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Blueprints to Benefits: Towards an Index to Measure the Impact of Sustainable Product Development on the Firm's Bottom Line

Muhammed Sajid [1] and Myriam Ertz [2,*]

[1] School of Management Studies, Cochin University of Science and Technology, Kochi 682022, India; sajidnasar4@gmail.com
[2] LaboNFC, Department of Economics and Administrative Sciences, University of Quebec in Chicoutimi, Saguenay, QC G7H 2B1, Canada
* Correspondence: myriam_ertz@uqac.ca

Abstract: This study pioneers the development of the Sustainable Product Impact (SPI) Index, a novel framework designed to bridge the gap in existing sustainability assessment methodologies by focusing specifically on the influence of sustainable product development on a firm's financial outcomes. For the first time, this research draws on the core principles of economics, marketing, and environmental sciences research fields to provide a comprehensive tool that enables businesses to quantify the multifaceted impacts of their sustainability initiatives within a corporate context. The SPI Index is an innovative metric that evaluates various factors, including financial and market performance, operational efficiency, brand perception, regulatory benefits, and long-term strategic advantages. This holistic approach allows for a more nuanced understanding of how sustainable practices influence a company's bottom line and overall market position. Key findings of this research reveal that integrating sustainable product development into business strategies enhances environmental stewardship and impacts financial performance. The SPI Index has demonstrated its capacity to provide detailed insights into the specific areas of sustainability that most strongly affect profitability, thereby guiding businesses in their strategic planning and decision-making processes. In terms of originality and value, this study contributes to the existing body of knowledge by offering a unique and practical tool for businesses. The SPI Index stands out in its ability to translate sustainability efforts into quantifiable financial metrics, promoting a more integrated and balanced approach to corporate sustainability and profitability. Hence, this research plays a crucial role in guiding companies toward responsible corporate citizenship while focusing on economic viability in the modern business landscape.

Keywords: product development; sustainable; environmental stewardship; market performance; sustainability assessment

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1. Introduction

Sustainable product development is paramount to contemporary firms, offering a dual advantage. It caters to the growing consumer preference for environmentally friendly products, enabling companies to tap into an expanding market and enhance their brand equity [1,2]. Simultaneously, by embracing sustainable practices, firms become active contributors to environmental preservation [3–5]. This entails responsible resource management, waste reduction, and emissions control, all of which minimize their ecological footprint [5,6]. This dual benefit aligns with modern consumer expectations and underscores firms' pivotal role as stewards of the environment under the extended producer responsibility paradigm [7].

Consequently, scholars have diligently invested substantial efforts in formulating a multitude of techniques for sustainable production, including continuous process technology and simulation techniques, among others [8,9]. In addition, an extensive array of sustainability assessment methodologies exists, scrutinizing the sustainability of operations and products. Examples include the Sustainability Performance Index [10], the Eco-Index Methodology [11], the Ecological Footprint [12], the Composite Sustainability Performance Index [13], the G-Score Method [14], the Life Cycle Index [15] and the Product Sustainability Index [16], among several others. However, despite the abundance of sustainability assessment methods, none of these are specifically designed to examine the impact of sustainable product development on the firm itself. Instead, these methodologies predominantly focus on evaluating the environmental or societal ramifications of such initiatives, thus failing to assess their influence on the economic dimension, which remains foundational to sustainable development [17].

Examining the impact of sustainable product development on a firm is crucial for several reasons. Businesses do not exist solely for the purpose of environmental preservation; instead, they are primarily driven by the imperative of revenue generation and profitability [18,19]. An analogy can be drawn here with Porter's [20] argument regarding the rise of the Internet. Many believed this technological innovation rendered traditional business rules obsolete. Hence, they decreased their focus on profitability, leading to poor decision-making and the dot-com crash in 2000 [20]. Therefore, Porter's [20] perspective offers a different insight, suggesting that the Internet's emergence actually re-emphasized the crucial importance of profitability in business strategies.

In a similar vein, within the sustainability movement, some companies have been observed to overly prioritize showcasing their Environmental, Social, and Governance (ESG), Corporate Social Responsibility (CSR), and Sustainable Development Goals (SDG) performances, sometimes at the expense of profitability (e.g., Bud Light, Ben & Jerry's, and Target) [21]. However, instead of seeing profitability and sustainability as competing objectives, they should be viewed as interconnected and mutually reinforcing.

Pursuing a broader set of corporate objectives encompassing ESG goals makes profitability even more crucial. Profitability serves as the financial foundation that enables companies to fund programs and initiatives aimed at achieving these comprehensive objectives. For example, solar energy remains a costly option in contrast to non-renewable sources due to high upfront costs while reducing the corporate energy bill in addition to the corporate environmental footprint in the long run [22]. More profitable organizations would thus be at an advantage since they would be able to finance such an investment and reap both environmental and economic benefits from it. Recognizing the interconnections between these objectives becomes imperative, as they can significantly influence one another. Therefore, just as the rise of the Internet eventually emphasized the importance of profitability in business strategies, the sustainability movement underscores the significance of profitability within the context of corporate sustainability and responsibility. Hence, assessing how sustainable product development initiatives affect a company's financial bottom line is paramount.

Now that we have made the case that creating value for shareholders remains a key business objective, maximizing value entails increasing profits [23]. Therefore, without tangible evidence of positive impacts, firms may hesitate to invest (further) in sustainability efforts [24,25]. Yet, sustainable product development can incur additional costs, such as investments in eco-friendly materials, cleaner production processes, or renewable energy sources [26,27]. A clear understanding of how these investments translate into financial gains or cost savings is thus essential to encourage companies to commit to sustainability.

Moreover, measuring the impact of sustainable product development helps firms identify areas requiring improvement or corrective actions. Sustainability is an evolving field, and continuous assessment allows companies to adapt to changing regulations, consumer preferences, and emerging technologies [28,29]. It also fosters transparency and accountability, both internally and externally, meeting the rising demand for evidence of a firm's commitment to sustainable practices [30]. In today's business landscape, where sustainability is a competitive advantage and a necessity increasingly required from diverse stakeholders for long-term viability [31,32], understanding the impact of sustainable product development on a firm is essential for profitability, adaptability, and responsible corporate citizenship. As businesses strive to balance economic success with environmental and social responsibility, they rely on comprehensive impact assessments for informed decision-making and sustainable growth.

To address the aforementioned knowledge gap, we conduct a literature review to formulate an index to quantify the impact of sustainable product development on a company's bottom line. The process involves retrieving relevant research articles from reputable databases such as Scopus, Web of Science, and Proquest. Our focus within this study centers on an extensive examination of the existing literature on sustainable product development frameworks and methodologies for sustainability assessment. Our literature review encompasses theoretical and empirical articles, all sourced from reputable peer-reviewed journals. The findings from the extensive literature are then used to develop an original metric termed the Sustainable Product Impact (SPI) Index.

For the first time, the proposed SPI Index is a comprehensive framework for evaluating the multifaceted impacts of sustainable product development within a business context. It encompasses a range of critical performance and strategic matrices to provide a holistic perspective on how sustainability efforts influence a company's bottom line. The SPI Index assesses financial metrics, such as cost savings and return on investment (ROI), demonstrating the tangible economic benefits of sustainable practices. Market performance indicators, such as market share and customer retention, shed light on how sustainability initiatives can enhance competitiveness and profitability. Operational efficiency factors, including waste reduction and supply chain optimization, underscore the operational advantages of sustainable product development. Meanwhile, the SPI Index delves into the realm of intangibles by examining brand value and image, considering consumer perception and brand valuation as measures of the enduring value that sustainability can bring to a company's identity. Furthermore, it recognizes the regulatory and compliance benefits of sustainable practices, highlighting the potential to avoid fines and leverage tax incentives. Finally, the SPI Index emphasizes long-term benefits, such as risk mitigation and an innovation pipeline fueled by sustainable product development. This comprehensive framework empowers businesses to quantitatively assess the impact of their sustainability initiatives, supporting informed decision-making and the integration of sustainability into corporate strategies.

