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Posted Date: 2 April 2024

doi: 10.20944/preprints202404.0133.v1

Keywords: Sustainability Practices; Life-Cycle Assessment; Product Development Process; Market Performance; Systemic approach.

Article

A Systemic Approach on Product Life Cycle for Product Development Process in Agriculture

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Abstract: For a long time, a company's Product Development Process (PDP) was seen as supporting the operations department, although PDP decisions and mistakes have a considerable impact on market performance. This is critical even in agriculture where bad habits and practices in the PDP can lead rural producers to great losses. Therefore, this research investigated the effect on the market performance of rural products (banana) in the southern region of Brazil, based on two analyses: (i) how sustainability practices support the PDP phases and (ii) how the phases of the Product Life Cycle Assessment (LCA) mediate sustainability practices and PDP phases. This study presents a quantitative analysis using Confirmatory Factor Analysis (CFA) and hierarchical ordinary least squares (OLS) regression of data obtained from a survey of 110 rural producers who directly participate in the banana production and planning process in southern Brazil. Our results shows that sustainability practices support the PDP, and we confirm that the product development and post-development phase has an effect on market performance. In addition, we identified that in the pre-development phase of the PDP, dealing with rural products (bananas), the maturity stage of the LCA mediates sustainability. In the PDP development phase, we concluded that rural families that develop economic and environmental practices with their products in the market growth phase may have reduced results. As for the post-development phase of the PDP, we conclude that when companies invest in environmental and social practices, there is a complete mediation of the effect, where these practices lose strength if the product is in the introduction and maturity phases in the market. As originality, our study contributed to demonstrate value on the product life cycle for the product development process in agriculture using sustainability practices through a systemic approach, filling the gap in the literature due to the lack of research on these areas seen in an integrated way.

Keywords: sustainability practices; Life-Cycle Assessment; product development process; market performance; systemic approach

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1. Introduction

[1], highlight the use of management processes based on a systemic approach in the management of organizations aims at the perception of organizations in a more comprehensive way, integrating the various activities through the verification of the horizontal view of customer satisfaction. In this way, it is possible to obtain relevant insights to improve market performance in companies by analyzing different areas together. In this work, we opted for the theoretical lens of the systemic approach due to the objective of this study to consider different topics of this research, such as the Product Development Process, Life-Cycle Assessment, and Sustainability.

Sustainability is divided into three practices: economic, environmental, and social. [2,3] report that the economic and environmental practices of sustainability have been the most common issues

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in the manufacturing industry, while the social practices have been neglected; their results confirmed these practices. Understanding the relationship between sustainability practices in companies is essential to externalize to decision makers that it is necessary to find a balance between these three pillars. Individually, this task becomes more difficult, so this study proposes the analysis of sustainability interconnected with phases of the product development process (PDP) and Life-Cycle Assessment (LCA), that is, making use of a systemic approach.

As for PDP, [4], organizations from countries that classify themselves as developed usually make use of the innovative aspect of new products as a strategy to circumvent the problem of economic crises or increase their revenues, which consequently contributes to the increase in market performance, from the increase in the product portfolio. [5,6], see that the new business competition is focused on the development of new products; therefore, it forces this area to be dynamic and flexible in organizations [7]. In view of [8,9], they report that the process of developing new products is a risky activity because just as it can converge into a success, being converted directly into profits for the company, it can also be a failure, which implies in lost expenses with investments.

One way to evaluate the PDP is the Life-Cycle Assessment (LCA). LCA is an approach that aggregates all the business processes related to products and allows companies to control all the information of their products throughout the lifecycle, from initial conception until discard [10,11]. LCA is an integrated approach for managing data throughout the life cycle of a product: from specification, design, manufacturing, distribution, and maintenance to recycling [12,13]. By enabling process optimization and integration and reducing costs, LCA can manage the data concerning a product and all the internal and external factors involved in the development of this product. [12] considers LCA as a system that supports the evolution and change of data during the product life cycle.

