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Impact of Cleaner Production and Environmental Management Systems on Sustainability: The Moderating Role of Industry 4.0

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Abstract. The study aims to establish a framework by integrating the emerging topics and assisting the manufacturing companies, government, and policy-makers to encourage product innovation through cleaner production, environmental management techniques, and Industry 4.0 towards attaining sustainable development goals. The paper will conduct a survey using a structured questionnaire to collect data from the manufacturing companies in different states in Malaysia. Simple random sampling will be used to collect responses, and Structural Equation Modeling (SEM) will be used for data analysis. Cleaner production and environmental management systems enable organizations to create innovative products and contribute to developing environmental sustainability. Accordingly, the emerging and eco-friendly technologies of Industry 4.0 will support organizations in greener and innovative product creation through the minimum consumption of natural resources and reduce environmental pollution. This study intends to explore the developing topics essential for the current manufacturing atmosphere, as environmental sustainability is currently a significant concern for society. Furthermore, inspired by the recent research gap, this study will measure the moderating effect of Industry 4.0 on the relationship between product innovation and environmental sustainability.

1. Introduction
Cleaner production techniques and environmental management systems enhance production competency through a balanced use of natural resources and forward organizations towards sustainable product innovation. Organizations boost manufacturing processes and offer customized products using environmental practices and cleaner production, that steadily minimize waste and environmental pollution [1] and improve production efficiency [2]. In this regard, the smart technologies of Industry 4.0 can assist in product innovation [3] by reducing product and service-related problems [4], including inadequacies that cause longer times to market [5]. In addition, the positive effects on the organization and its production shop floors, Industry 4.0 technologies will affect the entire business patterns, products, and services. Although digital automation and remote-control sensors may have a significant role to play in manufacturing systems [6], other technologies of Industry 4.0, such as big data, cloud computing, and quick prototyping, can assist achieve dramatic

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enhancements in product improvement and service innovation [7]. Following the idea, the moderating effect of Industry 4.0 technologies on the relationship between cleaner production and competitiveness, leading organizations towards sustainability, was analyzed by Tortorella [8]. Accordingly, Industry 4.0 is viewed as an array of numerous high-tech technologies and is featured in “Cyber-Physical Systems (CPS)”, “Internet of Things (IoT)”, “Big Data”, “Cloud Computing” for cleaner production and lower lead times as well as optimized stock. Industry 4.0 was also argued to be a pathway towards creating a constructive, automatic and self-configured production infrastructure to accomplish ethical industry [9].

Researchers explored cleaner production methods in various market segments and sizes, leading to sustainable innovation [10]. Cheng [11] stated that product innovation significantly affects business performance and minimizes impacts on the environment, and gains business efficiency by understanding the value of the environmental management systems. Numerous studies have been carried out to define technological and operational factors connected to product innovation in environmental sustainability [12]. Severo [1] evaluated the relationships between product innovation, cleaner production, and environmental management and showed that the analyzed companies based upon the product innovation were much more successful than other firms. This research also found that “cleaner production” is closely linked to “environmental management systems”.

Nevertheless, existing research provides fewer insights into this method, particularly in terms of cleaner output, product innovation, sustainability, and how they can be efficiently combined [13]. On the other hand, considering the internal and external features of Industry 4.0 and cleaner production, it is uncertain whether their simultaneous accomplishment in the industrial sector will contribute to increased efficiency. In comparison, cleaner production requires a business atmosphere where issues and difficulties become prospects for organizations [14] [15]. Therefore, this paper proposes a conceptual model integrating the two emerging concepts of environmental management systems and cleaner production where product innovation is a mediating variable and Industry 4.0 is a moderating variable. The proposed model explicitly considers that the manufacturing companies can forward product innovation with cleaner production and environmental management practices will lead them to sustainability, where the role of Industry 4.0 is significant.

2. Objectives of the study
The study primarily deals with the following objectives,
1) To assess the impact of cleaner production and environmental management on environmental sustainability.
2) To understand the effect of product innovation on environmental sustainability.
3) To reveal the mediating impact of product innovation on cleaner production, environmental management, and environmental sustainability; and
4) To explore the moderating effect of Industry 4.0 on the relationship between product innovation and environmental sustainability.

3. Literature review & hypotheses development
3.1. Background of the study
The 11th Malaysian Plan has established six pillars to place the country to meet global challenges, while the fifth pillar is planned to promote environmental sustainability through cleaner production. As stated in the 11th Malaysian Plan, strategy one focuses on the stepping up of climate change mitigation, further strengthened by reducing greenhouse gas emissions in main emitting industries. The initiatives include expanded use of renewable energy, optimizing electricity usage, facilitating low carbon mobility, and supporting clean and green buildings. The federal government’s green procurement program will help to stimulate a cleaner economy. A larger variety of cleaner
technologies, like Industry 4.0, will improve cleaner technology adoption, driving companies to move to cleaner environmental output. This research will bridge the gap by addressing the above issues.

3.2. Hypotheses development
The study proposes the following framework for investigating the relationship among cleaner production, environmental management systems, product innovation, and environmental sustainability.