Following the introductory section, the subsequent part will present a thorough account of the methodology. Afterward, an elaboration on various sustainability assessment methods will be provided, followed by the derivation of the SPI Index. An exhaustive and comprehensive discussion of the index and an illustration of the SPI Index will follow this.

2. Methodology

This study employed a comprehensive literature review methodology to synthesize existing scholarly works. To identify relevant research articles, we conducted searches on well-established databases, including Scopus, Web of Science, and Proquest. Since the three cited databases already cover a vast array of publication outlets, we excluded ABI/Inform from the retrieving process to avoid redundancies and duplicates. The focus of this article was on the literature pertaining to linking sustainable product development and a firm bottom line. Our review encompassed theoretical and empirical articles that have undergone peer review and have been published in Scopus/Web of Science/ABS/ABDC indexed journals.

Our search strategy incorporated a set of specific keywords identified through a preliminary secondary data analysis phase, such as "sustainable product development", "sustainability assessment", "green product development", "sustainable manufacturing", "environmental impact assessment", "life cycle assessment", "eco-design", "sustainability metrics", and "triple bottom line assessment". These keywords were determined through an extensive literature review. Our inclusion criteria mandated that the studies examined sustainability assessment methodologies, sustainable product development, and their impact on a firm's bottom line. We also required that these studies be published in English, excluding those in other languages. Furthermore, we confined our search to articles and reviews, excluding book chapters and conference proceedings. This selection process encompassed studies published over the past 25 years, from 1997 to 2022.

Most selected articles were sourced from esteemed peer-reviewed journals specializing in business management. These include but are not limited to *Sustainability, Journal of Cleaner Production*, *Resources Conservation and Recycling*, *Business Strategy and the Environment*, *International Journal of Production Economics*, *Sustainable Production and Consumption*, and *Journal of Industrial Ecology*.

Importantly, these journals have a track record of publishing seminal articles that significantly contribute to the topical body of knowledge. Moreover, articles from these journals provide robust support for the conceptual framework proposed in this study. These journals are recognized as top-tier publications in the domain, being indexed in reputable databases. In addition, to ensure the inclusion of relevant sources, we systematically examined the reference lists of recent articles, prioritizing those with a substantial number of citations.

Research articles for the study were selected in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology [33]. This is because PRISMA ensures the inclusion of relevant, high-quality articles by filtering through extensive databases and applying stringent criteria for selection. The initial identification of articles was conducted in three major databases: Scopus (n = 1427), Web of Science (n = 1669), and ProQuest (n = 318), yielding a total of 3414 articles. Following the first screening, which involved the removal of 561 duplicates, the remaining count stood at 2853. In the second screening, 2304 articles were excluded due to non-compliance with our predefined inclusion/exclusion criteria. These criteria encompassed factors such as the publication timeframe, language, and format. Expressly, articles were excluded if they were not published within the designated timeframe, were not written in English, or did not conform to accepted academic format, i.e., journal articles. This rigorous selection process ensures the relevance and quality of the studies included in our literature review. In the third step, specific eligibility criteria were applied to refine the selection of articles. These criteria were established to ensure the relevance and quality of the publications included in the study. Articles were excluded if they did not mention the predefined search terms or keywords in their title, abstract, or keyword sections. This measure ensured that only publications directly relevant to the research topic were considered. The rigorous application of these eligibility criteria resulted in the exclusion of 423 articles, focusing the review on the relevant articles.

In the fourth step of the literature review process, a deeper analysis of the entire content of each publication was conducted. This step was essential to determine the fit of each article within the scope of the study. Unlike the previous steps, which primarily focused on titles, abstracts, and keywords, this stage involved thoroughly examining the full text of each remaining publication. The objective was to assess the relevance, depth, and contribution of each article in relation to the specific research questions and objectives. Publications that did not align closely with the study's scope, lacked sufficient depth of analysis, or failed to contribute meaningfully to the research topic were excluded. Finally, 94 articles were selected for the review (See Figure 1).

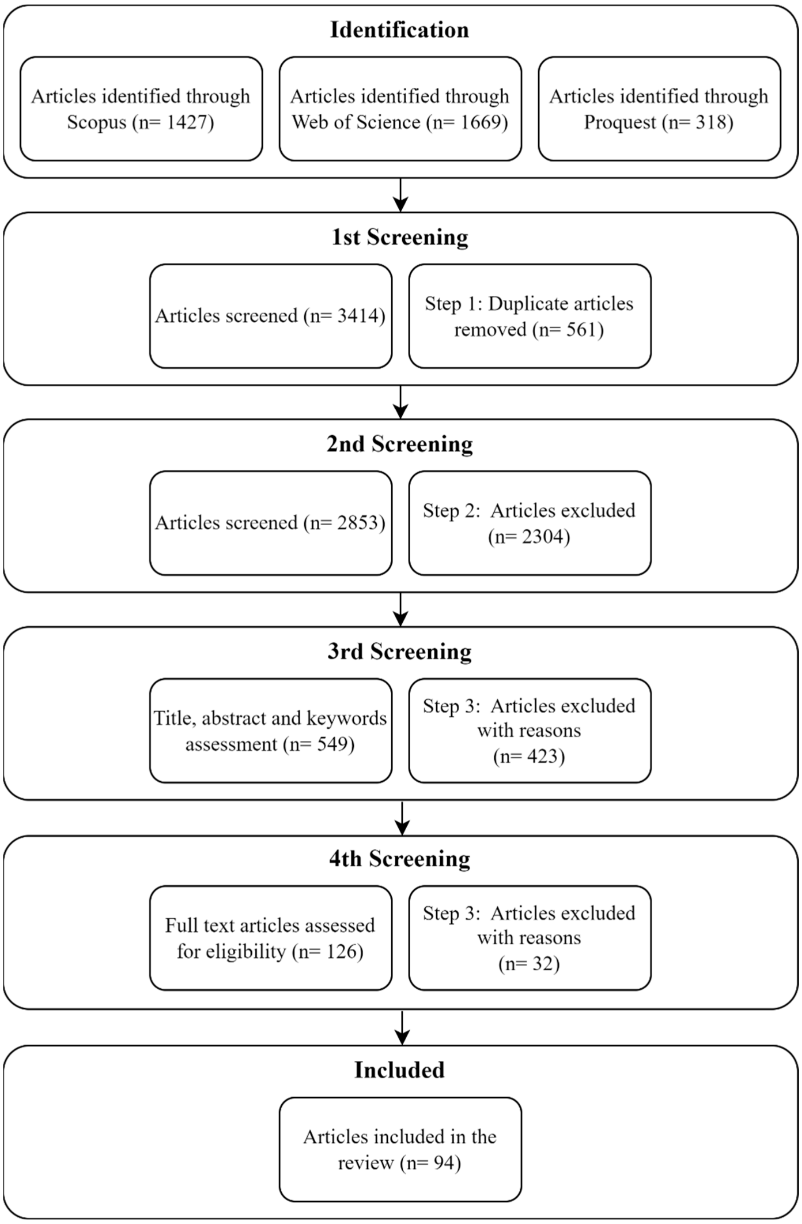

Figure 1. Retrieval and selection process of the articles.

3. Sustainability Assessment Methods

The content analysis of the resulting body of literature shows that various sustainability assessment methods have been developed to evaluate the environmental impact and overall sustainability of products, processes, and industries. These methods play a crucial role in guiding decision-making towards more sustainable practices. Here is a summary of a few existing sustainability assessment methods:

Eco-Points (Eco-Scan): Based on a "distance to target" approach, this methodology assesses sustainability by comparing the current state to the target state across all life cycle stages of an offering. Eco-points are assigned to materials, energy, processes, usage, and transportation based on their environmental impact. It provides databases like Eco-indicator 95, Idemat 96, and Eco-indicator 97 to support the assessment [34].

Eco-Compass: Developed by Dow Chemical, the Eco-Compass simplifies Life Cycle Assessment data. It encompasses six dimensions: energy intensity, mass intensity, health and environmental risk, resource conservation, re-valorization, and service extension. It is based on eco-efficiency indicators developed by the World Business Council for Sustainable Development [35].

