

# Green Production and Green Technological Innovation: A Theoretical Review<sup>1</sup>

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## Abstract

Environmental threats such as global climate change, depletion of natural resources and environmental pollution have led businesses to develop sustainability-oriented strategies. In this context, green production, green technological innovation and green supply chain management (GSCM) concepts stand out as tools that play a critical role in ensuring environmental sustainability. The study addresses the effects of green production and innovation practices on the environmental, economic and competitive performances of enterprises and examines how these processes are integrated in the context of supply chain management. Based on a narrative literature review and conceptual synthesis, this study examines practices such as. sustainable production models, green product innovation, eco-design, green purchasing, reverse logistics and environmentally friendly supplier relationships. The findings show that green practices not only reduce environmental impact but also provide firms with significant contributions such as long-term competitive advantage, cost savings and brand reputation. In addition, it is understood that economic and organizational sustainability concerns are the determinants of firms' orientation towards green innovation rather than environmental motivations. In conclusion, green production, technological innovation and supply chain practices should be evaluated holistically to achieve sustainable development goals. To ensure this integrity, the study provides strategic recommendations for both businesses and policymakers and makes a theoretical contribution to the literature.

**Keywords:** Green Production, Green Technological Innovation, Green Supply Chain

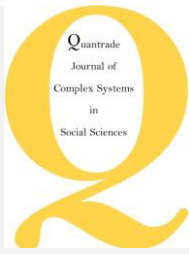
## Yeşil Üretim ve Yeşil Teknolojik İnovasyon: Kuramsal Bir İnceleme

### Öz

Küresel iklim değişikliği, doğal kaynakların tükenmesi ve çevre kirliliği gibi çevresel tehditler, işletmeleri sürdürülebilirlik odaklı stratejiler geliştirmeye yönlendirmiştir. Bu bağlamda yeşil üretim, yeşil teknolojik inovasyon ve yeşil tedarik zinciri yönetimi (GSCM) kavramları, çevresel sürdürülebilirliğin sağlanmasında kritik rol oynayan araçlar olarak öne çıkmaktadır. Çalışma, yeşil üretim ve inovasyon uygulamalarının işletmelerin çevresel, ekonomik ve rekabetçi performanslarına olan etkilerini ele almakta; bu süreçlerin, tedarik zinciri yönetimi bağlamında nasıl entegre edildiğini incelemektedir. Literatür taraması ve kavramsal senteze dayanan bu çalışma, sürdürülebilir üretim modelleri, yeşil ürün inovasyonu, eko-tasarım, yeşil satın

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alma, tersine lojistik ve çevre dostu tedarikçi ilişkileri gibi uygulamaları incelemektedir. Bulgular, yeşil uygulamaların sadece çevresel etkiyi azaltmakla kalmadığını, aynı zamanda firmalara uzun vadeli rekabet avantajı, maliyet tasarrufu ve marka itibarı gibi önemli katkılar sunduğunu göstermektedir. Ayrıca, firmaların yeşil inovasyona yönelmesinde çevresel motivasyonlardan çok, ekonomik ve kurumsal sürdürülebilirlik kaygılarının belirleyici olduğu anlaşılmaktadır. Sonuç olarak, sürdürülebilir kalkınma hedeflerine ulaşmada yeşil üretim, teknolojik inovasyon ve yeşil tedarik zinciri uygulamaları bütünsel bir yaklaşım içinde değerlendirilmelidir. Çalışma, bu bütünlüğü sağlamak adına hem işletmeler hem de politika yapımcılar için stratejik öneriler sunmakta ve literatüre teorik bir katkı sağlamaktadır.

