirical study conducted on 292 industrial companies in Saudi shows the importance of technology in improving new product development and firm performance (Aloulou, 2019). Based on this argument, a hypothesis is proposed.

Hypothesis 6: *Production technology affects firm performance.*

3.7. Production technology and green supply chain adoption

The application of green production technology has a role in producing high-quality products for customers who are inseparable from the role of suppliers who consider the part of the environment, called the green supply chain (Adnan et al., 2019; Basana et al., 2022a). Adopting technology can improve production methods, increase production yields, and increase company revenues (Kumar et al., 2020). The use of technology in producing green manufacturing as a manufacturing process by creating less pollution, less waste, and less loss in production (Dubey et al., 2015). The use of technology can consume less energy and minimum resources (Sellitto et al., 2019). The technology used in production can reduce the number of processes and the use of machines automatically to provide convenience in routine procedures (Kazancoglu et al., 2020). Technology can also support organizations to use materials that can be used repeatedly and recycled (Chuang and Huang, 2018; Bag et al., 2020). Green production/manufacturing is an important concept that can lead to competitive advantage by maximizing efficiency while producing process quality and output by minimizing costs (Dubey et al., 2015). Another hypothesis is defined as follows.

Hypothesis 7: *Production technology affects green supply chain adoption.*

3.8. Supply Chain Integration Relationship and Green Supply Chain Adoption

Companies must strengthen cooperation with partners in the supply chain by paying attention to environmental and sustainable company performance (Del Giudice et al., 2021; In Vaio & Varriale, 2020; Jawaad & Zafar, 2020). Supply chain integration is formed in the company by involving components in the internal and external of the company, but the participation rate of each member of the supply chain is uneven (Genovese et al., 2017). Supply chain integration is closely related to the company's ability to run a green supply chain (Chen et al., 2018; Kotzab et al., 2023). Green supply chain integration is a company collaboration to focus on goals by considering the environment (Tarigan et al., 2020). This argument leads to a hypothesis as follows.

Hypothesis 8: *Supply chain integration affects green supply chain adoption.*

3.9. Supply Chain Integration Relationship and Firm Performance

Supply chain integration in companies can increase customer satisfaction by improving adequate services (Alsadi & Aloulou, 2021). Supply chain integration in companies can produce competitiveness with competitive advantages (Lii & Kuo, 2016). Supply chain integration can also improve performance (Siagian et al., 2022a). Supply chain integration influences the company's operational performance (Lu et al., 2018; Yuen & Thai, 2017; Basana et al., 2022a). Company performance can be improved by adopting internal and external supply chain integration (Li et al., 2019). The ability of companies to build inter-organizations using technology to be integrated can result in increased business and financial performance (Alsadi & Aloulou, 2021; Alsadi & Aloulou, 2021; Golicic & Smith, 2013). At the same time, some studies report no negative relationship between supply chain integration and firm performance (Alsadi & Aloulou, 2021). The performance measurements most used and influenced by supply chain integration are financial performance, customer-oriented performance, and operational performance. The customer-oriented performance consists of actions related to improvement.

Hypothesis 9: *Supply chain integration affects firm performance.*

3.10. Green Supply Chain Adoption and Firm Performance

Environmentally friendly activities contribute significantly to the company's financial performance (Jawaad & Zafar, 2020). Eco-friendly practices have a positive relationship with reducing operational costs and efficiency in material purchases (Zhang & Wang, 2014). The reduction of expenses has an impact on improving the company's performance. Green supply chain management practices affect market performance and company operations (Golicic & Smith, 2013; Del Giudice et al., 2021; Santoso et al., 2022). The company took the initiative to pay attention to the environment as a form of green innovation to improve firm performance (Kushwaha & Sharma, 2016). Green innovations in organizations complying with government regulations can reduce ecological impacts to produce environmental and firm performance (Abu Seman et al., 2019; Guo et al., 2020; Huang & Li, 2017; Kraus et al., 2020). Environmental management is related to firm performance in stock market finance (Schrettle et al., 2014). Green practice and care for the environment can improve management efficiency, create knowledge, and configure internal processes that impact competitiveness and financial performance (Guang Shi et al., 2012). Schrettle et al. (2014) found that the varied afforestation phases of the supply chain impact increased competitiveness and better economic performance. Green supply chain management improves environmental and economic performance (Schrettle et al., 2014; Santoso et al., 2022). Relationships state that companies adopting green supply chains can improve financial and environmental performance (Khan et al., 2021; Wong et al., 2020). A green supply chain is one of the drivers of company performance and success (Zailani et al., 2012). Excellence in environmental protection can result in waste reduction and efficiency gains in operations (Schrettle et al., 2014). The last hypothesis is formulated as follows.