Eco-Indicator 99: This tool evaluates life cycle impacts based on damage-oriented impact assessment. It considers three damage categories: human health, ecosystem quality, and resource depletion. Specific models assess effects like respiratory impacts, global warming potential, and species disappearance, quantifying them in terms of disability-adjusted life years (DALY) and resource depletion [34].

Environmental Assessment for Cleaner Production Technologies: Developed by Fijał [36], this method allows quantitative analysis of environmental impacts by examining material and energy flows, waste, and product profiles. It is particularly useful for evaluating cleaner production technologies and conducting comparative analyses.

COMPLIMENT: COMPLIMENT combines life cycle assessment, multi-criteria analysis, and environmental performance indicators to provide comprehensive information on an industry's environmental impact. It considers various impact categories such as global warming, acidification, eutrophication, ozone precursors, and human health. Weights are assigned based on different perspectives (local, regional, national) and then aggregated to form an index [37].

Eco-Efficiency Framework: Allows organizations to assess economic and environmental sustainability using appropriate indicators, facilitating a holistic performance evaluation [38].

Product Sustainability Index (ProdSI): This methodology offers a metrics-based approach to comprehensively assess product sustainability across its life cycle stages. ProdSI adds to the array of sustainability assessment methods, aiding informed decision-making and fostering sustainable practices [16] (see Table 1 for an overview of sustainable assessment methods).

Table 1. Sustainability assessment methodologies and focus.

Methodology	Dimensions	Focus	Source
Eco-Points (Eco-Scan)	Life cycle stages, materials, energy, processes, usage, and transportation.	Product and Process Sustainability Assessment	[34]
Eco-Compass	Six dimensions: energy intensity, mass intensity, health, resource conservation, re-valorization, and service extension.	Product and Process Sustainability Assessment	[35]
Eco-Indicator 99	Damage-oriented impact assessment (human health, ecosystems, minerals, fossil fuels).	Product and Process Sustainability Assessment	[34]
Environment Assessment for Cleaner Production Technologies	Environmental impact of cleaner production technologies.	Product Sustainability Assessment	[36]
COMPLIMENT	The environmental impact of industries includes global warming, acidification, eutrophication, ozone precursors, and human health.	Industry Sustainability Assessment	[37]
Eco-Efficiency Framework	Economic and environmental sustainability.	Organisational Sustainability Assessment	[38]
Product Sustainability Index (ProdSI)	Comprehensive assessment of product sustainability across life cycle stages.	Product Sustainability Assessment	[16]

4. Derivation of the Index

4.1. Sustainable Product Development and Financial Performance

Sustainable product development profoundly impacts a firm's financial performance indicators, thereby significantly influencing the bottom line. Firstly, cost savings are pivotal in contributing to a firm's bottom line [39–41]. Sustainable product development involves optimizing processes to reduce resource consumption and minimize waste [42,43]. This leads to tangible cost reductions, such as lower procurement costs due to the sustainable features of the product, such as using recycled materials and making the product recyclable [44]. Additionally, it results in decreased operational expenses through the sustainable manner in which the product is being manufactured, such as reduced energy use to produce the item [45,46]. As a result, the cost of goods sold (COGS) decreases, directly enhancing profit margins and overall cost efficiency. These savings can be re-invested or contributed directly to the firm's bottom line.

Further, ROI is a critical metric influenced by sustainable product development, and its impact becomes increasingly apparent as sustainability initiatives mature [47,48]. While there may be initial investments in research, technology, and process optimization, these expenditures yield substantial long-term benefits. Sustainable practices lead to persistent reductions in operational costs by optimizing manufacturing processes and conserving resources, resulting in ongoing cost savings that positively contribute to ROI [49]. Based on the above discussion, we formulate the following proposition:

Proposition 1. *Sustainable product development exerts a positive influence on financial performance indicators, including cost savings and ROI, collectively exerting a constructive impact on the firm's bottom line.*

4.2. Sustainable Product Development and Market Performance

Sustainable product development is a strategic approach that profoundly influences a company's market performance indicators, including market share and customer retention [50–52]. These effects, in turn, play a pivotal role in shaping the firm's bottom line. One of the most striking impacts of sustainable product development is its ability to confer a competitive advantage [53]. Sustainable products set a company apart in the market, resonating with environmentally and socially conscious consumers who may not have previously considered the company's offerings [54,55]. This expanded customer base contributes to an increase in market share.

Sustainable product development also contributes to customer retention [56,57]. In today's conscientious consumer landscape, customers seek products that align with their values and contribute positively to society and the environment [58,59]. A company that consistently delivers sustainable products cultivates a loyal customer base [60,61]. These customers are more likely to stay with the brand over time, reducing churn rates and maintaining market share [62,63]. Thus, we propose:

Proposition 2. *Sustainable product development exerts a positive influence on market performance indicators, including market share and customer retention, collectively exerting a constructive impact on the firm's bottom line.*

4.3. Sustainable Product Development and Operational Efficiency

Sustainability product development profoundly impacts operational efficiency indicators such as waste reduction and supply chain optimization, all of which can significantly influence a firm's bottom line. Waste reduction is a critical aspect of sustainability in product development. By adopting eco-friendly materials and production methods, firms can minimize waste generation and disposal expenses [64,65]. The "reduce, reuse, and recycle" principles are at the core of sustainability, resulting in more efficient resource utilization [66]. Waste reduction strategies not only cut waste management costs but also bolster the company's image as a socially responsible entity, appealing to environmentally conscious consumers.

Moreover, sustainable supply chain practices, such as sourcing materials locally, reducing transportation-related emissions, and optimizing inventory management, contribute to operational efficiency [67,68]. A streamlined supply chain is less susceptible to disruptions [69,70], which can result in production delays and increased costs. Additionally, by minimizing the distance and energy required to transport materials and finished products, businesses can reduce transportation expenses, enhance cost-effectiveness, and improve profit margins. Therefore, we assume that:

Proposition 3. *Sustainable product development exerts a positive influence on operational efficiency indicators, including waste reduction and supply chain optimization, collectively exerting a constructive impact on the firm's bottom line.*

4.4. Sustainable Product Development and Brand Value and Image

Sustainable product development profoundly influences a company's brand perception, affecting brand value and image, which ultimately impact the firm's bottom line. Firstly, sustainable product development can significantly enhance a brand's value [71,72]. Consumers become increasingly concerned about environmental and social issues, so they are more likely to favor brands that demonstrate a commitment to sustainability [73,74]. Products that are produced sustainably are often associated with higher quality, durability, and responsibility. This can lead to consumers perceiving the brand as offering premium products, allowing the company to command higher prices and, consequently, increasing its revenue and profitability [75,76].

Secondly, sustainability efforts contribute to shaping a positive brand image. Companies prioritizing sustainability are considered forward-thinking and socially responsible [77,78]. Such a positive image can attract environmentally conscious consumers and a broader customer base. It fosters trust among consumers, as they believe in the brand's ethical practices [79]. This trust translates into customer loyalty, repeat business, and positive word-of-mouth recommendations, all contributing to a healthier bottom line. Thus, we propose:

Proposition 4. *Sustainable product development exerts a positive influence on brand perception indicators, including brand value and brand image, collectively exerting a constructive impact on the firm's bottom line.*

4.5. Sustainable Product Development and Regulatory and Compliance Benefits

Sustainable product development shapes a company's regulatory and compliance standing. Firstly, it can lead to a reduction in fines and penalties. Sustainable product development often involves adherence to strict environmental and social regulations [80,81]. By integrating sustainability practices into their products and processes, companies can proactively reduce non-compliance risk. This decreases the likelihood of facing fines and penalties imposed by regulatory authorities for violations. For example, businesses that invest in sustainable materials, waste reduction, and emissions control are less likely to face costly legal consequences for environmental violations. As a result, they can preserve their financial resources and protect their bottom line.