**Anahtar Kelimeler:** Yeşil Üretim, Yeşil Teknolojik Inovasyon, Yeşil Tedarik Zinciri

## Introduction

One of the greatest dangers to human progress in the twenty-first century is the undeniable truth of global warming (Yina et al., 2020). Global environmental crises have been exacerbated by human activities such as population growth, industrialisation, and excessive consumption, necessitating immediate action to preserve energy, water, and other natural resources (Dornfeld, 2014). Human survival and achieving sustainable development targets are under jeopardy due to resource depletion caused by the fast expansion of economic and social productive forces (Shuzhen, 2012). Today, environmental problems directly affect not only ecological balance but also economic development and the performance of businesses (Soewarno et al., 2019). In this context, the manufacturing sector assumes a critical role as one of the basic building blocks of the global economy (Singh et al., 2016). The manufacturing industry of countries makes significant contributions not only to economic growth but also to the determination of competitiveness (Yina et al., 2020). However, production activities that ignore environmental quality are the main source of environmental damage (Soewarno et al., 2019). In today's world, no manufacturing industry can afford to ignore environmental concerns. According to Jayant et al. (2018), production processes put a lot of strain on the environment because of the amount of energy, water, and materials used. Natural resources are depleted, and other harmful environmental byproducts, including waste, hazardous chemical emissions, excessive energy consumption, and carbon emissions, are produced by the resources utilized in these processes (Dornfeld et al., 2013). Businesses are under growing pressure from interested parties to improve resource efficiency and reduce greenhouse gas emissions such as CO, CO<sub>2</sub>, and fly ash during production (Soewarno et al., 2019). A shift to green production practices—less harmful to the environment—is thus essential for achieving long-term economic growth (Jha, 2016). Using environmentally friendly technology in manufacturing is a crucial part of this shift. Building future manufacturing systems that can withstand technological advancements requires new production models. The idea of environmentally friendly innovation now takes center stage. Through green innovation, companies can lessen their negative effects on the environment while simultaneously boosting productivity, improving their corporate image, and gaining an edge in new markets by projecting an image of being environmentally conscious (Meidute-Kavaliauskiene et al., 2021). In this direction, while the importance of green production approach is increasing daily, green technological innovation practices are considered one of the main tools of this transformation. In this study, the concept of green production and its importance are emphasised, and then detailed explanations of green innovation practices are presented. This study does not follow a systematic review methodology. Rather, it adopts a narrative literature review approach to conceptually synthesize key discussions and findings from selected academic sources, aiming to provide a theoretical framework for understanding green production, green innovation, and green supply chain practices (Kaya ve Yıldız, 2024). The conceptual model proposed for the research is presented in Figure 1.

Figure 1 presents a conceptual framework illustrating the interrelationship between green production, green technological innovation, and green supply chain management, developed based on the integrative

perspectives of Sezen and Çankaya (2013), Maruthi and Rashmi (2015), and Meidute-Kavaliauskiene et al. (2021).

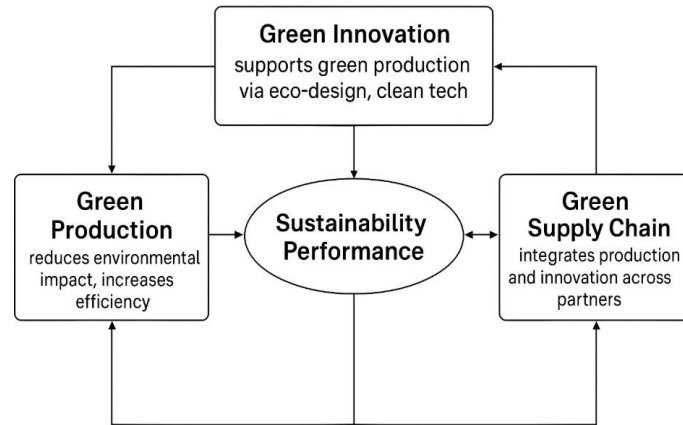


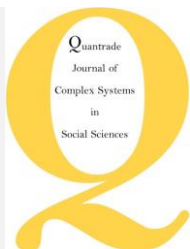
Figure 1. Conceptual Model

## 1. Green Production

Green production is a relatively new concept that has started to appear in literature since the 1990s and is still developing. Academic studies in this field are limited in number, and research on the scope and applications of the concept has been met with increasing interest (Handfield et al., 1997; Sezen & Çankaya, 2013). In general terms, green production is defined as a methodology that aims to minimize waste and environmental pollution in the production process (Davim, 2013). However, this definition may be insufficient to reflect the multidimensional structure of green production.

Green manufacturing is an all-encompassing system that targets the reduction of negative impacts on the environment and the maximization of resource efficiency through the identification, measurement, evaluation, and management of environmental waste streams (Maruthi and Rashmi, 2015). It does this by integrating production planning and controlling processes with product and process design. Green manufacturing, in this sense, is an all-encompassing method that makes an impact before, during, and after production. Green production is defined by Jha (2016) as: using materials and techniques that are economically feasible while minimizing environmental consequences, conserving energy and natural resources, and being safe for employees, consumers, and society. According to this explanation, "green production" takes into account the long-term aims of society and the economy in addition to the environment (Demiroğlu and Ulusoy, 2024). Giving the idea a more methodical spin, Handfield et al. (1997) define green manufacturing as an integrated, system-wide, economically based strategy to minimize or eradicate waste at every stage of the product life cycle, from design to use to disposal. Making sure the supply chain is sustainable from start to finish is the goal of this strategy (Üster, 2024). Green manufacturing is an industrial process that uses eco-friendly materials and technologies to lessen environmental impact (Srivastava, 2007). Therefore, the significance of technical decisions in guaranteeing environmental sustainability is highlighted.

