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ORIGINAL ARTICLE

Modelling sustainable manufacturing practices effects on sustainable performance: the contingent role of ownership

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Abstract
This study empirically investigates the effects of sustainable manufacturing practices on sustainable performance, focusing on the moderation effect of companies' ownership (foreign or local) between sustainable manufacturing practices and sustainable performance. In this study, a survey was conducted among ISO 4001-certified manufacturers in Malaysia, and structural equation modelling was used to examine the moderating effect of a company's ownership on the relationship between sustainable manufacturing practices and sustainable performance. The findings showed that there was a positive relationship between both sustainable product design and sustainable manufacturing processes and sustainable performance for Malaysian manufacturers. However, the positive relationship between both sustainable product design and sustainable end-of-life practices on sustainable performance was stronger for foreign companies compared with that for local companies. The results showed the strengths of foreign-owned companies were at the implementation of their sustainable product design and sustainable end-of-life management practices of the product manufacturing process. The findings identified in this paper extend previous research and provide empirical evidence that a company's ownership impacts the relationship between sustainable manufacturing practices and sustainable performance.

Keywords Sustainable manufacturing practices · Sustainable performance · Structural equation modelling · Ownership

1 Introduction

Sustainability considerations have been applied in numerous fields, especially in the manufacturing industry, although the terms used may vary from one field to another. The importance of this subject has been widely emphasised in the literature and in the industry. Manufacturers worldwide have increasingly realised the importance of sustainability, especially on the need to incorporate sustainability strategies into the company's existing practices. In Malaysia, scheduled wastes generated from metal plants, metal refineries, chemical industry, and electrical and electronics industry contributed up to 57% to the total scheduled wastes in 2019 [1]. Thus, the Malaysian government is committed to propel the sustainability agenda and this is reflected in the Malaysian Budget 2021, which has a special focus on sustainability [2]. Nowadays, Malaysian companies are more aware on the importance of having responsible manufacturing practices to reduce environmental, social, and governance impacts on society as well as to increase economic sustainability [3].

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Sustainable manufacturing (SM) practices are the most important strategies in sustainable development [4–6] as manufacturing companies contributed significantly to the diminishing quality of the environment. Attaining sustainable performance (SP) through SM practices and their implementation have been the focus of numerous studies over the last decade. For example, studies by Mangla, Govindan [7], Rosen and Kishawy [8], and Wu and Pagell [9] showed that it is crucial for manufacturing companies to strive to achieve environmental stewardship and sustainability, while at the same time not jeopardising companies' profit. There are increasing studies on SM, for example Bhanot, Rao [5], Millar and Russell [10] investigated the challenges in implementing SM practices in companies. and Shankar, Kannan [11] look into SM practices commonly used by companies. In terms of measuring the effectiveness of these strategies, several studies have been carried out to investigate the relationships between green or SM initiatives and the company's performance such as the studies of Aboelmaged [12] and Rusinko [13]. These include the studies that look at green supply chain management practices [14, 15] and environmental management practices [16, 17] on the companies' performance.

Although many studies have investigated the impact of either green or SM practices on companies' performance, there is still a paucity of studies on how a company's characteristics moderate this relationship. According to Hintošová Aneta and Kubíková [18], numerous studies have looked into the comparison of performance between foreign-owned and local-owned companies. Several studies have concluded that foreign-owned companies are better than local-owned companies, although some studies have found otherwise. Gu, Cao [19] stated that the impact of foreign ownership on company performance is not clear and there are mixed findings in the literature. According to Balasubramanian, Shukla [20], the impact of a company's characteristics on environmental sustainability has yet to be evaluated. Balasubramanian, Shukla [20] suggested that environmental practices are better in foreign-owned companies compared with that in local-owned companies in most developing countries. It was also found that foreign ownership in companies (e.g. partnership) in developing countries has a positive impact on the general adoption of sustainable technology [21]. Ye, Zhao [22] suggested that investigation on the forms of ownership will give deeper insight into the effect of ownership on the relationship between the implementation of reverse logistics and companies' performance across distinct industries.

According to official figures from KeTTHA [23], small- and medium-sized enterprises make up 95% of Malaysia's manufacturing sector. The remaining 5% are large enterprises, where most of the foreign-owned companies are in this category. Looking into the SM practices of local-owned and foreign-owned companies can help managers and policymakers in highlighting the role of knowledge transfer and incorporate best practices to achieve greater SP. This study is intended not only to examine the relationship between SM practices and SP. Most importantly, this study empirically investigates the impact of SM practices on SP, focusing on the moderation effect of companies' ownership (foreign or local) between SM practices and SP. Specifically, the following research questions will guide this investigation of the manufacturing companies operating in Malaysia:

RQ1. Do sustainable manufacturing (SM) practices influence companies' sustainable performance (SP)?
RQ2. Is the relationship between the strength of sustainable manufacturing (SM) practices and sustainable performance (SP) different for foreign and local-owned companies?

This paper will give knowledge contribution on how SM practices affect sustainable performance with regard to company's ownership in a developing economy context that is under researched. The findings can be used to develop strategies for local companies in Malaysia in improving their SP. This paper is organised into 6 sections. Section 1 introduces the background of the study. Section 2 comprises the literature review and the hypotheses development of this study. In Sect. 3, the research methodology is elaborated. The data analysis and results of this study are presented in Sect. 4. The discussion on the results, implications, and limitations of this study are given in Sect. 5. In Sect. 6, conclusions and directions for future research are presented.