Furthermore, sustainable product development can also open doors to tax incentives and benefits. Many governments worldwide are incentivizing sustainable practices by offering tax breaks, credits, or deductions to companies that adopt eco-friendly initiatives [82–85]. These incentives can translate into significant cost savings for the business. For instance, a company that develops energy-efficient products may be eligible for tax credits or reduced tax rates. This not only reduces the tax burden but also contributes positively to the company's financial performance. Hence, we argue that:

Proposition 5. *Sustainable product development exerts a positive influence on regulatory and compliance benefits indicators, including fines, penalties, and tax incentives, collectively exerting a constructive impact on the firm's bottom line.*

4.6. Sustainable Product Development and Long-Term Benefits

Sustainable product development serves as a crucial tool for long-term risk mitigation. Firstly, it helps companies proactively address regulatory and compliance risks [81,86]. By integrating sustainability practices into their products, businesses can stay ahead of evolving environmental and social regulations. This reduces the likelihood of facing fines, penalties, or legal challenges, thus safeguarding the firm's financial stability over time. Moreover, sustainability efforts contribute to reputation risk mitigation. Brands that prioritize sustainability are less prone to negative publicity related to environmental or ethical concerns [87]. This positive reputation protects against potential damage, ensuring the company's long-term viability and financial performance.

Furthermore, sustainable product development nurtures an innovation pipeline within a company. It encourages the exploration of eco-friendly materials, processes, and technologies, fostering a culture of continuous improvement [88,89]. This innovation pipeline leads to the creation of more sustainable products, which can differentiate the company in the market. Innovative sustainable products often appeal to environmentally conscious consumers, providing a competitive edge and long-term revenue potential. Thus, it is assumed that:

Proposition 6. *Sustainable product development exerts a positive influence on long-term benefits indicators, including risk mitigation and innovation pipeline, collectively exerting a constructive impact on the firm's bottom line.*

Considering that P1–P3 pertain to different propositions related to the firm's performance, we categorize financial performance, market performance, and operational efficiency together under the "performance matrix". Concurrently, P4–P6 deals with propositions related to strategic impact, leading us to categorize brand perception, regulatory and compliance benefits, and long-term benefits under the "strategic impact matrix". This categorization results in the SPI Index, as illustrated in Figure 2.

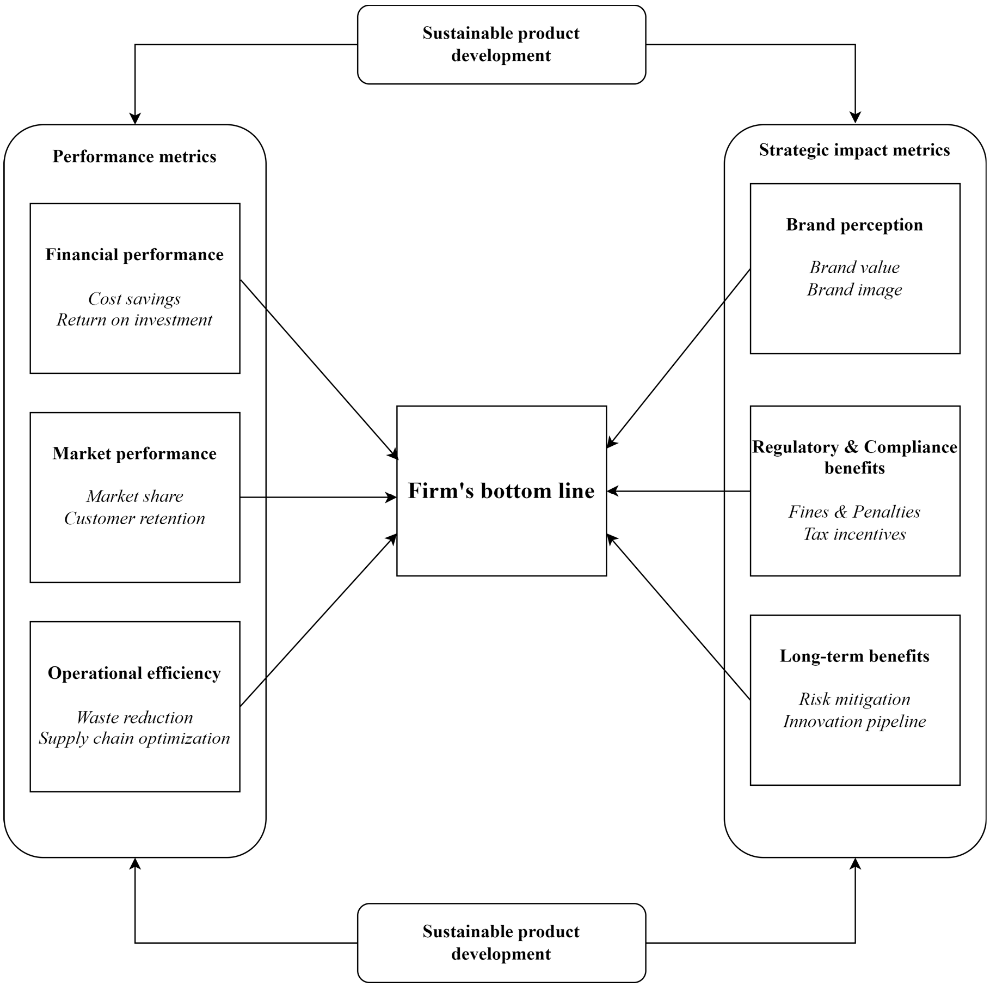

Figure 2. Sustainable product development impact index.

5. Quantification of the Matrix

In the following sub-sections, we present equations that quantify the matrices discussed, providing a detailed explanation of how these factors directly impact a firm's bottom line, building on the conceptual insights previously introduced. For clarity in our exposition, we number first-level equations using standard Arabic numerals and second-level equations with Roman numerals.

5.1. Financial Performance

Measuring cost savings and ROI resulting from sustainable product development is essential for assessing the financial viability and environmental impact of such initiatives. Several key performance indicators and methods can be employed to quantify these outcomes.

5.1.1. Cost Savings Measurement

Cost savings from sustainable product development can be determined by comparing the expenses associated with traditional product development and those incurred when adopting sustainable practices. Thus, the equation for Cost Savings Percentage (CS) can be expressed as:

$$\mathrm{CS}\ (\%) = ((\mathrm{C_t} - \mathrm{C_s})/\mathrm{C_t}) \times 100 \qquad (1)$$

C_t refers to the "Cost of Traditional Development", which includes expenditures related to raw materials, energy consumption, and specifically, the expenses required to manage excess waste, along with other production costs associated with non-sustainable practices. C_s, which represents the Cost of Sustainable Product Development, encompasses all expenses associated with adopting eco-friendly materials, implementing energy-efficient processes, employing waste reduction strategies, and other sustainable approaches in the product development process. If the firm does not have a non-sustainable alternative to the sustainable product, they may utilize the cost of traditional development of their competitors. In cases where these data are unavailable, industry standards can be employed as a substitute for the cost of traditional development.

5.1.2. Return on Investment (ROI) Measurement

ROI [90,91] is a crucial metric for evaluating the financial performance of sustainable product development initiatives. The ROI (%) formula is:

$$\text{ROI (\%)} = ((\text{Net profit from sustainable product development} - \text{Initial investment})/\text{Initial investment}) \times 100 \qquad (2)$$

"Net Profit from Sustainable Product Development" includes the total profit generated from the sustainable product initiative, which accounts for revenue increase and cost savings. The "Initial Investment" represents the initial capital invested in developing and implementing sustainable practices. To calculate ROI accurately, it is important to include all relevant costs and benefits over the project's life cycle, considering factors like product life cycle stages, maintenance, and market trends.