Green production also has an interdisciplinary structure. This approach, which includes using less material, intensive design practices and reducing energy consumption, is critical in reducing the pressure on the environment (Jha, 2016). Among the standards set for achieving green production are zero potential safety risk, zero health threat to employees and product users, minimum environmental pollution in the production process, waste recycling, and implementation of effective disposal methods (Gao et al., 2009).



Reducing both raw material and energy consumption is directly related to minimizing waste generation. This situation not only supports environmental sustainability but also allows businesses to achieve financial benefits by increasing productivity. In this respect, green production is considered a "win-win" strategy that can provide environmental and economic benefits at the same time. While industrial productivity, profitability, and competitiveness can be increased through green production, the environment and the health of consumers and employees are also protected (Fore and Mbohwa, 2015).

The green production approach, which applies to all industries, is a production method to reduce waste and environmental pollution. This method not only slows down the excessive consumption of natural resources but also significantly reduces the amount of waste diverted to landfill sites. More efficient production is aimed at through strategies such as reducing the number of parts, rationalizing the use of materials and reusing components (Shrivastava and Shrivastava, 2017).

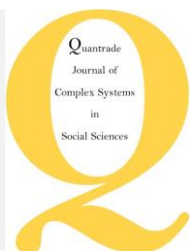
Minimizing negative effects on the environment and conserving resources are key goals of green manufacturing systems. According to Prasad et al. (2016), this method allows for product creation while reducing energy use and environmental consequences. Here, "green production" refers to a multi-faceted approach that encompasses waste management, environmental protection, compliance with regulations, pollution control, redesign, recycling, and remanufacturing (Jawahir et al., 2006; Rehman et al., 2016).

Green production offers wide opportunities not only in terms of environmental protection but also in terms of increasing organizational efficiency. Balancing environmental and economic performance is of critical importance for businesses today, especially in the face of regulatory pressures, competitive conditions and social responsibility expectations. For this reason, many countries have launched campaigns to support green production by developing policies that encourage low energy consumption and recycled materials (Rehman et al., 2016).

One of the environmental concerns that is particularly relevant here is greenhouse gas emissions. According to Erdoğan (2020), almost 90% of the greenhouse gases in the atmosphere are produced by human activities. Greenhouse gases are defined as gases with the ability to trap heat in the atmosphere. Most greenhouse gas emissions come from burning fossil fuels, cutting down trees, farming, and other industrial processes. The term "emission" describes the scheduled release of these gases into the atmosphere and is closely linked to the phenomenon known as global warming. Environmental pollution is one of the main problems that green production aims to reduce. The reaching of toxic chemical substances on land, water and air, and the conscious or unconscious pollution of the environment with wastes generated by human activities are among the defining elements of environmental pollution. Today, our environment is full of organic and inorganic pollutants because of industrial activities, rapid urbanization, and inappropriate environmental management practices, which cause these pollutants to be released into the environment in different ways (Ahmadpour et al., 2012).

Traditional air pollution management approaches generally focus on controlling pollutants at the source and do not provide solutions to remove pollutants already present in the air. This creates the need for innovative solutions. One such new strategy is using urban vegetation, which can reduce air pollutants through microclimate effects and dry deposition processes. The large surface area and rough surface of the branches and leaves of plants make them an effective sink for pollutants. Furthermore, plants reduce indoor temperatures through shading, thereby reducing the use of air conditioning, which indirectly contributes to the reduction of emissions from power plants (Yang et al., 2008).

Although green production is a relatively new area of research and discussion in the academic literature, it is gaining more and more importance in the context of the Sustainable Development Goals. In this context, integrating green practices into production processes is critical for technological sustainability and maintaining the economic competitiveness of both today's society and future generations (Singh et al., 2016).



Accurately and comprehensively defining why a focus on green manufacturing is necessary is critical for awareness and progress in this area. Today, indicators such as energy consumption, global temperature increases, rising levels of carbon dioxide (CO<sub>2</sub>) in the atmosphere, the negative effects of industrialization and rapid population growth make it clear that current conditions are becoming increasingly challenging and less sustainable. In this context, it seems inevitable that factors such as energy costs, access to energy resources, waste disposal and treatment costs, and material supply will become more costly and complex (Dornfeld et al., 2014).

Green production practices have developed as a response to these threats and have become an approach that adopts production systems to reduce greenhouse gas emissions, the use of toxic substances and waste generation. In this context, green production offers both environmental and economic benefits by enabling the development of more efficient processes and technologies in the transformation of materials. The ultimate goal is to protect future generations' living conditions by adopting sustainability principles (Davim, 2013).

This process's energy efficiency is a key metric. Doğan and Yılkırkan (2015) define energy efficiency as "reducing energy consumption per unit of product or service while increasing the standard of living and service quality in buildings and reducing energy consumption per unit of product or service without decreasing the quality and quantity of production in industrial enterprises". According to this explanation, energy efficiency is about more than just cutting costs; it's also about boosting output and livability.