2 Theoretical development and hypotheses

2.1 Sustainable manufacturing practices

Sustainability is a term first suggested by Elkington [24], which is defined as *"the expansion of corporate perspective, which considers environmental, social, and economic aspects"*. It is also famously known as the triple bottom line (TBL) dimensions. Sustainable manufacturing (SM) is a key initiative towards achieving sustainable development [6], which integrates sustainability concepts into manufacturing operations. Thus, in this context, the TBL comprising environment, economic, and social aspects are incorporated into manufacturing practices. SM is defined by the United States Department of Commerce [25] as *"the creation of manufactured products that use processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers and are economically sound"*.

Manufacturing is the core operation and important phase in any product's supply chain and therefore, it is an imperative move for manufacturers to incorporate SM strategies. This is due to the decisions made by manufacturers that will impact sustainability decisions along the product's life cycle supply chain [26, 27]. According to Kishawy, Hegab [28] and Jawahir, Badurdeen [29], SM covers product, process, and system levels and the interactions between them. Improving sustainability while keeping productivity and profitability are becoming important strategies for manufacturing companies. Although many manufacturing companies understand the concept of sustainability, many are still uncertain about how to incorporate them into their business activities [30]. In this paper, sound sustainable practices that can improve SP along the product value chain are reviewed. Therefore, visiting the concept of SM is relevant and thus we have incorporated in this paper.

To implement SM, one must consider decisions at the design stage, preferably as early as possible [28], as this will influence subsequent decisions on other sustainable strategies in the later stages. According to Rosen and Kishawy [8], manufacturers who focus to establish a sustainability culture in their companies during product design are more successful in achieving sustainability. Various design strategies can be incorporated to achieve sustainable design, namely design for disassembly [31, 32]; design for less material consumption [33, 34]; design for repairability, rework, and refurbishment [33, 35]; design for maintenance [36]; design to recover obsolete products (e.g. leasing, product service system) [37, 38]; design that prioritises environmentally friendly materials [39]; design to minimise energy consumption [40]; design that prolongs the life of material usage [33]; and design that eliminates hazardous materials [41].

Achieving sustainability through cleaner production is crucial in manufacturing processes as these processes consume significant amounts of natural resources such as energy and materials [42]. Lovins, Lovins [43] emphasised that in the USA, normally only 1% out of 100% of the natural capital extracted to make a product will still be in use six months after-sales. This means that 99% of the natural capital becomes wastes within the extractive and industrial processes, and within six months after-sales. Owing to the significant amount of wastes generated during these stages, it is vital for manufacturers to strive in order to minimise impact on environment while still maintaining manufacturing productivity and product quality [44]. Several strategies can be employed to achieve a sustainable manufacturing processes such as implementing material recovery [45–47] and waste recovery strategies [31, 47]. Strategies such as improving manufacturing processes and machine efficiency [10, 48, 49], minimising manufacturing steps [44] and minimising energy consumption [5, 44] are also important to reduce the amount of wastes generated. It is also evident that manufacturing companies that adopt lean production can increase production efficiency and minimise waste generation [47, 50]. Other than the strategies implemented at the operational level, many strategies adopted at the management level will help companies to achieve sustainability by implementing various green and sustainability programmes, subscribing to standards and regulations [51], setting environmental goals [52] and most importantly, measuring and auditing material flows and wastes [53].

Sustainable supply chain management (SSCM) has gained popularity over the years and many companies are striving to implement them in practice. It is important for emerging economies to implement SSCM as they do not only serve their own market but are also a part of the global manufacturing base [54]. Seuring and Müller [55] defined SSCM as *"the management of material, information, and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e. economic, environmental, and social, into account which are derived from customer and stakeholder requirements"*. Based on the literature, SSCM practices involve sustainable packaging [56–59], selecting green suppliers [56, 60], using energy-efficient transport and logistics [61], and collaborating with suppliers [14, 62, 63]. Since manufacturing companies' decisions can influence customers downstream and suppliers upstream, manufacturers can pollinate their practices along the supply chain. By adhering to certain standards and regulations, and procuring sustainable materials and products, the companies can influence their suppliers [64] and also train them [2, 65] to practice sustainable initiatives. Similarly, companies can influence customers to accept sustainable products or solutions [66].

According to Rose, Stevels [67], end-of-life is *"the point in time when the product no longer satisfies the initial purchaser or first user"*. Manufacturers must increase resource efficiency of the available resources by emphasising the recovery of materials or products at the end of the products' useful life. Among the techniques that can be employed are reuse, remanufacturing, recycling, and energy recovery and is termed as waste hierarchy by Jackson [68], Jackson [69]. De Brito and Dekker [70] proposed the product recovery inverted pyramid, which shows options categorised into direct recovery and process recovery. Direct recovery involves resale/reuse/redistribution whereas process recovery involves repair, refurbishing, remanufacturing, retrieval, recycling, and incineration. Under sustainable end-of-life management practices, manufacturing companies could opt for strategies such as providing maintenance and support services to customers [71], treating hazardous waste [72], managing product warranty returns [73], and providing recycling support by using components and material coding standards [74]. The goal of managing end-of-life of products is to capture its value, whether in the form of function or materials, with the least energy and costs. This means that the minimum energy and cost that the manufacturer will spend will be at the highest hierarchy of product recovery. Thus, by strategically managing the products' end-of-life, manufacturing companies will be able to reduce the impact of their manufacturing production towards the environment at minimal costs.

2.2 Sustainable performance

In general, the TBL concept recommends companies to assess their business decisions and strategies based on economic, environmental, and social dimensions. Koberg and Longoni [75] defined performance as *"the successful execution or outcome of work"*. According to Maxwell [84], measuring companies' performance around TBL will be beneficial to achieving the goal of (a) eliminating/reducing adverse environmental impacts, (b) reducing adverse social impacts, and (c) enhancing economic benefits. There are a significant number of studies have been conducted to assess the impact of either green or sustainability practices on companies' performance based on the TBL concept and it was shown that these practices can improve companies' environmental performance [15–17, 56, 76–80]. However, studies measuring the impact of SM practices considering TBL are still lacking, with only a few studies evaluating the implementation of SM and companies' competitiveness capability (e.g. Aboelmaged [12], Malek and Desai [81]).