The globalized scenario of organizations is increasingly competitive, and understanding what actions are necessary to perform internally and externally in companies is not a matter of choice but of survival. This study sought to contribute strategically to increase the market performance of rural producers in southern Brazil. These producers are responsible for the production and trade of the Brazilian banana market. This market stands out for having great social and economic relevance, serving as a source of income for many rural producer families, which allows generating jobs in the countryside and in cities and promoting the development of the regions directly and indirectly involved with this production, whether nationally or internationally [14].

Brazil is the fourth largest banana producer in the world, and annually harvests 7 million tons of the fruit for the domestic market. Currently, the cultivation areas are concentrated in the south, southeast and northeast regions of Brazil. Banana production has an important social role, since this fruit can be produced all year around, which represents benefits for the generation of employment and income for rural producers [15].

From this context, it becomes relevant to assess how the social, environmental, and economic practices of sustainability are associated with the pre-development, development, and post-development stages of banana production with the intention of allowing those involved to achieve greater market performance. In addition, it is important to know how the LCA phases are associated with PDP and sustainability practices to contribute to the market performance of these banana producers. Evaluating these relationships in an integrated way justifies the use of a systemic approach as it allows the dimensioning of the impact on the entire system from the combination and interrelationships of its subsystems to enable effective decision making.

To reach the goal of this research, the following steps were carried out: (i) application of a survey with the banana producers in the southern region of Brazil, then (ii) treating and analyzing the database, (iii) raising hypotheses for the research, (iv) proposing a conceptual model relating the topics of Sustainability, Life-Cycle Assessment, Product Development Process and market performance, (v) apply an econometric study using Confirmatory Factor Analysis (CFA) and hierarchical ordinary least squares (OLS) regression, (vi) validate the hypotheses raised, (vii) apply methods of response bias, endogeneity and robustness to the results, (viii) analyze the main contributions and practical implications.

As a contribution, it was possible to verify how the areas of Sustainability, integrated with PDP and LCA can contribute to lead to a market performance for banana producers. Moreover, a preliminary study was carried out by [16], who carried out a systematic review of the literature to verify relevant papers that addressed the themes of Sustainability, Life-Cycle Assessment (LCA), and Product Development Process (PDP) using construct technique. As a result, no study was obtained in these topics, thus becoming a gap in the literature for carrying out the research.

2. Theoretical Background

2.1. Product Development Process (PDP) and Market Performance

PDP is conceptually defined as the complete process needed to take a product from concept to market availability. It also can introduce an old product to a new market or renew an existing product. This includes identifying a market need, conceptualizing a solution and the product, product development, launching the product, and collecting feedback. Currently, there are several PDP models, they vary in relation to the number of subprocesses or activities for the development, and their stages go through the generation of the concept; the product design; the preparation for the production, and the product launch in the market [6]. Even though the PDP models can be different from one company to another [17], all types of business stand by the fact that demand must be big enough to make creating and launching a new product worthwhile. In other words, the company's decision to meet the need of the final customer is driven by where you are in terms of product lifecycle management.

Regardless of the different approaches to the purpose of PDP, in this context, PDP is approached as one aspect of strategic product planning by incorporating environmental issues into corporate culture and business decision-making for sustainability. The main approaches in the literature on sustainable product development are focused on single products and do not consider product architecture and implications during the stages of use and final disposal [18]. For this reason, there is increasing pressure on the time to the product launch in the market, which come into conflict with the analytical approach normally required when using conventional environmental management accounting (EMA) tools such as Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) [19]. [18], [20,21] say that there are several existing methods focused on improving the sustainability performance of products, and the most frequent topic approach used in product development is Lifecycle Assessment (LCA). LCA is oriented to measure product impacts at all stages of the life cycle, considering the relative importance of specific indicators selected previously [18]. Moreover, rather than focusing on explaining the definition and conceptualization of PDP, this research explains and supports the PDP initiatives and LCA implementation toward improved environmental performance and sustainable market performance.