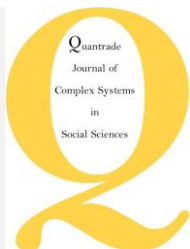
In this context, integrating renewable energy sources with green production has become an inevitable necessity. Renewable energy sources such as biomass, hydroelectricity, geothermal, solar, wind and marine energy will play an important role in ensuring energy supply security in the future due to their domestic, sustainable and environmentally friendly nature (Panwar et al., 2011).

The devastating effects caused by forest fires, floods and other natural disasters all over the world in recent years have led to increased concern in both public and academic circles about climate change and global warming. Continuously rising CO<sub>2</sub> emissions are considered the most dangerous form of air pollution due to their environmental diffusion power and their potential to remain in the atmosphere for a long time. Especially in developing countries, air pollution is largely caused by transport vehicles and industrial facilities. Most industrial air pollutants consist of emissions from heavy industries such as iron and steel, oil refineries and small-scale industrial establishments. Such polluting industries are able to survive due to inadequate environmental regulations, low environmental standards and underdeveloped pollution control technologies in developing countries (Asif et al., 2020). Because of this, green production is now essential for the sake of public health, economic stability, and the environment. Redesigning industrial systems with a sustainability viewpoint is crucial for preventing long-term environmental damage and using current resources better.

With the rise of international environmental regulations such as the Montreal Protocol, the Kyoto Protocol, the Waste Electrical and Electronic Equipment Directive (WEEE) and the Restriction of the Use of Certain Hazardous Substances Directive (RoHS), the growing environmental awareness among consumers has a significant impact on businesses around the world. Türkiye has taken important steps to fulfil its international environmental responsibilities in this context. Turkey officially became a party to the United Nations Framework Convention on Climate Change (UNFCCC) on 24 May 2004 and the Kyoto Protocol on 26 August 2009. To comply with these international agreements, the Turkish government has made various environmental legislation amendments. This situation has led Turkish enterprises to develop environmentally friendly production and management practices to fulfil environmental obligations and meet consumer expectations. Firms that adopt proactive strategies of environmental management can not only ensure legal compliance but also integrate innovative products and processes as well as green practices and spread environmental protection targets to all departments of the company (Sezen & Çankaya, 2013). This integrated approach allows businesses to strengthen both their environmental and corporate performance.

Green production provides significant environmental improvements through various sustainability practices. These gains include reduction in greenhouse gas emissions that cause global warming such as carbon





dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O) and chlorofluorocarbons (CFCs), increase in recyclability rates, improvements in the reuse of materials, reduction in energy consumption, reduction of pollution levels in environmental elements such as air, water and soil (Jha, 2016).

The success of green production practices is not limited to the company's own production processes. Today, many companies transfer certain parts of their production modules to subcontractors or business partners. Since the environmental performance of these actors can directly affect the environmentally friendly quality of the final product, they are considered among the "high-risk" groups in terms of the environment. Therefore, it is recognized as a critical strategy to encourage these stakeholders to adopt environmentally friendly procedures and, if possible, to design green products and services (Rao, 2004).

The main goal of green production is to adopt production processes that minimize environmental damage (Jha, 2016). However, to achieve this goal, only well-intentioned practices are not enough; instead, a systematic framework of principles should be established, and existing processes should be evaluated in line with this framework. Thus, it is possible to objectively measure "how green" the system or solution is and identify potential areas for improvement. Helu and Dornfeld (2013) propose five basic principles for this purpose: Systems Approach: Production processes should be assessed with a holistic system approach regarding environmental performance. Multi-Directional Review: The system should be analyzed comprehensively, both vertically (over time, along the process) and horizontally (along the supply chain). Minimization of Harmful Inputs/Outputs: All inputs and outputs in the system that are harmful to the environment and human health should be minimized or completely eliminated. Reduction of Resource Utilization: Net resource consumption should be minimized to the lowest possible level. Temporal Impact Assessment: The environmental impacts of the production system should be continuously monitored with their changes over time.

Strategic plans to be developed within this framework will not only reduce environmental risks, but also have the potential to increase the long-term competitiveness of enterprises.

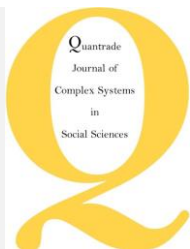
## **2. Green Technological Innovation**

### **2.1. Green Technology**

Green technology, with origins dating back to the pre-Industrial Revolution period when windmills powered basic production activities, was largely overshadowed by the rise of fossil-fueled engines. Over time, energy systems and technological development became heavily reliant on fossil resources, often neglecting environmental consequences. In recent decades, however, green technology has re-emerged as a comprehensive, interdisciplinary response to global environmental challenges. At its core, green technology refers to the integration of environmental science and engineering to develop systems, tools, and processes that minimize the ecological footprint of human activity. It encompasses many functions, including monitoring, control, pollution prevention, remediation, and ecosystem restoration. The aim is not only environmental protection but also the simultaneous advancement of economic, social, and technological development in a balanced and sustainable manner (Habash, 2017).