Environmental performance is a strategic indicator that is essential for companies and must be aligned to enhance business efficiency and profitability [14, 60]. According to Zhu, Sarkis [82], good environmental performance must reflect on the manufacturing companies' ability to reduce waste, pollution, hazardous material consumption, and environmental accidents and improve resource efficiency. Many studies have shown that green and sustainable initiatives can improve environmental performance such as those by Green, Zelbst [15], Klassen and McLaughlin [16], Montabon, Sroufe [17], Zailani, Jeyaraman [56], Abdullah, Mohamad [76], Eltayeb, Zailani [77], Eltayeb, Zailani [78], and Wagner [79]). Malek and Desai [81] suggested that SM practices are one of the most significant environmentally conscious strategies and perceptions that can improve companies' environmental performance.

The economic performance of companies implementing sustainable strategies needs to be assessed to know whether these strategies are cost-effective. Zhu and Sarkis [83] defined economic performances as *"financial returns that can result from the adoption of green supply chain initiatives"*. In this study, the SP is measured through the TBL lens, thus for measuring the economic performance, the authors had adopted and combined indicators of economic outcomes and operational outcomes from Zhu and Sarkis [83] and Zhu, Sarkis [82]. Zhu, Sarkis [82], defined economic performance as "an ability to achieve cost reduction of materials purchasing, energy consumption, waste treatment, waste discharge, and fines for environmental accidents" [82, 83]. On the other hand, the operational outcome reflects the manufacturing companies' ability to shorten customer lead time, inventory, and scrap rate, as well as the companies' ability to improve product quality, product line, and capacity utilisation [82]. Thus, in this study, the economic and operational outcomes obtained from sustainable practices are measured as the capability of the companies to deliver products to customers while minimising costs and impacts associated with environmental and social factors. A study by Green, Zelbst [15] has shown that the adoption of green initiatives will improve both environmental and economic performance, which in turn, influences operational performance.

Among the TBL dimensions, social performance is the most difficult to quantify. The social impact of SM practices needs to be measured by assessing not only the employees' health and safety but also their working environment [28, 84, 85] and the company's good relationship with the stakeholders and surrounding community, as well as improve the quality of life of the community [84]. The findings of Yawar and Seuring [86] revealed that most companies are more concerned with social issues that have an immediate effect on their performance (e.g. issues that are damaging the company's image and which will reduce the company's financial gains) rather than looking at social issues that can damage the society over the long term. A study by Zailani, Jeyaraman [56] showed that SSCM practices have positive effects on social performance.

2.3 Effect of sustainable manufacturing practices on a company's sustainable performance

All SM practices and considerations at each production phase along the product's life cycle, starting with product design, then manufacturing process, followed by the product's supply chain and its end-of-life management, contribute to a company's environmental, operational, economic, and social performance. According to Handfield, Melnyk [87], environmental impacts resulting from all these phases are originated from the decisions made during the design stage. Similarly, strategies employed during manufacturing processes, in particular, can minimise the use of materials, energy, and other resources, which can significantly reduce the environmental impact while increasing the product's value [88]. According to Smith and Ball [89], improved environmental performance will increase the company's profits since the operating costs are reduced. Thus, companies should adopt these sustainable processes and systems so they can achieve SM [4]. In terms of the implementation of sustainable supply chain in manufacturing companies, a study by Green, Zelbst [15] showed that these practices are necessary for the company's economic performance. Shankar, Kannan [11] showed that SM practices give a positive impact on consumer perception, which then reflects on the company's profit. In terms of the social aspect, a study by Yusoff, Imran [90] found a positive relationship between employee empowerment on companies' SP. This shows that implementing sustainable practices can improve work culture, safety, as well as employee's commitment to their work, which in turn can improve companies' performance. Having proper end-of-life management practices that are able to handle product characteristics in product and material recovery can lead to higher profits and better environmental performance [91].

However, based on literature evidence, it seems that most companies tend to focus on environmental and economic outcomes, with less attention given to social aspects such as safety and employee fulfilment [11]. Based on these findings, it is posited that:

H1: Sustainable product design and development has a positive effect on SP.
H2: Sustainable manufacturing process practices have a positive effect on SP.
H3: Sustainable supply chain management practices have a positive effect on SP.
H4: Sustainable end-of-life management practices have a positive effect on SP.

2.4 Moderating effect of ownership between sustainable manufacturing practices and sustainable performance

The discussion of ownership and company performance has been built from the perspective of the agency theory which was the work of [92] and later further developed by [93]. The agency theory describes the institutional relationship of problems in the principal-agent relationship between owners and managers. There may be situations where there are conflicting interests between several stakeholders that could lead to a significant increase in agency cost [92]. Jensen and Meckling [92] defined agency cost as the sum of the monitoring expenditures by the principal (owners), the bonding expenditures by the agent (managers) and the residual loss. In developing countries, foreign ownership would have a better ability to reduce agency costs due to the advantages such as better access to technologies, resources and management expertise [94, 95]. Numerous studies utilised agency theory to explain better the performance of foreign owned companies as compared to local owned companies in developing countries such as studies by Gu, Cao [19], Shrivastav and Kalsie [95], Jusoh [96], Nguyen, Pham [97] and Dharwadkar, George [98]. The agency theory proposes that increasing and disclosing sustainability achievements could overcome agency issues between owners and managers in terms of reducing information asymmetries, mitigating agency costs, and creating value for the owners [99–101].