Hypothesis 10: *Green supply chain adoption affects firm performance.*

4. Research Methods

This research investigates the influence of knowledge management, production technology, supply chain integration, and green supply chain adoption on firm performance in the manufacturing sector. This research is causal research which examines the relationship between research constructs (Sekaran & Bougie, 2016). The population of this study was manufacturing companies of medium and large size that had more than 20 employees and business entities registered on the official website of the Central Statistics Agency of East Java, Indonesia. Each company is represented by only 1 (one) respondent. Research respondents have a minimum senior staff position, two years of work experience, and a permanent employee. This minimum criteria requirement ensures that respondents know the company profile where they work. The questionnaire, designed with a five-point Likert scale in Google Forms, is distributed online via E-mail, Instagram, LINE, LinkedIn, and WhatsApp. The survey obtained as many as 115 from 145 questionnaires that were filled out. Thirty (30) questionnaires were rejected due to not meeting the respondent criteria. The respondent's profile is shown in Table 1.

Table 1
Respondent Profile

Profile	Description	Sum	%
Department	Accounting and Finance	15	13%
	Engineering	2	2%
	Marketing and Sales	44	38%
	Operational and Production	12	10%
	Production Planning & Inventory Control (PPIC)	6	5%
	Purchasing	7	6%
	Quality	13	11%
	Top Management (General)	11	10%
	Warehouse/Logistics	5	4%
Position	Director	17	15%
	General Manager (GM)	15	13%
	Manager	31	27%
	Supervisor (SPV)	27	23%
	Senior Staff	25	22%
Length of Service	2 to less than three years	18	16%
	3 to less than five years	15	13%
	5 to less than seven years	17	15%
	7 to less than ten years	8	7%
	Ten and over ten years	57	50%

The respondents work in several departments, as shown in Table 1. First, the marketing department is 44 respondents, 38%, followed by Accounting and Finance (13%), quality (11%), operation and production (10%), top management (10%), purchasing (6%), PPIC (5%), warehouse (4%), and engineering (2%). Besides, the respondents have positions as managers 27%, followed by supervisors (23%), senior staff (22%), directors (15%), and general managers (13%). Finally, the respondents have work experience of more than ten years, as many as 50%, followed by two to less than three years (16%), five to less than seven years (15%), three to less than five years (13%), and seven t less than ten years (7%). This composition demonstrated that respondents are knowledgeable, have adequate work experience, and understand the company's operations. Data analysis used SmartPLS software 4.0 version. The first step of the research examined the measurement model to assess the validity and reliability of the indicators, as shown in Table 2. Then, further evaluation is the inner model assessment for predicting causality relationships between latent variables. Furtherly, the bootstrapping process examined the t-statistical to predict causality relationships and proposed hypotheses.