Green technology focuses on long-term resource productivity by promoting the planned and sustainable use of natural assets such as air, water, soil, vegetation, and biodiversity. As such, it represents a technological pathway toward achieving sustainability goals by linking ecosystem management with innovation. Positioned as a strategic driver of both current and future economies, green technology encourages the transition from environmentally harmful practices to sustainable, cost-effective, and practical alternatives. Key focus areas include sustainability, reusability, reduced resource dependency, innovation, and ease of implementation. These pillars support broader efforts to enhance efficiency, conserve resources, and reduce greenhouse gas emissions (Sezen & Çankaya, 2013; Habash, 2017).

### **2.2. Green Innovation**



Innovation, in the broadest sense, is a creative and entrepreneurial action to discover ways to realise an existing process, product or service in a more effective, efficient or different way (Ulusoy ve Saeed, 2022). This process consists of a combination of elements such as creativity, risk-taking and entrepreneurship (Wong, 2012). Today, innovation is considered not only a tool focused on providing economic benefits, but also a strategic approach that contributes to environmental and social sustainability.

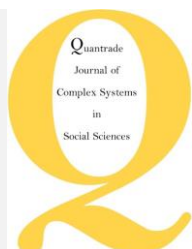
The idea of environmentally friendly innovation is highlighted in this setting. All breakthroughs in energy efficiency, pollution avoidance, waste recycling, green product design, and corporate environmental competitive strategies are considered part of green innovation, according to Chen et al. (2006). According to Wicki and Hansen (2019), "green innovation" is the process of creating new goods, services, and business models that are either less detrimental to society and the environment or have a positive effect on both.

Products and services that are less harmful to human health and the environment can be developed through the green innovation process, which is centered around the use of environmentally friendly technology and production processes (Wong, 2012). Not only is this a technological shift, but it also mirrors the long-term goals of environmentally conscious businesses. When seen from a strategic perspective, green innovation is seen as a way for companies to show they care about the environment and get an edge in the market. Businesses can achieve their reputational and sustainability goals through programs to reduce pollution, manage products' environmental impact, and implement clean technology (Soewarno et al., 2019). A wide range of corporate functions, including procurement, operations, and marketing, are encompassed by green innovation. According to Aguilera-Caracuel and Ortiz-de-Mandojana (2013), innovative techniques like these not only help enterprises financially, but also have positive effects on society and the environment. As a result, they play a big role in corporate sustainability.

### 2.3 Green Technological Innovation

Both environmental responsibility and technical innovation can be viewed in the embrace of green practices (Lin and Ho, 2011). Equipment, goods, procedures, policies, and projects that are novel to an organisation are all considered innovations. Here, "technological innovation" means changes to the foundational systems and procedures of a company's production, as well as new goods, services, and manufacturing methods (Damanpour, 1991). Of course, in order for these to happen, attention should be paid to technology management activities. Technology management is essentially defined as the process of planning, implementing and controlling existing processes related to technology. Considering the recent past, technology management is frequently mentioned in the private sector. One of the most important reasons for this situation is the strengthening of competitiveness as the technology management levels of countries increase (Şen, 2024). If implemented, green technologies might vastly outperform their conventional counterparts in terms of environmental impact. Thus, in order to guarantee environmental sustainability, green technology breakthroughs should be incorporated into sectoral and national development plans (Habash, 2017). To reduce negative effects on the environment, it is essential that these advances are widely used, particularly in the manufacturing and industrial sectors. A plethora of green technologies is fundamental to environmentally friendly production. To accomplish this, cutting-edge techniques and materials are utilised, which enhance the ecological system while simultaneously decreasing resource consumption and pollution. As an all-encompassing term, "green technological innovation" encompasses developments in manufacturing, research and development, social consumption analysis, and waste recovery, among other fields. According to Yina et al. (2020), the primary goal of this innovation type is to lessen the impact on human health, the environment, and the consumption of natural resources.

The corporate sector's interest in green technology advances has skyrocketed in response to rising worldwide worries about environmental deterioration. Assuming environmental responsibility is critical for all businesses, but notably those in polluting manufacturing industries, for reasons including protecting the environment, maintaining a positive company image, and satisfying consumers' expectations. Companies can



reap multiple benefits, including reduced costs, increased profitability, and more effective use of resources, by reorganizing their operations to incorporate environmentally friendly methods. That is why pollution is a sign of inefficiency, resource waste, and environmental danger. When it comes to solving environmental challenges, green technology is seen as a powerful weapon, and this realization leads to the adoption of green innovation as a long-term strategy. According to Xie et al. (2019), green technology innovation is expected to bring about a "double win": firstly, it lessens the environmental impact, and secondly, it speeds up economic growth through its role in technical modernization.