2.2. Product Life-Cycle Assessment (LCA)

The life cycle of a product comprises all the stages that the product goes through, from its conception to its final disposal after use. In simple terms, the product life cycle stages are introduction, growth, maturity, and decline. References to Product Life Cyclestarted appearing around the beginning of 2000, and since then, the concept has developed as organizations have also had to adapt to this evolution. Life cycle assessment is a technique for assessing the environmental practices associated with a product over its life cycle [21]. The most important applications are these: (i) analysis of the contribution of the life cycle stages to the overall environmental load, usually with the aim to prioritize improvements on products or processes; and (ii) comparison between products for internal use. LCA is a primarily anthropocentric approach focused on processes that occur in the techno sphere (economies and societies) and (even if only partially) in their environment. Therefore, the effects of natural resource consumption are quantified based on the balance between what human activities remove and what remains [22].

Global awareness of product life cycle issues and the competitive advantages of implementing end-of-life recovery strategies, thinking about reuse, remanufacturing, and recycling are prerequisites for more sustainable business actions [23]. [24] compliment by saying that LCA is an analysis technique used to assess the environmental loads of products or production processes. It also aims to compare the potential environmental impacts associated with products, processes, systems, or supply chains throughout their life cycle [24]. Therefore, it is a moment that allows the optimization and integration of processes and cost reduction; In this way, it can manage the data related to a product and all the internal and external factors involved in the development of this product that is, it is seen as a system that supports the evolution and change of data during the product life cycle [25]. In general, LCA deals with the behavior of products and/or services, from their launch to their decline, i.e., it concerns the set of production line stages, which may vary from one product to another, given their characteristics, such as sales, marketing, profit, and so on.

That is why it is important that companies have full knowledge regarding the management of their business, also, about design tools, data warehouse systems, and support systems for the maintenance, repair, and disposal of products [26]. One of these tools is eco-design, which gathers a large amount of design information and covers the product life cycle from the raw material acquisition phase to the recycling and disposal phase in order to predict its effects on the environment [27].

LCA is indirectly concerned with the origins of resources and materials, as provenance can influence the results of the study [28]. Therefore, [29] investigated product life cycle issues and end-of-life recovery management to support product design decision-making by adopting closed-loop material flow. Consequently, LCA considers the aggregative inputs, such as resources and utilities, and undesirable outputs in relation to environmental effects that *span* the entire product life cycle [19]. One of them is product designers, who can quantify the environmental impacts of their designs, selecting the designs that have the most critical factors for developing a green brand [19]. Thus, the Model's emphasis on decision-making is in line with recent developments in the field of sustainability accounting [30,31]. So, one of the premises that can collaborate with sustainability accounting is long-term product design decisions. Product design decisions can significantly affect future financial and environmental performance [32]. Therefore, we must consider information systems, conceptual designs, and time to market, among others, which can collaborate through more accurate, reliable, complete, and relevant information to support the initial stages of product design selection [19].

2.3. Sustainability

It is known that the concept of sustainability, although questioned, worrying, and considered current by many, it is a concern that has persisted since the 70s.Therefore, it is not today that there is a need for an urgent break, facing the challenges of sustainability, because we need, according to [33], to understand that the breach is in the relationships, in the way of thinking, and not only in the technology. That without natural resources, a business will not survive, and we need to get out of our comfort zone and understand that ethical behavior brings economic gains. Aware that this cannot be done just for financial reasons but for the awareness of man's existence and survival.

The discussions about sustainability have been growing day by day since the movements around humanity's awareness of environmental problems and the scarcity of natural resources. As sustainability officially emerged through the World Commission on Environment and Development - WCED, its goal was to disseminate the concept and propose a global agenda to raise this awareness. And several events were taking place, such as: Stockholm (1972), WCED, Copenhagen (1980), the Brundtland report (1987), Rio (1992), the Kyoto Protocol, among others. Whereas, the impacts are masked by substitution agreements or financial compensation, yet the resources are not fully repaid, nor do they guarantee the continuity of humanity. More importantly, concerns are being configured and reconfigured, especially when it comes to decision making. Organizations yearn for sustainable alternatives to maintain their strategic and competitive position. Strategic actions have been developed based on product design. In the last decade, sustainability has become a key emphasis in product design, focusing on the integration of environmental, and social economic concerns [29].