Table 2
Mean, Validity, and Reliability Test Result

Item Measurement	Mean	Loading	Composite Reliability	Cronbach Alpha	AVE
Knowledge Management (KM)	**4.038**	0.705	0.862	0.806	0.558
Companies have reliable resources (KM1)	4.296	0.692			
The company has staff who are experts on the environment (KM2)	3.948	0.789			
The company conducts knowledge transfer between staff (KM3)	3.765	0.863			
The company has environmentally friendly technology (KM4)	4.122	0.666			
Compartments in the company are environmentally responsible (KM5)	4.061				
Production Technology	**4.248**	0.812	0.899	0.85	0.69
Companies using technology to produce products (PT1)	4.287	0.86			
The company adjusts the technology according to the characteristics of the product (PT2)	4.296	0.876			
The company chooses the technology that suits your needs (PT3)	4.243	0.771			
The company provides adequate training to staff in the use of technology (PT4)	4.165				
Supply Chain Integration (SCI)	**3.959**		0.93	0.899	0.768
Companies sharing information with external partners (SCI1)	3.772	0.817			
The company coordinates with partners in fulfilling orders (SCI2)	4.043	0.872			
The company has adequate internal integration between functions (SCI3)	4.052	0.9			
The company builds strategic collaborations with external partners (SCI4)	4.017	0.912			
Green Supply Chain Adoption (GSCA)	**3.928**		0.908	0.864	0.714
The company involves the external in implementing environmentally friendly (GSCA1)	3.896	0.886			
Companies using reliable green technology (GSCA2)	3.757	0.857			
The company uses environmentally friendly materials (GSCA3)	3.93	0.895			
Company to control waste to comply with regulations (GSCA4)	4.13	0.73			
Firm Performance (FP)	**4.101**		0.912	0.878	0.678
The company can reduce the delivery time (FP1)	3.87	0.649			
The company can respond to customer requests quickly (FP2)	4.2	0.863			
The company can deliver the product appropriately (FP3)	4.217	0.849			
The company can produce production capacity or volume on demand (FP4)	4.235	0.906			
Efforts to reduce production costs (FP5)	3.983	0.825			

Based on Table 2, the average value of measurement items for knowledge management has a value between 3,765 - 4,296. These values indicate that knowledge management has been adequately implemented. The smallest loading factor is found in KM5 items (departments in the company responsible for the environment) of 0.666 and AVE value of 0.558 > 0.500 so that they meet the validity requirements. The reliability test showed that a composite reliability value of 0.862, and the Cronbach Alpha 0.806 has exceeded 0.700 and is considered reliable. Validity and reliability tests for other variables, namely production technology, supply chain integration, green supply chain adoption, and firm performance, have met the requirements of validity and reliability.

5. Results and Discussion

Evaluation of the inner structural model relates to the percentage of variants between constructs of the study. This evaluation is carried out by looking at the R-square and Q-square values. The inner model or structural model is a structural model for predicting causality relationships between latent variables (Table 3).

Table 3
R-Square

Research Variables	R-square
Production Technology (PT)	0.280
Supply Chain Integration (SCI)	0.499
Green Supply Chain Adoption (GSCA)	0.532
Firm Performance (FP)	0.624

Table 3 demonstrates the goodness of fit of the research model in terms of R^2 value. Another measurement is using the Q^2 value, which is calculated using the R^2 values with the following formula: Q2: 1− [(1–0.0,280) × (1–0.499) × (1–0.532) × (1–0.624)] = 0.937 = 93.7%. The result shows the value of Q^2 is 93.7%, which implies that the variation of knowledge management, production technology (PT), supply chain integration (SCI), and green supply chain adoption (GSCA) explains the variation of firm performance up to 93.7%. The inner model was also tested for the relationship between the variables using the SmartPLS software. Through the bootstrapping process, t-statistical values are obtained and used to examine the hypotheses formulated (Fig. 1 and Table 4).