Hintošová Aneta and Kubíková [18] found that a company's performance will increase as its foreign ownership increases up to a certain maximum point, after which it will start to decline even though the foreign investment continues to increase. The degree of implementation of supply chain management in a company was found by Dries, Gorton [102] to be influenced by foreign ownership. Li, Ragu-Nathan [103] found that large-sized manufacturing companies in Malaysia gave more attention to supply chain practices compared with small-sized companies. A characteristic that requires further study is ownership where Gu, Cao [19] have highlighted that even though foreign ownership can improve company performance, it is still unclear whether there are moderating variables that will affect this relationship. Balasubramanian, Shukla [20] found that the implementation of environmental strategies at foreign-owned companies was greater compared with that of local-owned companies. Although there were numerous studies looking into the impact of SM practices over SP, there are no studies looking at how ownership moderates the relationship of SM practices over SP. To gain insight into this relationship, the moderating effect of ownership on the relationship between SM practices and SP will be evaluated. The following hypotheses are proposed:

H5: The positive relationship between sustainable product design and development practices and SP will be stronger for foreign companies compared with that for local companies.
H6: The positive relationship between sustainable manufacturing process practices and SP will be stronger for foreign companies compared with that for local companies.
H7: The positive relationship between sustainable supply chain management practices and SP will be stronger for foreign companies compared with that for local companies.
H8: The positive relationship between sustainable end-of-life management practices and SP will be stronger for foreign companies compared with that for local companies.

Most companies are willing to implement specific practices if they can improve the company's performance [10]. However, based on previous literature, there are limited studies concerning the impact of SM practices on a company's SP, let alone looking at the effect of these practices based on the company's ownership (whether they are foreign or local-owned). To investigate these relationships, the conceptual framework based on the literature review was developed, and then tested using structural equation modelling (PLS-SEM). The key constructs used in this model were generated based on an extensive review of the literature in this field. The framework developed is shown in Fig. 1.

3 Research methodology

3.1 Development of survey questionnaire

The proposed conceptual framework consists of four SM practices as four independent variables and one moderator, identified from the literature review. Based on this construct, a survey was designed to collect empirical data to test the hypotheses given in Sects. 2.3 and 2.4. The self-administered survey enables researchers to obtain data in a quicker, inexpensive manner compared with other techniques [104]. The measurement items used in the survey consist of existing measures extracted from the literature as well as one new measurement item. To ensure the quality of the survey instruments, the developed survey questions were refined by consulting statistical experts, and then pre-tested on five industrial practitioners for content validity and reliability. The new measurement item was added based on the suggestions by industrial practitioners during the pre-testing stage.

The questionnaire is divided into several parts. The first part consists of questions related to the company's details and characteristics such as the type of industry, the type of materials mostly used, the number of employees, and the types of customers. The second part consists of measurements of SM practices and SP. To improve data analysis, an eleven-point scale was used for the measurement, ranging from "Strongly disagree" to "Strongly agree". According to Batista-Foguet, Saris [105], an eleven-point scale could prevent a narrow response alternative which may force the respondents to categorise their opinions. The constructs and measurement items are provided in Appendixes 1 and 2.

3.2 Sampling characteristics and data collection method

The sample of the survey study consisted of all manufacturers, which are ISO 14001-certified in Malaysia and listed in The Federation of Malaysian Manufacturers (FMM) directory. The unit of analysis used is the individual companies. The sampling frame for this study was made up of 443 companies that are ISO 14001-certified identified from the FMM directory. The ISO 4001-certified companies were sampled because it is perceived that the companies that conform to ISO 14001 will be more likely to adopt environmental and sustainable practices [56].

The survey questionnaires were distributed using a web-based survey tool and conventional mail. In addition, the respondents were contacted through telephone calls as a follow up to increase the response rate. The G*power programme was used to determine the minimum sample size. For 9 predictors, a minimum number of 114 responses were required to test the hypotheses. One hundred and fifteen (115) responses were obtained from the 443 companies contacted (response rate: 38.52%), which fulfils the minimum sample size requirement to report significant effects.

The company representatives recruited for this study comprised key personnel who are knowledgeable about sustainability-related initiatives implemented in their respective companies. The representatives consist of general managers (67.8%), followed by the safety, health, and environmental managers and green technology managers (32.2%). The companies that participated in this study were from a wide range of industries, where most of the respondents were from various manufacturing industries (47%), followed by electrical and electronics (25%), automotive (11%), chemical and petroleum (9%), food (7%), and power generation (1%). The demographic and company characteristics are summarised in Table 1.

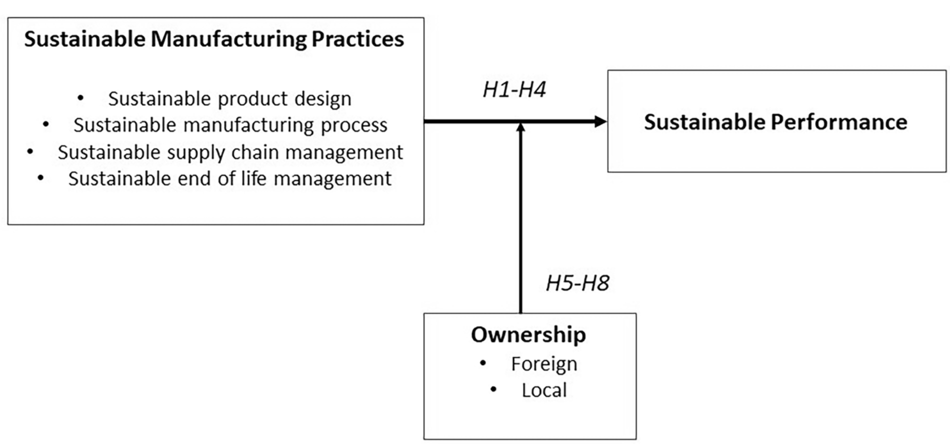

Fig. 1 Conceptual framework proposed in this study

Table 1 Demographic characteristics of the respondents

Demographic variables	Category	Frequency	Percentage (%)
Industry	Automotive	13	11
	Chemical and petroleum	10	9
	Electrical and electronics	29	25
	Power generation	1	1
	Food	8	7
	Manufacturing/others	54	47
Number of employees	Less than 51	10	9
	51–150	24	21
	151–250	21	18
	251–500	25	22
	More than 500	35	30
Company ownership	Local	51	44
	Foreign	64	56

4 Data analysis and results

The partial least squares approach to structural equation modelling (PLS-SEM) using SmartPLS 3.3.2 [106] was used to examine the measurement and structural model as it does not require normality assumption and as survey research is usually not normally distributed [107].