Identifying ways to improve the sustainability of production systems using sustainability assessment tools such as LCA requires a broad set of metrics that demonstrate impacts relative to

 doi:10.20944/preprints202404.0133.v1

planetary boundaries [34]. "Sustainability assessment covers the organization's entire supply chain, including stakeholder interests and end-of-life instructions for products" [35]. Understanding that there is still much to do realize that the environment is not something that serves only to exploit and generate wealth. About the concept of sustainability, [36] states that it does not need to be concerned with the development or the protection of the environment, but what kind of development should be implemented from now on, since after the creation of clean technologies - the new competitive advantage in the market - development and the environment will become complementary. For this reason, the tripod of sustainability is divided from the perspective of three dimensions: environmental, economic, and social.

[36] characterizes the dimensions as: environmental - as a production model compatible with the ecosystem, that is, produces/consumes while maintaining the self-repair capacity or resilience of the ecosystem. The economic - which aims to increase the efficiency of production and consumption, with increased natural resource savings through technological innovation - eco-efficiency. And the last dimension is the social dimension - a sustainable society presupposes that there is social justice and that all citizens have the minimum necessary for a dignified life. Regarding the use of resources, another important point is the life cycle of products, with phases ranging from development (start/design), introduction to the market, product growth and maturity, and product decline. It turns out that every product (good or service) generates some negative impact on the environment, in any of the stages of its existence, from resource extraction, production, distribution, consumption, and post-use. Although the concept of sustainability is advocated from a political perspective, in general, the economic practices is given more significance than the environmental and social practices, the latter often being ignored. This explains the fact that decision-making values business opportunities (economic dimension) and uses environmental capital only in an exploitative way, which in turn "forces" organizations to be environmentally responsible (environmental dimension). If sustainable development initially focused more on the environmental dimension, gradually, obligations concerning the social and economic dimensions were added [35]. Financial and non-financial factors should also be taken into consideration in relation to the costs and benefits of environmental issues. Thus, including quantitative and qualitative data by a broader, cross-company perspective in environmental impact assessment [18].

Therefore, organizations implement various strategies according to the interests of their stakeholders and best practices to make their processes environmentally efficient and socially and economically viable [35]. However, what we have been noticing is a reconfiguration of interests, taking into consideration that the tripod of sustainability, sustainable development, sustainability, and corporate social responsibility are themes that have constantly been growing in current discourses, leading to new goals and strategies to achieve multiple objectives, but involving only one main target - environmental sustainability, counting on the engagement of those involved and focusing on the three dimensions.

Furthermore, PDP is driven by LCA, and sustainability can be considered as a trend in all organizational activities so that when developing products, companies think about economic, social, and environmental practices at all stages of production, with the aim of making the supply chain more sustainable, long-lasting and with possibilities for profit generation. Consequently, Market Performance will depend on the behavior exercised by the company, which must take into consideration the generation and dissemination of information shared by different areas within the organization. The average is crucial to guarantee success, high competitiveness, and profitability.

2.4. Framework-Based Systemic Approach

According to [37] the systemic framework-bases approach is based on systems theory, which consists of a multi and interdisciplinary study of systems and is the process in which one seeks to understand how agents/resources/subsystems influence each other from a macro view of the process. According to the same author, currently, when it comes to international guidelines and regulations, they lead to changes in human activities. Thus, changes in human activities are caused by external forces, such as economic crises or natural disasters.

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One of the principles of the systemic approach, according to [38] is that the whole is greater than the parts. For example, the family is larger than its members. Based on this principle, the systemic approach is interested in the relationships between the most diverse systems and sub-systems to better understand the functioning of the whole. The systems approach was introduced in the mid-1960s and was defined as "an organized and united whole, composed of two or more independent parts, components or subsystems".

From this context, it is understood that a macro view of any system is fundamental, however, understanding the interrelationships and mediations that exist in each sub-system allows improving the efficiency of the system.

In this work, we opted for the theoretical lens of the systemic approach due to the objective of this study to consider different topics of this research, consecrated in the literature, such as Product Development Process, Life-Cycle Assessment and Sustainability. They are completely different areas, which when analyzed together, based on their relationships and connections, it is possible to obtain important insights to improve the market performance of organizations.