In this context, some countries, especially Japan, are pioneers in green technological practices. For example, Panasonic (formerly Matsushita Electric) completely switched to lead-free solder on printed circuit boards in March 2003, producing a total of 12,000 models in 22 plants in Japan and 79 plants overseas. Sony uses lead-free solder in approximately 80% of its products, including LCD televisions, mobile phones, notebook computers and digital cameras. Toshiba, on the other hand, has introduced lead-free soldering and halogen-free printed circuit boards (PCBs) in its new generation of hard disc drives (Jha, 2016). These examples show that green technological innovation can be successfully realized in theory and practice.

### **3. Green Supply Chain**

In recent years, there has been a rise in interest from academics and businesses in studying green supply chain (GSC) performance as a research subject. The idea of green supply chain management (GSCM) resulted from enhancing the conventional supply chain management (SCM) method and incorporating sustainability-focused practices into the supply chain. From an ecological sustainability standpoint, GSCM seeks to regulate the flow of services as well as materials and data among the producer, the logistics provider, and the consumer (Panja & Mondal, 2019).

When it comes to GSCM and green practices, manufacturing companies are major players. Integrating internal strategies like green purchasing and green production with external initiatives like cooperation with suppliers, distributors, customers, and reverse logistics is crucial for these practices to be effective (Sellitto, 2018). Improving environmental performance at every stage of the supply chain is the goal of this comprehensive approach.

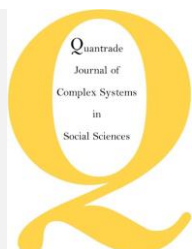
However, developing a GSCM strategy is not a simple process. This is because green practices may lead to an increase in some areas such as investment costs, operating expenses, personnel training and purchasing costs, while on the other hand, they may save some cost items through waste management, energy efficiency and efficient resource utilization. Therefore, managers should correctly analyze the cost-benefit balance provided by the practices. Research shows that companies can achieve economic benefits, especially through green production and green distribution-packaging practices (Yıldız Çankaya & Sezen, 2019).

Green suppliers, which are an important concept within the scope of GSCM, refer to supplier firms that operate with a focus on environmental sustainability. Similar to green product innovation, having such suppliers plays a critical role in improving the firm's environmental performance. The fact that suppliers have environmentally friendly practices enables the sharing of environmental responsibility in the entire supply chain (Andersen, 2021).

The term "green supply chain" refers to an eco-friendly approach to managing the supply chain that incorporates a number of sustainable practices, including sustainable procurement, transportation, manufacturing, building, and product end-of-life management (Mojumder and Singh, 2021). Companies and governments in developing economies are embracing GSCM practices as part of a more comprehensive strategy to management that seeks to lessen environmental impact and energy usage while simultaneously assuring long-term viability. According to Liu et al. (2020), these methods help achieve sustainable development by balancing economic rewards and environmental benefits.

Among the many aspects of green supply chain management, Liu et al. (2020) highlight five crucial for implementation. The following aspects are Environmental management within an organization, Buying





sustainably, Collaboration between eco-design clients and environmental organizations Logistics in reverse. All of these factors point to a comprehensive strategy for lowering environmental impacts along the supply chain.

A growing number of GSCM studies are concentrating on environmental policies. Manufacturers are more likely to create eco-friendly items when consumers show a greater interest in protecting the environment. Yet, environmental policies may be necessary to ensure that firms can continue to earn a profit, which means that the benefits to the environment in the long run may be modest. According to Gao et al. (2021), governments should provide incentives and regulations to help the supply chain become more environmentally friendly.

Environmentally friendly raw material production, processing methods, and green design are all part of what is known as "green procurement" (GS). This approach evaluates suppliers based on their green practices. Thus, GSCM is more intricately structured than SCM since it incorporates cost-benefit analysis into every step of the supply chain, not just the production and procurement phases. Despite the significant initial investment required, green practices boost a product's compound greenness and, as a result, provide environmental and economic benefits to all enterprises in the supply chain (Lou et al., 2020).

The increase in the environmental impacts of industrial activities has forced industrial sectors to take steps towards sustainable development. With the increase in the level of environmental sensitivity of consumers, green transformation in production processes has become inevitable. In this context, GSCM stands out with its function of not only providing environmental adaptation for the sectors but also offering protection against industrial hazards. Although it may seem more complex compared to traditional supply chain management, the applicability of GSCM in industrial sectors is increasingly recognized (Lamba and Thareja, 2021).