Since data was collected using a single source, we first tested the issue of common method bias by following the suggestions of Kock and Lynn [108] and [109] by testing the full collinearity. In this method, all the variables will be regressed against a common variable, and if the VIF ≤ 3.3, then there is no bias from the single source data. The analysis yielded VIF less than 3.3 thus single source bias is not a serious issue with our data.

4.1 Measurement model

The guidelines of Hair Jr, Howard [107] and Ramayah, Cheah [110] were followed to assess convergent validity and discriminant validity as part of the measurement model evaluation. The criteria used to assess convergent validity are by looking at the loadings (≥ 0.5), average variance extracted (≥ 0.5), and composite reliability (≥ 0.7). As shown in Table 2, the AVEs were all above 0.5 and the CRs were all above 0.7. Since there is a large number of items, the individual loadings are not shown. For type I, second-order construct (Sustainable Performance), acceptable levels of convergent validity were also achieved (see Table 2).

To assess discriminant validity, the more recent criterion of HTMT was used instead of the usual Fornell and Larcker criterion as this measure has been criticised in the past. Henseler, Ringle [111] and Franke and Sarstedt [112] suggested that the HTMT ratios should be lower than 0.90 (lenient criterion) or 0.85 (stricter criterion). As shown in Table 2, all the HTMT ratios were lower than 0.90, which confirms that the measures are discriminant.

4.2 Structural model

To test the structural model, a bootstrapping procedure was executed with 5000 resamples to generate the standard errors, *t*-values, *p*-values, and bias-corrected confidence intervals [107]. The R^2 value without the interaction effects was 0.623, indicating that the 4 predictors and the moderator explained 62.3% of the variance in sustainable performance while the addition of the 4 interaction effects increased the R^2 to 0.786, corresponding to an increase of 16.3%.

Sustainable product design ($\beta = 0.492$, $p < 0.05$) and sustainable manufacturing process ($\beta = 0.343$, $p < 0.05$) were positively related to SP while sustainable supply chain

Table 2 Convergent and discriminant validity of measures

Construct	CR	AVE	1	2	3	4	5	6	7	8	*9**
1. Economic	0.770	0.532									
2. Sustainable end-of-life management	0.783	0.550	0.289								
3. Environmental	0.876	0.547	0.192	0.558							
4. Sustainable manufacturing process	0.887	0.558	0.563	0.438	0.342						
5. Operational	0.929	0.689	0.169	0.496	0.767	0.278					
6. Sustainable product design	0.897	0.524	0.203	0.652	0.651	0.26	0.591				
7. Social	0.799	0.502	0.556	0.349	0.505	0.829	0.439	0.501			
8. Sustainable supply chain management	0.899	0.759	0.078	0.318	0.261	0.186	0.164	0.296	0.473		
9. Sustainable Performance*	0.815	0.551	—	0.559	—	0.595	—	0.643	—	0.289	

*Second-order factor

Table 3 Hypothesis testing

Hypothesis	Relationship	Std beta	Std error	*t*-value	*p*-value	BCI LL	BCL UL	f^2	Results
H1	SPDesign ➔ SP	0.492	0.241	2.042	0.021	0.049	0.775	0.372	Supported
H2	SMProcess ➔ SP	0.343	0.192	1.783	0.038	0.067	0.640	0.207	Supported
H3	SSCM ➔ SP	0.023	0.167	0.139	0.445	−0.296	0.243	0.001	Not supported
H4	SEOL ➔ SP	0.118	0.081	1.449	0.074	−0.017	0.252	0.020	Not supported
H5	SPDesign*Ownership ➔ SP	0.455	0.259	1.756	0.040	0.152	0.946	0.251	Supported
H6	SMProcess*Ownership ➔ SP	−0.080	0.128	0.623	0.267	−0.482	0.025	0.014	Not supported
H7	SSCM*Ownership à SP	−0.042	0.348	0.121	0.452	−0.867	0.266	0.004	Not supported
H8	SEOL*Ownership à SP	0.389	0.250	1.558	0.060	0.126	0.877	0.123	Supported

management and sustainable end-of-life management were not significant. Hence, H1 and H2 were supported whereas H3 and H4 were not supported (see Table 3).

Next, the moderating effect of ownership on the 4 relationships was tested. The SPDesign*Ownership à Sustainable MP ($\beta = 0.455$, $p < 0.05$) and SEOL*Ownership à Sustainable MP ($\beta = 0.389$, $p < 0.1$) were significant whereas ownership did not moderate the sustainable manufacturing process and sustainable supply chain management relationships. Thus, H5 and H8 were supported while H6 and H7 were not supported.

To explain how the moderator changes the original relationships, the interactions were further plotted in Figs. 2 and 3. As shown in Fig. 2, the positive relationship between sustainable product design practices and SP was stronger for foreign companies compared with that for local companies, as indicated by the steeper gradient of the line representing the foreign companies.