5.1.3. Quantifying the Financial Performance Matrix

It is essential to amalgamate Equations (1) and (2) to quantify the financial performance matrix. As a preliminary step, weights should be allocated to each financial performance indicator: Cost Savings Percentage (CS; w_1) and ROI Percentage (w_2). These weights should reflect the relative importance of each metric to the firm's bottom line. Firms can allocate weights based on business goals, industry norms, or specific strategic priorities. For example, if a company places a high emphasis on cost savings, one might assign the following weights:

- Weight1 (w1) (Cost Savings Percentage):60%
- Weight2 (w2) (ROI Percentage): 40%

These weights add up to 100%, ensuring that the combined impact percentage remains within the 0–100% range. Now, the following equation can be used to quantify the Financial Performance Impact Percentage (FPI):

$$\text{FPI } (\%) = ((\text{CS} \times w_1) + (\text{ROI} \times w_2))/(w_1 + w_2) \quad (3)$$

5.2. Market Performance

Measuring market share and customer retention resulting from sustainable product development is essential for evaluating the impact of sustainability initiatives on a company's performance. Here is how to measure these key indicators:

5.2.1. Market Share Measurement

Market share can be measured as the portion of total market sales or revenue that a company captures with its sustainable products. The formula for calculating market share percentage (MS) is:

$$\text{MS } (\%) = (S_{sp}/S_{tm}) \times 100 \quad (4)$$

Here, "S_{sp}" represents the company's sales or revenue from sustainable products, which refers to the specific sales or revenue generated by the company from its sustainable products. These sustainable products are those designed with a focus on environmental and social responsibility, encompassing eco-friendly, ethically sourced, and long-term viable offerings. The second component, $S_{tm,}$ or total market sales or revenue, represents the aggregate sales or revenue across the entire market, including all products and services, regardless of their sustainability. By comparing the company's sustainable product sales to the total market sales, the equation quantifies its market share and position in the sustainable product segment, providing valuable insights into its competitive standing within that market.

5.2.2. Customer Retention Measurement

Customer retention measures the ability of a company to keep its existing customers engaged and loyal to its sustainable products over time. To calculate the customer retention rate (CRR), the following formula can be used:

$$\text{CRR } (\%) = ((C_{end} - C_{new})/C_{start}) \times 100 \quad (5)$$

The formula involves three key variables: "Number of Customers at the End of a Period," (C_{end}) which signifies the total count of customers still purchasing sustainable products at the period's conclusion; "Number of New Customers Acquired During the Period," (C_{new}) representing customers who initiated purchases during that timeframe; and "Number of Customers at the Start of the Period," C_{start} denoting those customers already engaged with the products at the period's commencement. This equation yields the customer retention rate as a percentage by comparing the retained customer count to the total customer count at the period's outset while considering the influence of newly acquired customers during that period.

5.2.3. Quantifying the Market Performance Matrix

To quantify the Market Performance Impact (MPI), we propose to amalgamate the values of market share and customer retention. For this, we follow the weighted average technique as used for quantifying the financial performance indicators. The equation is as follows:

$$\text{MPI } (\%) = ((\text{MS} \times w_1) + (\text{CRR} \times w_2))/(w_1 + w_2) \quad (6)$$

5.3. Operational Efficiency

Measuring waste reduction and supply chain optimization resulting from sustainable product development is crucial for assessing the operational benefits of sustainability initiatives. Here is how to measure these key indicators:

5.3.1. Waste Reduction Measurement

Waste reduction can be measured by comparing the waste generated before and after implementing sustainable practices. The formula for waste reduction percentage (WR) is:

$$\mathrm{WR}\ (\%) = ((w_{\mathrm{initial}} - w_{\mathrm{final}})/(w_{\mathrm{initial}})) \times 100 \tag{7}$$

This equation calculates the percentage reduction in waste generated. Waste reduction can be achieved through more efficient processes, recycling efforts, or using sustainable materials. W_{initial} represents the quantity of waste generated at the start of a defined period or process, serving as the baseline measure. On the other hand, W_{final} is the quantity of waste generated at the end of the same period or process once waste reduction measures have been applied.

5.3.2. Supply Chain Efficiency

Supply chain optimization in sustainable product development can be assessed through various metrics, including lead times, transportation costs, and inventory levels. We propose the following equation to compute the Sustainable Supply Chain Efficiency Ratio (SSCER):

$$\mathrm{SSCER}\ (\%) = (C_{\mathrm{SSC}}/S_{\mathrm{T}}) \times 100 \tag{8}$$

The SSCER quantifies the proportion of a company's total sales expended on sustainable supply chain expenses. Here, C_{SSC} denotes the total supply chain cost, while S_{T} signifies the total sales. To compute C_{SSC}, one needs to sum up all direct costs (such as sustainable sourcing, production, transportation, and waste management), indirect costs (like certification, training, monitoring, and carbon offset expenses), and any investments in sustainable technology or infrastructure. The ratio provides insight into how much revenue is directed towards sustainable operations.

5.3.3. Quantifying the Operational Efficiency Matrix

One can use a weighted average to compute the impact of operational efficiency on a firm's bottom line. Assign weights to each component based on their relative importance, and then calculate the Operational Efficiency Impact (OEI) percentage using the following formula:

$$\mathrm{OEI}\ (\%) = ((\mathrm{WR} \times w_1) + (\mathrm{SSCER} \times w_2))/(w_1 + w_2) \tag{9}$$

In the context of measuring Operational Efficiency Impact (OEI), two primary metrics are considered: WR, denoting Waste Reduction, and SSCER, which stands for the Sustainable Supply Chain Efficiency Ratio. Each of these metrics has an associated weight to signify its relative importance. Specifically, w_1 is the weight assigned to Waste Reduction, while w_2 is associated with SSCER. These weights allow for a balanced representation of each factor's contribution to the overall operational efficiency.

5.4. Increase in Brand Perception

The assessment of brand perception encompasses three key indicators: brand value, brand image, and brand reputation. These crucial aspects can be effectively gauged through cross-sectional surveys, which offer a reliable methodology for measurement. Employing established and well-validated scales for these constructs can significantly mitigate concerns related to scale reliability. To operationalize this measurement approach, we recommend using the established scale developed by Netemeyer et al. (2004) [92] for evaluating brand value, the scale crafted by Lee and Shavitt (2009) [93] for assessing brand image, and the scale designed by Veloutsou and Moutinho (2009) [94] to capture brand reputation. These scales have undergone rigorous scrutiny and validation, ensuring their appropriateness for measuring these specific facets of brand perception.

To further enhance the sensitivity and discernibility of responses, we suggest employing seven-point Likert scales for measuring these constructs. The expanded Likert scale allows for a more nuanced and fine-grained assessment, offering respondents greater flexibility in expressing their perceptions. Further, in this context, a mean value of responses exceeding 4 signifies favorable brand perceptions for each assessed construct. This approach ensures that a threshold of positivity is maintained, helping organizations gauge and monitor their brand's standing in the eyes of consumers more comprehensively. Assessing the improvement in brand perception is crucial to determining the impact of sustainable product development on a firm's bottom line. For this purpose, we propose the following equation to compute the WAIB percentage:

$$\text{WAIB (\%)} = w_{BV} \times (((BV_{after} - BV_{before}))/BV_{before}) \times 100 + w_{BI} \times ((BI_{after} - BI_{before}))/BV_{before}) \times 100)/w_{BV} + w_{BI} \quad (10)$$

In this equation for a weighted average increase in brand perception (WAIB), the weights w_{BV} and w_{BI} are assigned to the constructs of brand value and brand image, respectively, denoting their relative importance in the overall brand perception measurement. BV_{before} represents the brand value score before a specific intervention, like introducing sustainable product development, while BV_{after} is its score post-intervention. Similarly, BIbefore is the brand image score before the intervention, and BIafter captures its score afterward. These scores provide insights into the changes in brand perception due to the event or intervention.