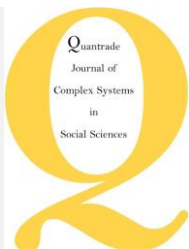
GSCM practices increase the capacity of firms to respond directly and indirectly to sustainability issues. For example, eco-design and green manufacturing practices reduce production costs, reduce waste and strengthen environmental sustainability. Similarly, green procurement emphasizes environmental criteria in external procurement decisions, putting pressure on suppliers to offer environmentally friendly parts and products. Thus, GSCM maximizes environmental benefits by increasing the green impact throughout the entire life cycle of a product from production to consumption and disposal (Kalyar et al., 2020).

The adoption of GSCM is considered as a strategic advantage that can provide competitive differentiation in today's uncertain and turbulent business environment. As consumer interest in green products and services increases, firms' environmental sensitivity plays a critical role in terms of positive brand image and customer loyalty. In this context, GSCM practices should be considered as an investment tool that supports organizational performance. On the other hand, firms that resist managerial change or avoid taking risks due to economic and technical uncertainties face the risk of being left behind in the market. Therefore, contingency theory can provide guidance in analyzing the internal and external environmental variables that influence firms' adoption of GSCM (Choi et al., 2018).

The success of GSCM practices depends on suppliers' strong commitment to their environmental commitments, especially in green sourcing processes. Starting from the top of the chain, the aim should be to reduce waste and harmful substances. In order to improve their own environmental performance, procurement firms should consider the level of commitment of suppliers to environmental practices and integrate this criterion into supplier evaluation and selection processes. Many studies in the literature show that suppliers' attitudes towards environmental quality are decisive in the success of green procurement strategies (Min and Choi, 2020).

#### **4. Green Innovation and Green Production**

Sustainability has become one of the key strategic elements driving both innovation and business growth through innovative product development initiatives of many companies today. In this context, sustainability-focused challenges are seen to stimulate new product innovations. For example, initiatives that go beyond government regulations in the automotive sector show that concrete outputs support sustainability goals. As a



matter of fact, BMW, within the scope of its car recycling strategy, has developed a disassembly design that can enable the production of 100% recyclable cars. Similarly, in the energy sector, companies such as BP and Shell are going beyond their traditional activities based on fossil fuels and increasing their investments in solar, wind and other renewable energy technologies (Sezen and Çankaya, 2013).

The study by Saunila et al. (2018), which looked at how different sustainability factors affect green innovation investment decisions, came to some noteworthy conclusions. Companies are more inclined to invest in environmentally friendly innovations if they prioritize long-term economic, organizational, and social viability. It is worth noting that companies' propensity to employ green technology is unrelated to their environmental sustainability assessment. This finding provides more evidence that environmental concerns play a secondary role to corporate responsibility and financial benefits when it comes to green innovation investments.

Companies in the manufacturing sector are facing new internal and external business environments as a result of the fast globalization of the economy. Businesses are finding that innovation is the best way to stay ahead of the competition, meet customer demands, and keep costs down. One of the most basic challenges businesses face today is the degradation of the environment and the exhaustion of natural resources. The latest news shows that more and more businesses are trying to innovate their way to better environmental protection (Zameer et al., 2020).

Given the high-stakes nature of new product development, the question of how to reduce market failure rates has emerged as a hot spot for academic and managerial interest. According to this line of thinking, green new product development procedures help ensure the long-term viability of the economy and the planet. Commercially successful green products do double duty: they boost companies' competitiveness and raise people's environmental consciousness. As a result, companies can strategically meet their environmental duties through the creation of these products (Huang and Wu, 2010).

## **5. Conclusion, Discussion and Recommendations**

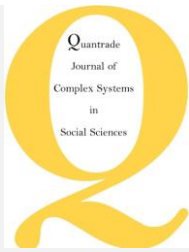
### **5.1. Conclusion**

As a result of global environmental challenges, companies are now compelled to adopt sustainable production models, which means that green technology innovation and green production are becoming strategic imperatives. Companies are reorganizing themselves in response to global challenges like climate change, resource depletion, rising waste, and energy inefficiency, which impact their economic, environmental and social obligations (Raharjo, 2019; Paul et al., 2014).

Green supply chain management, green technology, green innovation, and green production are all part of enterprise sustainability strategies that aim to reduce environmental impacts. These concepts are integrated according to the literature reviewed for this research. Maruthi and Rashmi (2015) and Meidute-Kavaliauskiene et al. (2021) found that using these techniques strengthens company reputation and reduces environmental impact and costs. Firms are compelled to embrace an eco-friendly production style by external factors such as government legislation, customer expectations, and social pressures (Meidute-Kavaliauskiene et al., 2021).