3. Hypotheses Development

Our literature review, carried out in the article by [16], on how the areas of sustainability, PDP and LCA contribute to lead to a market performance showed that the literature still lacks a framework that relates these areas using an approach systemic.

Thus, we intend to contribute by showing how these areas are related and how they can increase market performance for farmers in southern Brazil. This is represented in our conceptual model of Figure 1. This Figure 1 illustrates the perspective on how PDP-related sustainability practices contribute to market performance of banana producers. In addition, how LCA can mediate sustainability and PDP practices to allow banana producers a greater competitive advantage in terms of market performance.

The development of the hypotheses of this paper considered the most relevant needs for the interviewees (banana producers), that is, what would be the main contributions that the study could provide to them in terms of planning involving the areas of Sustainability, Life-Cycle Assessment, Product Development Process and Market Performance.

The conceptual model of this research was related as follows:

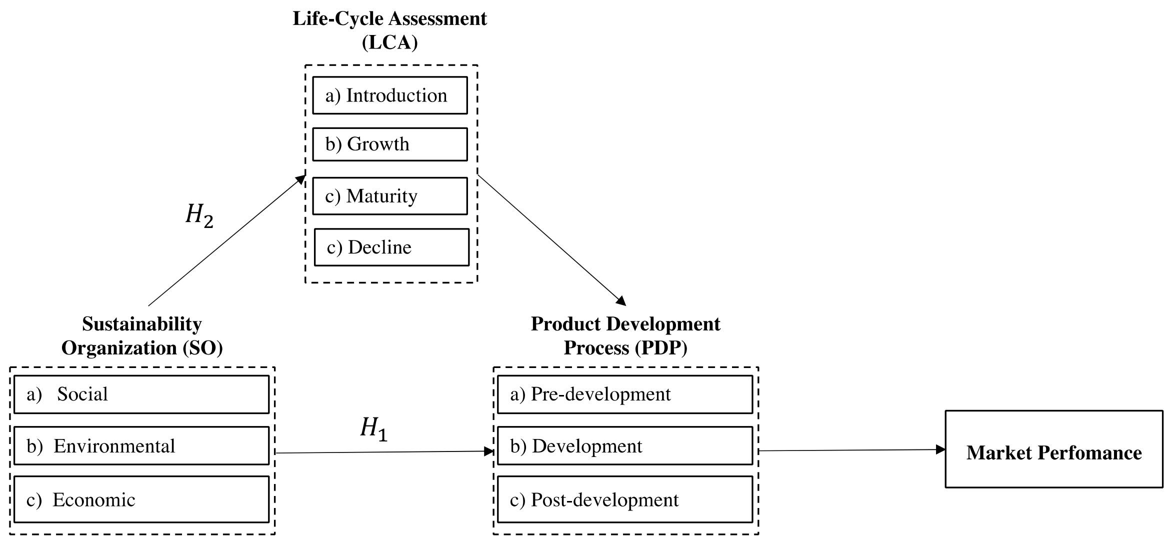

Figure 1. Conceptual framework. Source: Authors.

From the conceptual model, it is possible to raise hypotheses to validate them at the end of the research, using an econometric study, based on the collection of responses from the banana producers interviewed. As previously mentioned, strategic hypotheses were selected to investigate throughout the research. Two hypotheses were raised and presented in the following sections.

3.1. Sustainability Organization and Product Development Process

The literature on sustainability practices and PDP, described in [16], has already recognized the use of these areas for the elaboration of a conceptual model, however, not linked to market performance for rural producers. In this way, we use a systematic approach of these areas to allow rural banana producers to verify how the social, environmental, and economic practices related to the PDP phases are related, leading to an increase in market performance. Thus, we propose the following general hypothesis to represent these three dimensions in the production chain of banana producers:

H1. *Sustainability Organization has a positive association with the Product Development Process (PDP), leading to banana producers to obtain market performance.*

Hypothesis H1 seeks to identify whether there is a positive association between the sustainability construct, involving all its practices: economic, environmental, and social, and the phases of the Product Development Process (PDP) leading the company to a Market Performance. In other words, we sought to investigate which sustainability practices related to the PDP phases, pre-development, development, and post-development, would lead banana producers to obtain efficiency in terms of market performance.