5.5. Regulatory and Compliance Benefits

Measuring the reduction in fines and penalties, as well as tax incentives received from authorities resulting from sustainable product development, involves tracking financial gains and losses associated with compliance and sustainability efforts. Here is how to measure these key indicators:

5.5.1. Reduction in Fines and Penalties Percentage Measurement

Measuring the reduction in fines and penalties resulting from sustainable product development involves quantifying the decrease in financial liabilities associated with compliance issues. To do this, firms should calculate the difference between the fines and penalties that would have been incurred without sustainable practices and those actually incurred with sustainable practices in place. The formula for calculating the reduction in fines and penalties (RFP) is:

$$\text{RFP (\%)} = (\text{Fines without sustainable practices} - \text{Fines with sustainable practices})/(\text{Fines without sustainable practices}) \times 100 \quad (11)$$

This equation provides an accurate assessment of the reduction in financial liabilities due to the positive impact of sustainable practices on legal and regulatory compliance.

5.5.2. Tax Incentives Received Percentage

Tax incentives from authorities due to sustainable product development can be measured by summing up the tax benefits received over a specific period. The formula for calculating tax incentives received percentage (TIR) is:

$$\text{TIR (\%)} = (\text{Tax credits} + \text{Tax deductions} + \text{Tax rebates} + \text{Tax exemptions})/(\text{Total tax liability}) \times 100 \quad (12)$$

These components include various types of tax incentives provided by authorities to promote sustainable and environmentally friendly practices. The total financial benefits derived from tax incentives can be quantified by summing them up. In both cases, it is essential to maintain detailed records of fines, penalties, and tax incentives before and after implementing sustainable product development initiatives. This data should be tracked over time to assess the ongoing impact of sustainability efforts. Additionally, consider using key performance indicators (KPIs) related to sustainability compliance and financial outcomes. For instance, firms can track the number of regulatory violations before and after sustainability measures were put in place or measure the percentage change in tax expenses attributed to sustainability initiatives.

5.5.3. Quantifying the Regulatory and Compliance Benefits

We have conceptualized the RFP and TIR as tools to systematically assess the multifaceted determinants impacting a firm's financial outcomes from sustainable product initiatives. Consequently, we propose the following equation to elucidate the collective implications of Regulations and Compliance Benefits (RCB) percentage on an organization's net profitability.

$$\text{RCB}\ (\%) = ((\text{RFP} \times w_1) + (\text{TIR} \times w_2))/(w_1 + w_2) \quad (13)$$

This serves as a comprehensive framework to determine the RCB for a firm. In this equation, RFP represents the percentage reduction in fines and penalties, signifying the monetary savings due to compliant practices. TIR, on the other hand, denotes the percentage of tax incentives received, reflecting fiscal benefits derived from sustainable operations or products. W_1 and w_2 are weighted, allowing for the model customization based on each factor's relative importance. The equation offers an aggregate measure of the financial advantages associated with regulatory compliance and sustainable incentives.

5.6. Long-Term Benefits

Measuring risk mitigation and the impact on the innovation pipeline resulting from sustainable product development involves a combination of quantitative and qualitative assessments. These measurements are essential for evaluating the effectiveness of sustainability initiatives within an organization.

5.6.1. Risk Mitigation Measurement

To measure the impact of sustainable product development on regulatory and compliance risk mitigation, firms may utilize key performance indicators (KPIs) related to regulatory compliance. Track the number of regulatory violations, fines, penalties, or legal challenges before and after implementing sustainability practices. The equation for measuring the reduction in compliance risk (CRred) could be:

$$\text{CRred}\ (\%) = ((\text{Number of violations before} - \text{Number of violations after})/(\text{Number of violations before})) \times 100 \quad (14)$$

This equation quantifies the decrease in compliance-related issues, showcasing the effectiveness of sustainability efforts in proactively addressing regulatory risks.

5.6.2. Innovation Pipeline Measurement

The innovation pipeline in this context can be measured by quantifying eco-friendly material adoption. This involves measuring the adoption of eco-friendly materials in the product development process. Calculate the percentage of sustainable materials used in the products compared to non-sustainable alternatives. The equation for measuring the eco-friendly material adoption rate (EMAR) is:

$$\text{EMAR}\ (\%) = (\text{Sustainable material usage}/\text{Total material usage}) \times 100 \quad (15)$$

This equation reflects the progress in integrating sustainable materials into the firm's product portfolio. A higher percentage signifies a significant commitment to eco-friendly practices, indicating that a substantial portion of product materials are sustainable.

5.6.3. Quantifying the Long-Term Benefits

In order to quantify the long-term benefits (LTB), we propose the following equation:

$$\text{LTB}\ (\%) = ((\text{CRred} \times w_1) + (\text{EMAR} \times w_2))/(w_1 + w_2) \tag{16}$$

The equation, which integrates CRred and EMR with their respective weights w_1 and w_2, provides a synthesized measure to capture critical dimensions of sustainable business practices. In this formulation, CRred signifies the reduction in compliance risk, highlighting a firm's proactive approach to adhering to regulatory standards and thereby potentially mitigating future liabilities or penalties. Simultaneously, EMR represents the eco-friendly material adoption rate, indicating the extent to which a firm has incorporated sustainable materials into its products or processes. By assigning weights w_1 and w_2 to CRred and EMR, respectively, the model allows stakeholders to prioritize and evaluate the relative significance of risk reduction and sustainable material adoption in their overall sustainable strategy assessment.

5.7. Quantifying the Overall Impact

In today's rapidly evolving business landscape, where sustainability and corporate responsibility are increasingly integral to success, there's a pressing need for robust metrics to assess the overall impact of sustainable product development (OI) on a firm's bottom line. Comprehensive metrics not only serve as performance indicators but also guide strategic decision-making, inform stakeholder communication, and provide competitive differentiation.

Given this backdrop, we propose the following equation:

$$\text{OI}\ (\%) = ((\text{FPI} \times w_{\text{FPI}}) + (\text{MPI} \times w_{\text{MPI}}) + (\text{OEI} \times w_{\text{OEI}}) + (\text{WAIB} \times w_{\text{WAIB}}) + (\text{RCB} \times w_{\text{RCB}}) + (\text{LTB} \times w_{\text{LTB}}))/(w_{\text{FPI}} + w_{\text{MPI}} + w_{\text{OEI}} + w_{\text{WAIB}} + w_{\text{RCB}} + w_{\text{LTB}}) \tag{17}$$

where

FPI = Financial Performance Impact
MPI = Market Performance Impact
OEI = Operational Efficiency Impact
WAIB = Weighted average increase in brand perception
RCB = Regulations and Compliance Benefits
LTB = Long-term benefits
w_{FPI} = Weight assigned to FPI
w_{MPI} = Weight assigned to MPI
w_{OEI} = Weight assigned to OEI
w_{WAIB} = Weight assigned to WAIB
w_{RCB} = Weight assigned to RCB
w_{LTB} = Weight assigned to LTB

The assignment of weights to individual components is, fundamentally, at the discretion of each respective firm, contingent upon their strategic objectives and operational nuances. Nevertheless, adhering to industry standards can enhance the consistency and comparability of outcomes across entities [95].

Using this matrix, we suggest the subsequent benchmark levels for assessing the impact on the firm's bottom line:

- 75–100%: Optimal—Firms are maximizing the benefits of sustainable product development [96].
- 50–74%: Proficient—Above average practices but not at the pinnacle [97].
- 25–49%: Emerging—Initiating sustainable efforts with substantial room for enhancement [98].
- Below 25%: Lagging—Indicating a dire need for strategic adjustments in sustainable practices [99].

These specified threshold limits are pertinent to each separate index as well. By employing this matrix and its associated benchmarks, organizations can more accurately determine their standing in terms of translating sustainable product development into bottom-line results.

5.8. Case Study

Due to the unfeasibility of calculating this index using secondary data sources, we construct a hypothetical case study for XYZ Ltd. to elucidate the computation methodology. Table 2 provides the requisite values for the formulation of the matrix, facilitating an illustrative demonstration of the calculation procedure. The use of this case study adds a unique dimension to this study, enhancing its practical applicability and understanding.

Table 2. Data inputs for XYZ Ltd.'s matrix calculation.