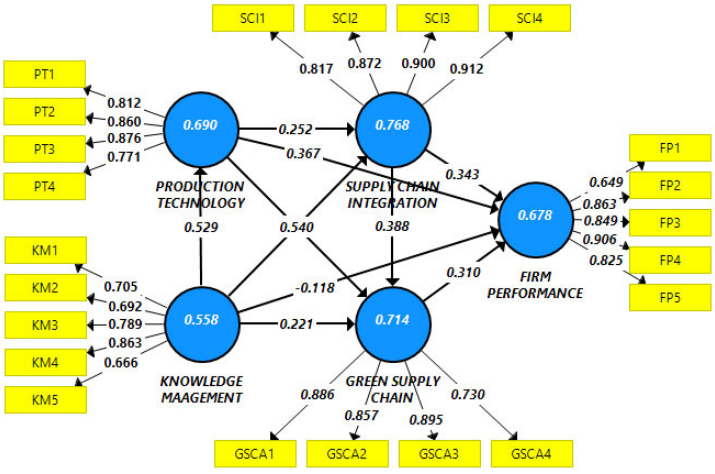

Fig. 1. Path Coefficient Research Results

Table 4
Research Hypothesis Test Results

Direct Effect		Original Sample	T-statistics	P-values
H1	Knowledge Management → Production Technology	0.529	8.070	0.000
H2	Knowledge Management → Supply Chain Integration	0.540	7.358	0.000
H3	Knowledge Management → Firm Performance	-0.118	1.238	0.216
H4	Knowledge Management → Green Supply Chain Adoption	0.221	2.178	0.029
H5	Production Technology → Supply Chain Integration	0.252	2.961	0.003
H6	Production Technology → Firm Performance	0.367	4.158	0.000
H7	Production Technology → Green Supply Chain Adoption	0.243	2.559	0.011
H8	Supply Chain Integration → Green Supply Chain Adoption	0.388	3.461	0.001
H9	Supply Chain Integration → Firm Performance	0.343	3.623	0.000
H10	Green Supply Chain Adoption → Firm Performance	0.310	2.815	0.005

Based on the results in Fig. 1, and Table 4, the test results of the research hypothesis are determined. The first research hypothesis (H1), knowledge management affects production technology, is supported by a t-statistical value of 8,070 > 1.96 and a p-value of 0.000 (<0.05). Knowledge management affects production technology significantly. The company's ability to transfer knowledge among staff and use environmentally friendly technology as a form of knowledge management influences the implementation of production technology. The results of this study are in line with the results of research which states that knowledge management has a significant effect on production technology (Wilkesmann & Wilkesmann, 2017; Ilvonen et al., 2018; Lee & Ha, 2018; Gift, 2018).

The second hypothesis (H2), namely, knowledge management affects supply chain integration, is also supported by a t-statistical value of 7,358 > 1.96 and a p-value of 0.000 (<0.05). This finding proved that knowledge management significantly affects supply chain integration. Knowledge management built by the company by increasing reliable resources and transferring knowledge between staff can produce supply chain integration with increased coordination with partners. This study's results support the earlier research that knowledge management significantly affects supply chain integration (Tan & Cross, 2012; Li et al., 2012; Wong et al., 2020). The third hypothesis (H3), knowledge management affects firm performance, is not supported with a t-statistical value of 1,238 < 1.96 and a p-value of 0.216 (>0.05). The results of the third hypothesis found that knowledge management did not significantly affect firm performance. The company's efforts in having reliable resources and being responsible for the environment as a form of knowledge management do not directly impact firm performance. The results of knowledge management are an effort to enhance the ability of employees who do not directly reduce production costs and timely delivery of products. This research is different from previous research in that knowledge management affects firm performance (Shahzad et al., 2020; Tseng & Lee, 2014; Kianto et al., 2017; Wong et al., 2020).
The fourth hypothesis (H4), knowledge management impacts green supply chain adoption, is supported by a t-statistical value of 2,178 > 1.96 and a p-value of 0.029 (<0.05). Knowledge management realized by transferring knowledge between staff and having environmentally friendly technology can enhance the effectiveness in green supply chain adoption, namely using ecologically friendly materials and green technology that is relied on. The results of this study support the statement that knowledge management significantly influences green supply chain adoption (Agyabeng-Mensah et al., 2022; Lim et al., 2017; Pérez-Luño et al., 2019; Wong et al., 2020; Abbas & Sağsan, 2019).