3.2. Life-Cycle Assessment, Sustainability Organization, and Product Development Process

The literature recognizes the use of LCA phases connected to PDP phases, according to [16], however, they do not analyze LCA as a mediator between sustainability practices and PDP phases leading to market performance. We understand that these relationships are important for obtaining competitive advantages from agricultural products, then we formulate the following general hypothesis to represent the possible mediation of LCA between sustainability and PDP.

H2*: Life-Cycle Assessment (LCA) mediates the relationship between Sustainability and Product Development Process (PDP), leading the banana producers to Market Performance.*

Hypothesis H2 seeks to identify whether the phases of the product life cycle can mediate the relationship between sustainability practices and the product development phases, leading the company to market performance. This hypothesis then involves 3 constructs with different variables. The product life cycle (LCA) construct has the phases of introduction, growth, maturity, and decline; the sustainability construct has three practices, economic, environmental, and social; the Product Development Process construct has its 3 phases: pre-development, development, and post-development. With this, we seek to understand whether the LCA phases can mediate sustainability practices with the PDP phases, which promote efficiency in terms of the market performance for banana producers.

4. Research Method

4.1. Sampling

The main interviewees for this study were executives from banana producers in southern Brazil, responsible for managing product planning and development. The banana production market has great socioeconomic relevance, especially after the pandemic scenario resulting from COVID-19, where the world economy went into recession and unemployment levels worsened. In economic terms, the banana production market is an important source of income for several rural families in the South, Southeast and Northeast regions of Brazil. In social terms, this market has the advantage of its production being continuous throughout the year and adaptable to different climatic conditions and soil characteristics, generating employment for several agricultures. Currently, Brazil occupies the fourth position in the world in banana production and according to [39], the amount of banana produced in Brazil was approximately 7 million tons and has growth estimates over the next few years.

During the quarantine, caused by the COVID-19 pandemic, the Brazilian population underwent changes aimed at concerns related to health, safety, and finances [40]. In terms of health, the population started to have a healthier lifestyle and eating habits. According to [15] the banana was the most consumed fruit in Brazil, as it is a versatile fruit, rich in potassium, vitamins, and fiber. In this context, of social-economic impacts and changes in consumption patterns in Brazil, the development of studies related to increasing the performance of rural products (banana) becomes increasingly necessary to guide producers on the relevant aspects that impact on obtaining a competitive advantage in the market.

A survey was then developed online to collect data for the study. Once the research was created, the authors invited researchers and industry experts to test the research. This was done to ensure the face validity, readability, and comprehensibility of the scales, in addition to ensuring that key informants could answer all survey questions. Changes were made to the scales to reflect feedback from participants. Once the changes were made, a pre-test was sent to 12 potential respondents, 100% of whom completed the survey. The response rate for the pretest was total. Modifications were made to the questionnaire based on the pre-test, after which the final questionnaire was applied. In the final survey, 217 producers were contacted and 110 responded, giving a response rate of 50.69 percent.

To pre-qualify respondents, they were asked if their job involved working with PDP. This is because our interviews and discussions with industry experts indicated that producers working with PDP would be able to answer the question in our survey. Only those who indicated working with PDP were invited to respond to the survey.

The questionnaire consisted of 71 questions in total, divided into five main blocks. The first block of questions had a total of 11 questions of a socioeconomic practices. For the construction of the socioeconomic profile, the following aspects were addressed: name and personal contact, if banana farming is their only activity, level of education, if they are registered in the Association of Banana Producers of the Southern region of Brazil, age, number of employees who work directly in the banana plantation and annual revenue. The objective was to know the reality of the respondents and be able to trace their profiles. Blocks 2, 3, 4, and 5 were, respectively, referring to the constructs: Sustainability, Life-Cycle Assessment (LCA), Product Development Process (PDP), and Market Performance.