Items	Value
C_s	USD 1,230,000
C_t	USD 1,980,000
Net profit from sustainable product development	USD 3,533,890
Initial investment	USD 3,400,000
Weight for CS	40%
Weight for ROI	60%
S_{sp}	USD 993,000
S_{tm}	USD 4,600,000
C_{end}	8912 Consumers
C_{new}	2356 Consumers
C_{start}	16,345 Consumers
Weight for MS	30%
Weight for CRR	70%
$W_{initial}$	145 Kg
W_{final}	97 Kg
C_{ssc}	USD 1,300,000
S_T	USD 5,700,000
Weight for WR	50%
Weight for SSCER	50%
BV_{after}	5.16
BV_{before}	6.33
BI_{after}	5.19
BI_{before}	5.24
Weight for BV	50%
Weight for BI	50%
Fines without sustainable practices	USD 17,500
Fines with sustainable practices	USD 9300
Tax credits	0
Tax deductions	0

Table 2. *Cont.*

Items	Value
Tax rebates	USD 21,000
Tax exemption	USD 9400
Weight for RFP	30%
Weight for TIR	70%
Number of violations before	3
Number of violations after	1
Sustainable material usage	549 Kg
Total material usage	2000 Kg
Weight for CRred	60%
Weight for EMAR	40%

5.8.1. Financial Performance Impact

We introduce the concept of Financial Performance Impact (FPI), which combines the cost savings (CS) and the return on investment (ROI) with their respective weights. The equation for CS is as follows:

$$\text{CS}\ (\%) = ((\text{C}_t - \text{C}_s)/\text{C}_t) \times 100 \tag{18}$$

$$\text{CS} = ((1{,}980{,}000 - 1{,}230{,}000)/1{,}980{,}000) \times 100$$

$$\text{CS} = 37.88\%$$

Interlude: The result of 37.88% in CS reflects the efficiency gained through sustainable practices.

$$\text{ROI}\ (\%) = ((\text{Net profit from sustainable product development} - \text{Initial investment})/\text{Initial investment}) \times 100 \tag{19}$$

$$\text{ROI} = ((3{,}533{,}890 - 3{,}400{,}000)/3{,}400{,}000) \times 100$$

$$\text{ROI} = 3.94\%$$

Interlude: An ROI of 3.94% demonstrates the initial financial benefits of the investment in sustainability.

Application of Equations (18) and (19) to Equation (20):

Applying the results from Equations (18) and (19) to the FPI formula, we assign weights $w_1 = 40$ and $w_2 = 60$, respectively.

$$\text{FPI}\ (\%) = ((\text{CS} \times w_1) + (\text{ROI} \times w_2))/(w_1 + w_2) \tag{20}$$

$$\text{FPI} = ((37.88 \times 40) + (3.94 \times 60))/(40 + 60)$$

$$\text{FPI} = 17.56\%$$

5.8.2. Market Performance Impact

The Market Performance Impact (MPI) combines market share (MS) and customer retention ratio (CRR) to assess the performance in the marketplace.

$$\text{MS}\ (\%) = (\text{S}_{sp}/\text{S}_{tm}) \times 100 \tag{21}$$

$$\text{MS} = (993{,}000/4{,}600{,}000) \times 100$$

$$\text{MS} = 21.59\%$$

Interlude: The MS of 21.59% indicates a competitive stake in the market through the sale of sustainable products.

$$\text{CRR (\%)} = ((C_{end} - C_{new})/C_{start}) \times 100 \tag{22}$$

$$\text{CRR} = ((8912 - 2356)/16{,}345) \times 100$$

$$\text{CRR} = 40.11\%$$

Interlude: A CRR of 40.11% suggests that sustainable products have contributed to retaining a significant portion of the customer base.

Application of Equations (21) and (22) to Equation (23):

Combining these values with weights $w_1 = 30$ and $w_2 = 70$, the MPI is calculated as:

$$\text{MPI (\%)} = ((\text{MS} \times w_1) + (\text{CRR} \times w_2))/(w_1 + w_2) \tag{23}$$

$$\text{MPI} = ((21.59 \times 30) + (40.11 \times 70))/(30 + 70)$$

$$\text{MPI} = 34.55\%$$

5.8.3. Operational Efficiency Impact

The Operational Efficiency Impact (OEI) takes into account the Waste Reduction (WR) and Sustainable Supply Chain Efficiency Ratio (SSCER), which are crucial indicators of the efficiency of operations after the implementation of sustainable practices.

$$\text{WR (\%)} = ((w_{initial} - w_{final})/(w_{initial})) \times 100 \tag{24}$$

$$\text{WR} = (147 - 97)/(147) \times 100$$

$$\text{WR} = 34\%$$

Interlude: A WR of 34% signifies the successful reduction of waste through sustainable operations.

$$\text{SSCER (\%)} = (C_{SSC}/S_T) \times 100 \tag{25}$$

$$\text{SSCER} = (1{,}300{,}000/5{,}700{,}000) \times 100$$

$$\text{SSCER} = 22.80\%$$

Interlude: The SSCER of 22.80% indicates enhanced efficiency within the sustainable supply chain.

Application of Equations (24) and (25) to Equation (26):

With equal weights assigned to WR and SSCER ($w_1 = 50$; $w_2 = 50$), the OEI is computed as:

$$\text{OEI (\%)} = ((\text{WR} \times w_1) + (\text{SSCER} \times w_2))/(w_1 + w_2) \tag{26}$$

$$\text{OEI} = ((34 \times 50) + (22.80 \times 50))/(50 + 50)$$

$$\text{OEI} = 28.40\%$$

Interlude: An OEI of 28.40% demonstrates the overall operational benefits of sustainability initiatives.

5.8.4. Weighted Average Increase in Brand Perception

WAIB gauges the change in brand perception due to sustainable practices. It combines the brand value (BV) and brand image (BI) before and after implementing sustainability initiatives, weighted by their importance.

Application of Equation (10):

$$\text{WAIB (\%)} = w_{BV} \times (((BV_{after} - BV_{before)})/BV_{before}) \times 100 + w_{BI} \times ((BI_{after} - BI_{before}))/BV_{before}) \times 100)/w_{BV} + w_{BI} \tag{27}$$

$$\text{WAIB} = (50 \times ((5.16 - 6.33)/6.33) \times 100 + 50 \times ((5.19 - 5.24)/5.24) \times 100)/100$$

$$\text{WAIB} = -9.45\%$$

Interlude: A negative WAIB of −9.45% suggests that there is a decline in brand perception, possibly due to the initial costs and changes in brand positioning associated with the transition to sustainability. This underscores the need for effective communication strategies to educate consumers and stakeholders about the long-term benefits and value of sustainable practices.

5.8.5. Regulations and Compliance Benefits

The Regulations and Compliance Benefits (RCB) measure the financial benefits accruing from reductions in fines and penalties (RFP), as well as from tax incentives (TIR), which are direct consequences of adherence to sustainable practices.

$$\text{RFP } (\%) = (\text{Fines without sustainable practices} - \text{Fines with sustainable practices})/(\text{Fines without sustainable practices}) \times 100 \quad (28)$$

$$\text{RFP} = ((17{,}500 - 9300)/17{,}500) \times 100$$

$$\text{RFP} = 46.86\%$$

Interlude: A reduction of 46.86% in fines and penalties reflects the company's improved compliance with environmental regulations.

$$\text{TIR } (\%) = (\text{Tax credits} + \text{Tax deductions} + \text{Tax rebates} + \text{Tax exemptions})/(\text{Total tax liability}) \times 100 \quad (29)$$

$$\text{TIR} = ((0 + 0 + 21{,}000 + 9400)/640{,}000) \times 100$$

$$\text{TIR} = 4.75\%$$

Interlude: The TIR of 4.75% indicates additional financial benefits through tax incentives.

Application of Equations (28) and (29) to Equation (30):

Assigning weights $w_1 = 30$ and $w_2 = 70$ to RFP and TIR, respectively, the RCB is calculated as follows:

$$\text{RCB } (\%) = ((\text{RFP} \times w_1) + (\text{TIR} \times w_2))/(w_1 + w_2) \quad (30)$$

$$\text{RCB} = ((48.86 \times 30) + (4.75 \times 70))/(30 + 70)$$

$$\text{RCB} = 17.98\%$$

Interlude: An RCB of nearly 18% indicates that the company has accrued benefits from regulations and compliance, which have contributed positively to the financial performance.