Figure 3 shows that the positive relationship between sustainable end-of-life management practices and SP was stronger for the foreign-owned companies compared with that for local companies, as shown by the steeper gradient of the line representing the foreign-owned companies. For the local companies, the plotted line was almost horizontal.

Shmueli, Sarstedt [113] proposed using PLSpredict with a tenfold procedure to check for predictive relevance. Shmueli suggested that if all the item differences (PLS-LM) are "lower than", there will be a strong predictive power, whereas if all are "higher than", the predictive relevance is not confirmed. If the majority is "lower than", there is moderate predictive power and if the minority is "lower than", then there is low predictive power. Table 4 shows that all the errors of the PLS model were lower than the LM model, and thus, it can be concluded that our model has a strong predictive power.

5 Discussion

5.1 Main research findings

The results reveal that most recruited Malaysian manufacturing companies in this study perceive that sustainable product design practices have a positive and significant impact on the companies' sustainable performance. The results agree with the findings by Ar [114], which show that green product innovation generally has a positive impact on the companies' performance and competitiveness. According to Kushwaha and Sharma [115], in addition to environmental

Fig. 2 Interaction effect of ownership on the sustainable product design practices-sustainable performance relationship

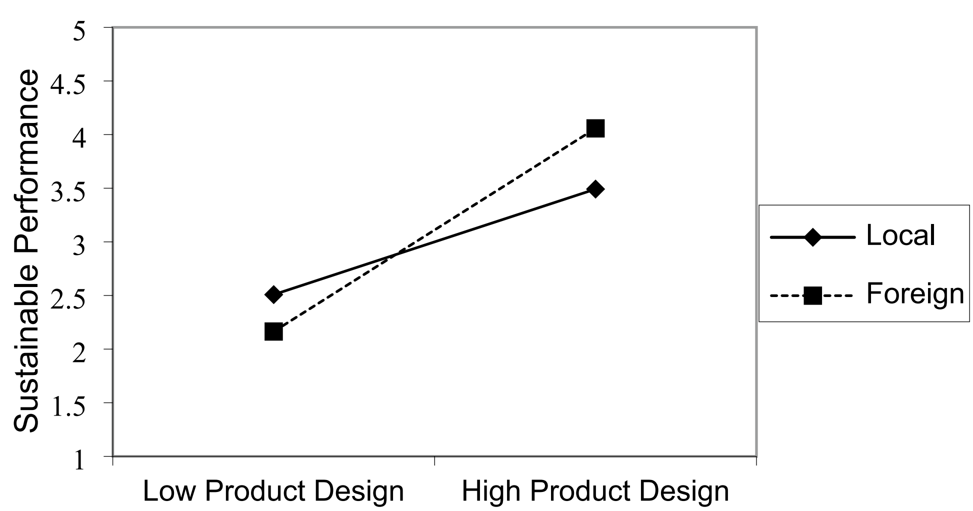

Fig. 3 Interaction effect of ownership on the sustainable end-of-life management practices-sustainable performance relationship

performance, companies must also pay attention to their products and economic performance. Kushwaha and Sharma [115] further demonstrated that green initiatives related to design have motivated automotive manufacturers in Japan to behave in a sustainable manner. Similarly, it is found that organisational innovation and technological capability for products can enhance companies' performance [116]. Thus, the company's capability in sustainable product innovation can result in superior sustainability performance. Abdullah, Mohamad [76] found that eco-design will improve all components of sustainable performance.

Based on the results obtained from this study, it can be said that sustainable manufacturing process practices have a positive impact on sustainable performance. This result is consistent with Zeng, Meng [117], who found that cleaner production positively affects a company's competitive performance. Similarly, Rusinko [13] also found environmentally sustainable manufacturing practices are positively related to company's competitive performance. However, Rusinko discovered that different types of environmental initiatives are associated with different types of competitive outcomes (e.g. manufacturing cost, product quality). The findings of this study also corroborated with the study of Wagner [79], which suggested that companies that have implemented pollution prevention-oriented corporate environmental strategies will have a more positive relationship between environmental and economic performance. Ghadimi and Heavey [118] in their study indicated that SM practices in procurement will promote the companies' competitiveness. Tan, Zailani [119] found that increasing the level of green production among Malaysian manufacturing companies will boost the company's competitiveness. Green production, according to Tan, Zailani [119], should involve utilising environmentally friendly raw materials, cleaner technology to reduce waste and to reduce water and energy usage, green production design, and internal recycling throughout all stages of production.

It is somewhat surprising that our findings showed no significant relationship on the impact of sustainable supply chain management practices on the companies' sustainability performance. These findings contradict those of Katiyar, Meena [54], Zailani, Jeyaraman [56], Eltayeb, Zailani [77], Kirchoff, Koch [120]. However, these findings need to be interpreted with care as different constructs were used by these researchers. For example, Eltayeb, Zailani [77] included eco-design in the green supply chain, and Zailani, Jeyaraman [56] used environmental purchasing and sustainable packaging as measures in the sustainable supply chain. Meanwhile, this study introduced additional measures such as good relationships and collaboration with suppliers and customers. However, Eltayeb, Zailani [77] found that green purchasing has no significant effect on SP. Likewise, Zailani, Jeyaraman [56] found that environmental purchasing impacted a different set of sustainable outcomes compared with sustainable packaging.

It is found for Malaysian manufacturing companies, sustainable end-of-life practices do not have any impact on overall SP. This finding concurs with the findings obtained by Tan, Zailani [119], who found that materials and waste recovery had no significant relationship with companies' competitiveness. Green, Zelbst [15] found that investment recovery strategies such as sales of scrap and used materials are positively linked to environmental performance but not to financial performance. The findings of Choi and Hwang [72] contradicted the results of this study, where they found that collecting, recycling, and remanufacturing policies have significant relationships with both environmental and company performance. Our findings corroborated with Eltayeb, Zailani [78] and Khor and Udin [121], who found that Malaysian manufacturers lacked interest in product take-back except for manufacturing-related and distribution-related returns. Eltayeb, Zailani [78] found that Malaysian manufacturing companies prefer to execute minor reuse activities such as recycling of packaging.