![Research framework](https://ssrn.com/abstract=3882047)

3.2.1. Cleaner production, product innovation & environmental sustainability. Cleaner production contributes to the conceptual convergence of preventive environmental interventions to increase efficacy and reduce human and ecological hazards in systems, materials, and products [16]. Cleaner production methods tend to conserve raw materials and power, mitigate or remove hazardous materials, reduce pollution and residual toxicity during the production processes and decrease the volume and toxicity of pollution [16]. Cleaner production is an internal business effort, implementing industrial process and product improvement workgroups, building partnerships with their vendors, leveraging natural resources in an environmentally sound manner, meeting production demands and minimizing environmental emissions, and increasing sustainable development [17]. The implementation of cleaner production methods allows organizations in waste removal, waste generation, environmental degradation, and efficient use of raw materials and resources to provide a viable option for industry to a cleaner production practice [18]. Cleaner production supports organizations in providing customized products and services [19], minimizing the usage of renewable energy, water, power, materials, and pollutant waste and production [20] [21]. Therefore, this study tends to formulate the following hypothesis,

H1: “Cleaner production is positively related to product innovation.”
H2. “Cleaner production is positively related to environmental sustainability.”

3.2.2. Environmental management systems, product innovation & environmental sustainability. Environmental sustainability requires transforming the competitive setting, calls for business improvements in evolving products, systems, technologies, innovations, and business structures, and utilizes the natural resources and processes to protect the environment [1]. Environmental management systems relevant to product and process innovation lead to sustainable development,
achieving a sustainable environment and economic prosperity for organizations [1]. Consequently, environmental management methods, like waste control systems, treatment plants, cleaner productions, will reduce environmental pollution [22]. Organizations should consider the importance of environmental management techniques in climate mitigation to achieve competitiveness [23]. The integration of environmental management and cleaner production offers organizations in product innovation leading to environmental sustainability [24]. Therefore, the associated hypotheses can be illustrated as follows,

H3. “Environmental management system is positively related to product innovation.”
H4. “Environmental management system is positively related to environmental sustainability.”

3.2.3. Product innovation and environmental sustainability. Product innovation involves the manufacturing, in terms of mechanical and practical systems, parts, materials, usability, or related efficient functions of a new product [25]. Product innovation enables organizations to offer a unique and improvised product to meet the demands emerged by consumers and society. Product innovation can also be viewed with its characteristics or intended implementations from previously developed goods to introduce a new or significantly increased product. Product innovation may be defined as launching with its features or the beneficial uses already rendered or significantly improved [26]. Product innovation considers environmental conditions to minimizing resource consumption, water, electricity, materials, better manufacturing procedures, and ecological policies to mitigate environmental impacts and reduce waste and pollutant production [1]. Therefore, the hypotheses can be denoted as follows,

H5. “Product innovation is positively related to environmental sustainability.”

3.2.4. Mediating effect of product innovation. Product innovation is closely linked to cleaner production and environmental management systems, enabling companies to achieve sustainability by executing Industry 4.0 technologies. Cleaner production practices minimize natural resource usage connected to environmental management practices, leading to producing innovative products [16]. Industry 4.0 is a network of adaptive, automated, independent, knowledge, and sensor-based; therefore, it forms the cornerstone of product innovation where cleaner production and environmental management system directs organizations towards environmental sustainability [27]. In a study conducted by Severo [1], Brazilian manufacturing organizations have reported a significant and optimistic link between cleaner production, environmental management, and sustainability, where product innovation mediates the relationships among the constructs. Therefore, the associated hypotheses can be formulated as follows,

H6. “Product innovation mediates the relationship between cleaner production and environmental sustainability.”

H7. “Product innovation mediates the relationship between environmental management system and environmental sustainability.”

3.2.5. Moderating effect of Industry 4.0. The emergence of Industry 4.0 directs organizations towards superior efficiency with the advance of their automation and interconnecting capacities. Ultimately, large and defined manufacturing methods such as cleaner production would require technologies that can, in turn, inhibit or encourage operational efficiency and sustainability [28]. Industry 4.0 significantly affects the machine’s creativity and influences the development of or in the finished product or goods [29]. As Industry 4.0 is a more recent study subject, there is relatively little evidence of the impact of contingencies. The few studies that have been conducted have vaguely examined the effect on the adoption level of Industry 4.0 of such contingencies such as firm size [30] and technological level [31], but ignored the topic of integrating with cleaner production, environmental management, and sustainability. Indeed, several studies have only established such contingencies that may influence the extent of implementation of Industry 4.0 and need more comprehension. Focusing the light on the research gaps, Tortorella [8] revealed Industry 4.0 as a moderator in cleaner production
practices and recommended further studies to assess the role of Industry 4.0 technologies in the implementation procedures of cleaner production. Therefore, the relationship can be formed as follows,

H8: “Industry 4.0 moderates the relationship between product innovation and environmental sustainability.”

4. Research Methodology
The survey will be conducted in the Malaysian manufacturing companies from six states, and 400 responses will be collected, and result will be analysed using Structural Equation Modeling (SEM) Questionnaire will be prepared after a thorough literature review.

5. Conclusion
The study proposes a conceptual model highlighting the relationship between cleaner production, environmental management practices, Industry 4.0, and product innovation, supporting the current industrial sector to attain sustainable development goals. The critical contribution of this study consists of building a model concentrating on the relationship between cleaner production, environmental management practices, Industry 4.0, product innovation, and environmental sustainability. This research will boost greater collaboration across industry, academia, and communities to create cleaner production and environmental sustainability. The study also offers a baseline measure through its proposed model for practitioners in Malaysian manufacturing industries about how the integration between cleaner production and environmental system can lead to innovative production, paving the way towards sustainable development through the execution of emerging technologies.

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