5.8.6. Long-Term Benefits

The Long-term benefits (LTB) assesses the sustainable advantages over the long term, taking into consideration the reduction in compliance risk (CRred) and the eco-friendly material adoption rate (EMR).

$$\text{CRred } (\%) = ((\text{Number of violations before} - \text{Number of violations after})/(\text{Number of violations before})) \times 100 \quad (31)$$

$$\text{CRred} = ((3 - 1)/3) \times 100$$

$$\text{CRred} = 66.67\%$$

Interlude: A CRred of 66.67% demonstrates a substantial decrease in compliance-related risks due to sustainable practices.

$$\text{EMAR (\%)} = (\text{Sustainable material usage}/\text{Total material usage}) \times 100 \quad (32)$$

$$\text{EMAR} = (549/2000) \times 100$$

$$\text{EMAR} = 27.45\%$$

Interlude: The EMR of 27.45% reflects the extent to which eco-friendly materials have been incorporated into the product line.

Application of Equations (31) and (32) to Equation (33):

Combining CRred and EMR with weights $w_1 = 60$ and $w_2 = 40$, the LTB is calculated:

$$\text{LTB (\%)} = ((\text{CRred} \times w_1) + (\text{EMAR} \times w_2))/(w_1 + w_2) \quad (33)$$

$$\text{LTB} = ((66.67 \times 60) + (27.45 \times 40))/(60 + 40)$$

$$\text{LTB} = 10.98\%$$

Interlude: The LTB of over 50% highlights the long-term strategic benefits of sustainability, which are likely to yield continuous improvements and competitive advantages.

5.8.7. Overall Impact

This comprehensive metric is calculated by considering the weighted sum of six different performance indicators. Each indicator reflects a facet of the company's performance related to its sustainable practices. The weights assigned to each indicator reflect their relative importance to the company's overall sustainability goals.

Application of Equations (20), (23), (26), (27), (30), and (33) to Equation (34).

Insert the specific values for each performance index along with their designated weights to compute the OI (here, FPI weight is assigned a value of 25%, while the weight for other factors is set at 15%). This mathematical operation consolidates the varied impacts of sustainability into a singular indicator.

$$\text{OI (\%)} = ((\text{FPI} \times w_{\text{FPI}}) + (\text{MPI} \times w_{\text{MPI}}) + (\text{OEI} \times w_{\text{OEI}}) + (\text{WAIB} \times w_{\text{WAIB}}) + (\text{RCB} \times w_{\text{RCB}}) + (\text{LTB} \times w_{\text{LTB}}))/(w_{\text{FPI}} + w_{\text{MPI}} + w_{\text{OEI}} + w_{\text{WAIB}} + w_{\text{RCB}} + w_{\text{LTB}}) \quad (34)$$

$$\text{OI} = ((17.56 \times 25) + (34.55 \times 15) + (28.40 \times 15) + (-9.45 \times 15) + (17.98 \times 15) + (10.98 \times 15))/(25 + 15 + 15 + 15 + 15)$$

$$\text{OI} = 16.759\%$$

Interlude: The calculated OI of 16.759% places the firm in the "Lagging" category regarding the impact of sustainable product development on its bottom line. This implies that the current financial return from sustainable product initiatives is below what could be considered effective or optimal. It suggests that despite the firm's efforts in sustainable product development, these are not yet significantly contributing to financial performance and that strategic realignments are necessary to enhance the impact on the firm's bottom line.

6. Discussion

6.1. Theoretical Contributions

This research significantly enriches the academic discourse in multiple facets. Primarily, this study fills a significant gap in the current literature by presenting an index tailored to assess the effect of sustainable product development on a company's financial performance. Previous research primarily concentrated on measuring various other dimensions of sustainable product development [16,36,37,100] but did not specifically focus on quantifying its direct impact on a firm's bottom line. Moreover, the study extends beyond mere empirical analysis to provide a conceptual framework that elucidates the pathways through which sustainable product development can bolster a firm's bottom line. By proposing and examining various propositions, this research clarifies the mechanisms by which sustainability initiatives can translate into economic benefits for organizations. Lastly, the study profoundly contributes by deepening the understanding of the broader implications of sustainable product development. It sheds light on how such practices not only enhance a firm's profitability but also foster its adaptability and responsible corporate citizenship. This research, therefore, plays an instrumental role in guiding businesses toward integrating sustainability into their core strategies, thereby aligning economic success with environmental stewardship and social responsibility in the contemporary business milieu.

6.2. Practical Implications

The SPI Index is a valuable tool for corporate decision-making, offering numerous practical implications for businesses striving to balance sustainability with financial performance. Here is how the SPI Index supports corporate decision-making:

Strategic Resource Allocation: By breaking down sustainability impacts into six sub-indices, the SPI Index provides detailed insights into various aspects of sustainable product development. Companies can identify which areas yield the most significant financial benefits or need improvement. This allows for a more strategic allocation of resources, ensuring investments in sustainability are both impactful and financially prudent.

Performance Benchmarking: The SPI Index enables firms to benchmark their performance against industry standards or competitors. This comparative analysis can guide decision-makers in identifying areas where they excel or lag, informing strategies to enhance competitive advantage and sustainability leadership.

Long-term Planning and Goal Setting: Regular monitoring of the SPI Index helps companies track the effectiveness of their sustainability initiatives over time. This ongoing evaluation is crucial for setting realistic and achievable long-term goals regarding sustainability and financial performance.

Risk Management: The SPI Index can also serve as a tool for identifying and managing risks associated with sustainable product development. By highlighting areas where sustainability practices might negatively impact financial performance, companies can proactively address these issues, mitigating potential risks before they escalate.

Investor Relations and Reporting: In an era where investors are increasingly concerned with sustainability, the SPI provides a quantifiable measure of a firm's sustainability efforts. This can be invaluable in communicating with investors, enhancing transparency, and potentially attracting more investment.

Adaptability to Market Changes: The SPI Index makes companies more responsive to market changes. By understanding how sustainability initiatives impact financial performance, businesses can swiftly adapt their strategies in response to evolving consumer preferences and regulatory environments.

6.3. Limitations and Future Research

The SPI Index currently encounters two significant limitations. The first is its reliance on extensive historical data, which can be challenging for companies with nascent sustainability strategies. To mitigate this, we recommend that companies proactively gather relevant data from the inception of their sustainable initiatives, focusing on key metrics that can serve as a baseline for future comparisons. Concurrently, future research should aim to identify and integrate non-historical indicators that are less dependent on extensive historical data, thus expanding the applicability of the SPI.

The second limitation is the SPI Index's inability to adequately reflect the positive environmental impacts resulting from a firm's sustainable product development efforts. This is primarily due to the complexities in uniformly quantifying these benefits. Addressing this requires the development of standardized, industry-specific guidelines for quantifying environmental benefits. Advanced data analytics, life cycle assessment tools, and sustainability reporting technologies can facilitate more accurate and comprehensive assessments of these impacts. Future iterations of the SPI should integrate these elements to capture the environmental contributions of sustainable practices more holistically, thereby enhancing the index's relevance and utility in measuring corporate sustainability performance.

7. Conclusions

This study presents the SPI Index, a comprehensive metric designed to evaluate the impact of sustainable product development on a firm's financial performance. This novel framework integrates various aspects, including financial and market performance, operational efficiency, brand perception, regulatory benefits, and long-term strategic advantages. The SPI Index stands out for its ability to quantify the financial implications of sustainability initiatives, thus aiding businesses in strategic planning and decision-making. By bridging the gap in existing sustainability assessment methodologies, this research contributes significantly to the field, offering a unique and practical tool for measuring and enhancing the alignment between corporate sustainability and profitability. Ultimately, this study underlines the importance of sustainable product development in fostering both environmental stewardship and financial success, guiding companies toward responsible corporate citizenship while maintaining economic viability.

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