Table 4 PLSpredict

MV	PLS		LM		PLS-LM	
	RMSE	MAE	RMSE	MAE	RMSE	MAE
Economic	1.054	0.729	3.563	1.692	−2.509	−0.963
Operational	1.026	0.477	2.720	0.901	−1.694	−0.424
Environmental	0.969	0.503	1.369	0.643	−0.400	−0.140
Social	1.195	0.734	2.388	1.076	−1.193	−0.342

Through the lens of the agency theory, this study supports the conjecture that foreign ownership leads to better companies' performance, which this study shows in the form that foreign companies have better SP as compared to local-owned companies in Malaysia. In terms of SM practices, it was found that the impact of sustainable product design practices on SP was stronger for foreign-owned companies compared with that for local companies. This is in line with findings by Ghazilla, Sakundarini [122], who found that there is inadequate research and development, as well as green design capability in order to support green manufacturing practices among Malaysian SMEs. This is likely due to the fact that Malaysian manufacturers prefer to use new materials and parts when producing new products owing to a lack of know-how in practising eco-design [123], and a lack of reverse logistics infrastructures to support end-of life recovery [124]. Similarly, the findings showed the effect of sustainable end-of-life practices on SP was stronger for foreign companies compared with that for local companies. This concurs with Balasubramanian, Shukla [20], who found that the implementation of environmental practices is generally greater for foreign companies compared with that for local companies. However, the findings showed that there are no differences between the impact of sustainable manufacturing process practices and sustainable supply chain management practices on SP, regardless of whether the companies are foreign- or local-owned.

5.2 Implications of the study

This empirical study contributes to theory, practice, and policy in order to enhance the implementation of SM practices by understanding which practices contribute the most to the companies' SP. The findings of this study reveal the relationship of each SM practice on the companies' SP in a developing country. This study also provides insight into the different strengths of capability along the product value chain between foreign-owned companies operating in Malaysia and local Malaysian manufacturing companies. Since the impact of sustainable product design and development practices on SP was stronger for foreign companies compared with that for local companies, this suggests that there is room for improvement for local companies to increase their efforts on sustainable practices in order to enhance their SP. This study will directly benefit industrial practitioners by providing a framework that outlines which practices and techniques can be implemented to enhance their overall SP. This will assist manufacturing companies, especially local-owned companies, to develop their manufacturing practices and contribute equally to sustainability. The results from this study also show that Malaysia is still generally behind in terms of eco-design, sustainable design, and end-of-life material recovery compared with other countries. This study can be used by policymakers to develop suitable policies and interventions in terms of providing infrastructures as well as financial and technical assistance. Furthermore, policymakers can consider embedding sustainable design and product recovery thinking awareness in the education system.

5.3 Limitations of the study

This empirical study has several limitations. Firstly, this is a cross-sectional design study of a single country that may limit the generalisation of the research findings. Despite this limitation, this study has identified rich empirical findings on the relationship between SM practices and SP and the effect of ownership (foreign or local) between SM practices and SP. Secondly, the population is limited to ISO 4001-certified companies as they are expected to implement sustainable practices. Companies that do not possess ISO 4001 certification were excluded from this study. For future studies, one can consider focusing on non-ISO 4001-certified companies in order to identify the implementation of SM practices. Lastly, this study did not focus on a specific industrial context. Further studies specific to a particular industry will be beneficial to provide findings related to the effect of ownership between SM practices and SP.

6 Conclusions and directions for future research

The most impactful decisions toward the environment along the value chain of the global economy are made at the manufacturing stage. The focus on sustainability in manufacturing is crucial alongside other important similar concepts such as the circular economy. However, a circular economy cannot be achieved if companies lack effective strategies to be implemented at the manufacturing level. One way of measuring the effectiveness of these strategies is by measuring their SP.

The 115 Malaysian manufacturing companies surveyed in this study offer insight into the relationship between the implementation of SM practices and SP. Overall, all 4 main SM practices, namely sustainable product design, sustainable manufacturing process, sustainable supply chain management, and sustainable end-of-life management contribute to the companies' SP. This study also revealed that there are different levels of strengths on SM practices implemented by foreign companies compared with that for local companies. Specifically, foreign-owned companies were found to be strong in implementing sustainable product design and end-of-life strategies compared with local companies. Future studies may be conducted based on specific industrial sectors for more depth and understanding of a specific industrial context.