Carbon emissions, energy savings, and the ecological efficiency of key industries are all positively impacted by green technology innovation (Sun et al., 2017; Deng et al., 2019). In this light, "green production" is seen as both a methodology for manufacturing and an ideology that embodies the ecological consciousness of businesses (Maruthi and Rashmi, 2015).

### **5.2. Discussion**



The findings show that green practices implemented by enterprises on the sustainability axis provide economic and competitive advantages and environmental performance. However, there are various obstacles such as high initial investment costs, lack of information and managerial resistance in the implementation of these practices. However, strengthening environmental regulations and increasing financial incentives, especially in developing countries, will play an important role in guiding businesses towards green transformation (Sezen and Çankaya, 2013; Gao et al., 2021).

In addition, an important result of the study is that environmental sustainability alone does not provide sufficient motivation to lead firms towards green innovation, but economic and organizational sustainability expectations trigger this process (Saunila et al., 2018). This shows that companies shape their environmental approaches more for the purpose of gaining a competitive advantage.

Green marketing strategies contribute to the achievement of environmental sustainability goals by facilitating firms' preference for green suppliers and encouraging green innovation. In addition, it has been found that green innovation not only reduces environmental impacts but also positively affects firm performance (Kütahyalı and Yıldız, 2024).

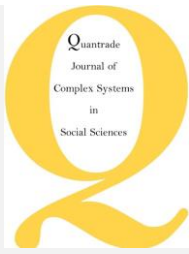
Green production is not only an attempt to protect the environment, but also a strategic element that increases the economic performance of firms. In the study conducted by Yıldız and Çavdar (2020), it was determined that the effect of green production on economic performance is significant, and this effect is further strengthened through reverse logistics practices. In the analysis conducted on 191 manufacturing firms, it was revealed that green production directly affects reverse logistics activities, which leads to an improvement in economic performance. This shows that reverse logistics activities such as recovery, reuse and recycling in production processes can create added value at the organizational level when considered together with green production policies (Yıldız & Çavdar, 2020).

### 5.3. Recommendations

Policymakers should provide stronger regulatory and fiscal incentives to encourage businesses to transition to green production and innovation. This will accelerate the transformation process, especially in emerging economies. Businesses should place sustainability at the center of their business models, not only through regulatory pressures but also through strategic awareness. Considering green innovation as an investment will lead to cost savings and improved corporate reputation in the long run. Universities and research institutions should increase their R&D studies in the field of green technology and share this knowledge with the private sector and turn it into practice. Public-private partnerships are critical in this process. At the supply chain level, firms should select their suppliers based on environmental performance and integrate these criteria into their procurement policies (Min and Choi, 2020). This approach will contribute to reducing environmental impact along the entire chain. Finally, increasing the environmental awareness of society will direct consumer demands towards environmentally friendly products, which will create a positive transformation pressure on firms. Additionally, academic researchers are encouraged to expand the theoretical underpinnings of green production and innovation through the development of integrative conceptual models. Future studies should focus on the creation of validated measurement tools for assessing green practices. Cross-disciplinary collaboration among fields such as engineering, environmental science, and organizational behavior will further enrich the scope and applicability of sustainability-focused research. Moreover, academics should actively engage in knowledge transfer activities by translating research findings into actionable insights for industry practitioners and policymakers.

### Ethical Considerations of the Study

It is declared that the study was designed to realistically and ethically meet the needs, and that integrity was maintained in obtaining data, concluding the study, and publishing the results. Ethical committee approval was not required for this research. No research requiring ethics committee approval was conducted in this study.



### Informed Consent

There was no need to obtain informed consent from individuals, as the study did not involve any procedures or interventions on human participants.

### Author Contributions

Idea/Concept: Z.Ü.; Design: Z.Ü.; Supervision/Consultancy: Z.Ü.; Resources: Z.Ü.; Data Collection and/or Processing: Z.Ü.; Analysis and/or Interpretation: Z.Ü.; Literature Review: Z.Ü.; Writing: Z.Ü.; Critical Review: Z.Ü.

### Conflict of Interest Statement

The author declares no conflict of interest.

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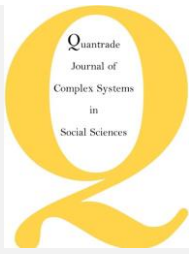
The study did not receive any financial support from individuals or institutions.

### Declarations

This study has not been presented at any congress.

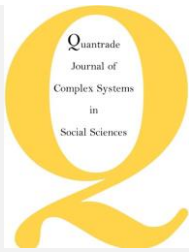
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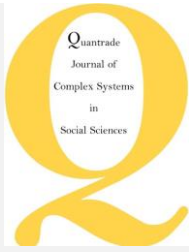


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