Furthermore, the fifth hypothesis (H5), production technology affects supply chain integration, is confirmed with a t-statistical value of 2,961 > 1.96 and a p-value of 0.003 (<0.05). These results show that production technology can improve supply chain integration with a positive coefficient value of 0.252. Production technology adopted technology adjustments following product characteristics, and this decision can improve supply chain integration through adequate integration of internal functions and strategic collaboration with external partners. The study results align with previous research stating that production technology affects supply chain integration (Wong et al., 2020; Huo, 2012; Yu et al., 2021; Nabila et al., 2021).
The sixth hypothesis (H6), production technology affects firm performance, is confirmed with a t-statistical value of 4,158 > 1.96 and a p-value of 0.000 (<0.05) so that the direct effect of the sixth hypothesis is supported. These results proved that production technology has a positive impact on improving firm performance. Production technology used by companies in producing products and technology adjustments following product characteristics as a form of technology adoption can increase firm performance due to the ability to make capacity or production volume on demand. The results of this study follow the results of previous research that production technology has a significant effect on firm performance (Tseng & Liao, 2015; Alsadi & Aloulou, 2021; Schrettle et al., 2014; Ali et al., 2016; tzokas et al., 2015).
In addition, the fifth hypothesis (H5), production technology affects supply chain integration, is proved with a t-statistical value of 2,961 > 1.96 and a p-value of 0.003 (<0.05). These results confirm that production technology positively affects supply chain integration by a path coefficient of 0.252. Production technology used based on technological adjustments under product characteristics can increase supply chain integration through internal functions and strategic collaboration with external partners. The study's results align with the earlier research results that production technology affects supply chain integration (Wong et al., 2020; Huo, 2012; Yu et al., 2021; Nabila et al., 2021).

The sixth hypothesis (H6) that has been determined, namely Production Technology, affects Firm performance with a t-statistical value of 4,158 > 1.96 and a p-value of 0.000 (<0.05) so that the direct effect of the sixth hypothesis is acceptable. These results show that production technology has an impact on significantly improving firm performance. Production technology used by companies in producing products and technology adjustments following product characteristics as a form of technology adoption can increase in firm performance due to the ability to produce capacity or production volume on demand. The results of this study are per the results of research that states that production technology has a significant effect on firm performance (Tseng & Liao, 2015; Alsadi & Aloulou, 2021; Schrettle et al., 2014; Ali et al., 2016; Tzokas et al., 2015).

The seventh hypothesis, production technology affects green supply chain adoption, is accepted at the t-statistical value of 2,559 > 1.96 and the p-value of 0.011 (<0.05). The company uses technology to produce products and provides adequate training to staff to adapt production technology to improve green supply chain adoption. This achievement is obtained by increasing environmentally friendly materials and waste control to comply with regulations. The results of this study agree with the results of research that states that production technology affects green supply chain adoption (Adnan et al., 2019; Kumar et al., 2020; Dubey et al., 2015; Sellitto et al., 2019; Kazancoglu et al., 2020; Chuang and Huang, 2018). The eighth

hypothesis (H8), namely supply chain integration, affects green supply chain adoption with a t-statistical value of 3,461 > 1.96 and a p-value of 0.000 (<0.05), so the direct effect of the eighth hypothesis is acceptable. Supply chain integration implemented by companies by having adequate integration in internal functions and strategic collaborations with external partners can improve supply chain adoption. The company's ability involves implementing external and environmentally friendly materials as a supply chain. The results of the study support the results of research that states that production technology affects green supply chain adoption (Del Giudice et al., 2021; Di Vaio & Varriale, 2020; Genovese et al., 2017; Chen et al., 2018; Kotzab et al., 2023; Han & Huo, 2020).