Appendix 1 Constructs and measurement items for SM practices

Constructs	Codes	Measurement items	Sources
Sustainable product design (SPDesign)	*SPDesign_1*	Elimination of hazardous materials	Ahmad, Wong [41], Zsidisin and Siferd [125]
	SPDesign_2	Design for disassembly	Duflou, Sutherland [31], Ghazilla, Sakundarini [32]
	SPDesign_3	Design for repair, rework, and refurbishment	Worrell, Allwood [33], Sabbaghi, Esmaeilian [35]
	SPDesign_4	Design to reduce material use	Worrell, Allwood [33], Pajunen, Watkins [34]
	SPDesign_5	Design to reduce energy consumption	Vezzoli [40], Kara and Li [126]
	SPDesign_6	Use environmental-friendly materials	Sakundarini, Taha [39], Zhu, Sarkis [127]
	SPDesign_7	Design to recover obsolete products (e.g. product leasing/ PSS)	Manzini and Vezzoli [37], Hirschl, Konrad [38]
	SPDesign_8	Design for maintenance	Desai and Mital [36], Baines, Lightfoot [128]
	SPDesign_9	Design to prolong life of materials	Worrell, Allwood [33, 129]
Sustainable manufacturing process (SMProcess)	*SMProcess_1*	Material recovery	Thiede, Bogdanski [45], Gupta, Dangayach [46], Singh, Ramakrishna [47]
	SMProcess_2	Waste recovery	Duflou, Sutherland [31], Singh, Ramakrishna [47]
	SMProcess_3	Energy savings	Bhanot, Rao [5], Gupta, Laubscher [44], Despeisse, Mbaye [130]
	SMProcess_4	Reduce CO_2 emissions	Ball, Evans [131]
	SMProcess_5	Improve manufacturing processes and machine efficiency	Millar and Russell [10], Bi and Wang [48], Raman, Haapala [49]
	SMProcess_6	Adopt lean production systems	Singh, Ramakrishna [47], Miller, Pawloski [50]
	SMProcess_7	Implement and adhere to environmentally conscious programmes, standards, or regulations	Ramanathan, He [51], Rachuri, Sriram [132]
	SMProcess_8	Set environmental objectives and targets	Hamner [52]
	SMProcess_9	Measure and audit material flows/ wastes	Bocken, Strupeit [53], Westkämper, Alting [59]
Sustainable supply chain management (SSCM)	SSCM_1	Select green/ sustainable suppliers	[56], Çankaya and Sezen [60]
	SSCM_2	Influence suppliers to practise green/ sustainable initiatives	Walton, Handfield [64], Masnita, Triyowati [133]
	SSCM_3	Collaborate with suppliers	Ahmed and Najmi [14], Sachs [62], Vachon and Klassen [63]
	SSCM_4	Training suppliers on sustainability	Hossan Chowdhury and Quaddus [2], Rao [65]
	SSCM_5	Influence customers to accept green practices, services, or products	Canning and Hanmer-Lloyd [66]
	SSCM_6	Use less, cleaner, or reusable packaging	Zailani, Jeyaraman [56], Sonneveld, James [57], James, Lewis [58], Westkämper, Alting [59]
	SSCM_7	Adopt energy-efficient transportation	Kam, Christopherson [61]
	SSCM_8	Adopt energy-efficient logistics	Kam, Christopherson [61]
Sustainable end-of-life management (SEOL)	SEOL_1	Prolong the service life of materials/ parts/products by providing maintenance and support services to customers	Famiyeh, Kwarteng [71], Seliger [134], Fiksel [135]

Constructs	Codes	Measurement items	Sources
	SEOL_2	Provide hazardous waste treatment in the plant for after-market recovery products/parts	Choi and Hwang [72], Frios [136]
	SEOL_3	Provide and manage product warranty returns	Kleyner and Sandborn [73]
	SEOL_4	Provide and manage product recalls	*
	SEOL_5	Provide recycling support by using components and material coding standards	Hamner [52], Lee and Na [74]

Appendix 2 Constructs and measurement items for SP

Constructs	Codes	Measurement items	Sources
Environmental performance (SPEnv)	SPEnv1	Reduced CO2 emissions	Garetti and Taisch [137]
	SPEnv2	Reduced wastewater discharge	Sachs [62], Evans, Gregory [138]
	SPEnv3	Reduced solid waste generation	Sachs [62]
	SPEnv4	Reduced energy consumption	Zhu, Sarkis [82], Yang, Hong [139]
	SPEnv5	Reduced toxic/harmful/hazardous/flammable substances discharges	Veleva, Hart [30], Zhu, Sarkis [82]
	SPEnv6	Decrease in material usage	Jeswiet and Kara [140]
	SPEnv7	Improved compliance with environmental standards	Luken and Van Rompaey [141], Jayaraman, Singh [142]
Economic performance (SPEco)	***Economic outcomes***		
	SPEco1	Improved market share	Eltayeb, Zailani [77], Rao and Holt [143]
	SPEco2	Improved company image	Rao and Holt [143, 144]
	SPEco3	Improved company's position in the marketplace	Rao and Holt [143], Smith [144]
	SPEpo4	Increased profitability	Wagner [79]
	Operational outcomes		
	SPEco5	Decreased material purchasing cost	Eltayeb, Zailani [77]
	SPEco6	Decreased utility bills	Zhu, Sarkis [82], Porter and Van der Linde [145]
	SPEco7	Decreased waste treatment fees	Kishawy, Hegab [28], Zhu, Sarkis [82]
	SPEcop8	Decreased waste discharge fees	Kishawy, Hegab [28], Zhu, Sarkis [82]
	SPEco9	Reduced environmental accident cases	Zhu, Sarkis [82], Geyer and Jackson [85]
	SPEco10	Reduced manufacturing costs	Yi-Chan and Tsai [146], Carter, Kale [147]
	SPEcoc11	Improved product quality	Zhu, Sarkis [82], Rao and Holt [143]
Social performance (SPso)	SPSo1	Improved relationship with the community and stakeholders	Maxwell, Sheate [84]
	SPSo2	Improved work safety	Geyer and Jackson [85]
	SPSo3	Improved work environment	Kishawy, Hegab [28], Maxwell, Sheate [84], Geyer and Jackson [85]
	SPSo4	Improved living quality of the surrounding community	Maxwell, Sheate [84]

Author contribution All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by Salwa Hanim Abdul-Rashid, Novita Sakundarini, Raja Ariffin Raja Ghazilla, Ramayah Thrusamay, and Marini Nurbanum. The first draft of the manuscript was written by Salwa Hanim Abdul-Rashid, Marini Nurbanum, and Ramayah Thurasamy, and the rest of the authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Declarations

Conflict of interest The authors declare no competing interests.

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