The supply chain integration relationship to firm performance has been determined as the ninth hypothesis (H9), and the result obtained a t-statistical value of 3,623 > 1.96 and a p-value of 0.000 (<0.05) so that the direct effect of the ninth hypothesis is acceptable. Based on these results, it is stated that supply chain integration to firm performance is 0.343 and significant. Therefore, companies that can build integration in the supply chain flow by sharing information with external partners and building strategic collaborations with external partners can produce improved company performance. The results of the improvement in company performance can be seen in the company's ability to reduce delivery cycle times and deliver products appropriately. Finally, the tenth hypothesis (H10), supply chain integration has a significant effect on firm performance, is supported by a t-statistical value of 2,815 > 1.96 and a p-value of 0.005 (<0.05). This result aligns with previous research (Alsadi & Aloulou, 2021; Lii & Kuo, 2016; Lu et al., 2018; Yuen & Thai, 2017; Li et al., 2019). Green supply chain adoption implements environmentally friendly systems, reliable green technology, and environmentally friendly materials that can improve company performance. The company's ability to respond to customer requests quickly and the company's ability to reduce production costs are based on an ongoing process. The results of this study confirm the results of the survey which states that green supply chain adoption has a significant impact on firm performance (Jawaad & Zafar, 2020; Zhang & Wang, 2014; Golicic & Smith, 2013; Kushwaha & Sharma, 2016; Abu Seman et al., 2019; Guo et al., 2020; Huang & Li, 2017; Kraus et al., 2020; Guang Shi et al., 2012; Schrettle et al., 2014; Khan et al., 2021; Wong et al., 2020; Zailani et al., 2012).
The supply chain integration relationship to firm performance has been determined as the ninth hypothesis (H9) so that it is obtained with a t-statistical value of 3,623 > 1.96 and a p-value of 0.000 (<0.05) so that the ninth hypothesis is acceptable. Companies that can build integration in the supply chain flow by sharing information with external partners and building strategic collaborations with external partners can improve company performance. The results of the improvement in company performance can be seen in the company's ability to reduce delivery cycle times and deliver products appropriately. The results of the study confirm the results of the study which states that supply chain integration has a significant effect on firm performance (Alsadi & Aloulou, 2021; Lii & Kuo, 2016; Lu et al., 2018; Yuen & Thai, 2017; Li et al., 2019). The last hypothesis, namely the tenth hypothesis (H10), which shows green supply chain adoption of firm performance, was obtained with a t-statistical value of 2,815 > 1.96 and a p-value of 0.005 (<0.05) so that the direct effect of the tenth hypothesis is acceptable.

The results of this study confirm the results of the study which states that green supply chain adoption has a significant impact on firm performance (Jawaad & Zafar, 2020; Zhang & Wang, 2014; Golicic & Smith, 2013; Kushwaha & Sharma, 2016; Abu Seman et al., 2019; Guo et al., 2020; Huang & Li, 2017; Kraus et al., 2020; Guang Shi et al., 2012; Schrettle et al., 2014; Khan et al., 2021; Wong et al., 2020; Zailani et al., 2012).

The results showed the importance of knowledge management to increase empowerment and knowledge sharing between staff in the company to improve capabilities in using adequate technology. The company's technology is tailored to the needs and can use environmentally friendly raw materials. The technology used can respond to the needs of company partners in the supply chain flow. Technology can produce supply chain integration and green supply chain in adequate company performance. The practical implications of research provide insight for managers and top management of companies about the need to increase employee knowledge and use updated production technology. Company employees can share knowledge with their peers to improve their ability to use technology. Company managers also need to understand the role of supplier partners and customers in supporting the company's performance in supply chain integration and the importance of a green supply chain in improving sustainable performance for companies.

6. Conclusion

Knowledge management is vital for companies in today's conditions, which are uncertain and require flexible employees to face global changes. The use of technology for companies requires employees who can operate and update technology to tailor their needs to rapid changes. Based on the results, several conclusions were withdrawn. First, knowledge management by transferring knowledge among staff and having environmentally friendly technology is capable of adopting production technology, implementing supply chain integration, and green supply chain adoption. Second, knowledge management does not directly impact firm performance, and this finding contradicts previous research. Third, companies should adopt production technology tailored to product characteristics and provide adequate training to staff. Fourth, production technology owned by the company enables the company to implement supply chain integration, green supply chain adoption, and firm performance. Fifth, supply chain integration demonstrated by coordinating with partners in fulfilling orders, using technology to integrate between functions in an adequate internal manner, and strategically collaborating with external partners can result in improved green supply chain adoption and firm performance. Sixth, the company's ability to adopt a green supply chain

enhances performance by prioritizing environmentally friendly materials and involving external partners in implementing ecologically friendly materials. Seventh, companies should be able to produce products that can control waste to comply with applicable regulations. Finally, the company's decision to adopt the green supply chain enhances company performance by appropriately delivering products, production capacity, or volume on demand and responding to customer demands quickly. The theoretical contribution of the research is to enrich the resource-based view theory with an approach to achieve a competitive advantage in knowledge management and operational technology. This research shows managers that knowledge management, supply chain integration, production technology, and green supply chain are essential in improving firm performance. The current global market has become paying attention to global environmental sustainability in the long run.

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