No specific profile of respondents was selected to reduce bias and increase sample randomization. An endogeneity and self-selection bias test were conducted (section 4.6). The questionnaire was sent five times to respondents via google forms from March 2022 to July of 2022. Our sample, according to Figure 2, is mostly composed of respondents who participate in companies with annual revenue of 100m to 200m (51%), where most have high school complete (32%), 64% still do not participate in the banana producers association, and most are between 20 and 30 years old (25%).

 doi:10.20944/preprints202404.0133.v1

	Description	%
Revenue	More than R$ 200m	19
	Between R$ 100m and 200m	51
	Between R$ 50m and 100m	19
	Between R$ 10m and 50m	6
	Less than 10m	5
Scholarity	Incomplete elementary school	13
	Complete elementary school	22
	Incomplete High School	17
	Complete High School	32
	Incomplete Undergraduate	5
	Complete Undergraduate	11
Participation of the banana producers association	More than 10 years	9
	Between 5 and 10 years	8
	Between 3 and 5 years	4
	Between 1 and 3 years	7
	Less than 1 year	8
	no participation	64
Age	More than 71 years	1
	Between 61 - 70 years	7
	Between 51 - 60 years	16
	Between 41 - 50 years	17
	Between 31 - 40 years	34
	Between 20 - 30 years	25

Figure 2. Sample Composition. Source: Authors.

4.2. Measures and Survey Instruments

The questionnaire was developed based on consolidated constructs in the literature. The constructs were: Sustainability, Life-Cycle Assessment (LCA), Product Development Process (PDP), and Market Performance. The sustainability construct includes issues of economic, environmental, and social practices. The Life-Cycle Assessment construct includes questions about the introduction, growth, maturity, and decline phases of the product. The Product Development Process construct includes questions regarding the pre-development, development, and post-development phases of the product. The Performance construct includes issues related to marketing and operational performance.

The items used in the measurement of each construct and their respective references are shown in Figure 3. In addition, factor loadings were also presented.

For identification, in the sustainability construct, the acronyms SUS1, SUS2, SUS3 were used, referring to the three sustainability practices in the economic, environmental, and social spheres, respectively. For the Life-Cycle Assessment (LCA) construct, the acronyms LCA1, LCA2, LCA3, and LCA4 were used, referring to the phases, introduction, growth, maturity, and decline of the product, respectively. For the Product Development Process construct, the acronyms PDP1, PDP2, and PDP3 were used, referring to the pre-development, development, and post-development phases of the product, respectively. Finally, for the Market Performance construct, the acronym MP was used.

For the sustainability construct, for each economic, environmental, and social practice, five questions were applied for each. However, one question from each group was eliminated after analyzing the loading factor; it did not meet the standard of being greater than 0.5. However, for reasons of resilience and reference in the literature, we chose to remain with a question related to the economic practice, which presented a loading factor of 0.45, as we judged its importance to remain in the analysis. The author who inspired this construct was [41].

For the Life-Cycle Assessment construct, for each phase of introduction, growth, maturity, and decline, five questions were applied. However, one question from each group was eliminated; after analyzing the loading factor, it did not meet the standard of being greater than 0.5. Except for the decline phase, two questions were eliminated. The author who inspired this construct was [42].

For the Product Development Process construct, for each phase of pre-development, development, and post-development of the product, five questions were applied. However, one question from the pre-development phase was eliminated, and for the development and post-development phases, two questions from each were eliminated after analyzing the loading factor not meeting the standard of being greater than 0.5. The author who inspired this construct was [43].

For the Performance construct, for each performance rating, both marketing and operational, five questions were applied. However, one question from each group was eliminated; after analyzing the loading factor, it did not meet the standard of being greater than 0.5. The author who inspired this construct was [44].

For the Market Performance construct, five questions were applied. However, one question was eliminated after analyzing the loading factor, it did not meet the standard of being greater than 0.5. The author who inspired this construct was [44].

Regarding the dependent variable, the Market Performance construct was used. This construct was added as a dependent variable because it seeks to analyze the fulfillment of hypotheses 1 and 2 that lead to marketing performance.

We measured all the questions of the constructs using the Likert scale, which it has a range of 1 (strongly disagree) to 5 (strongly agree).

Only 5 control variables were selected, namely: banana producer, scholarly low, scholarly high, revenue low, and revenue high. All were evaluated with a binary scale [0.1]. For the banana producer control variable, we sought to identify respondents for which banana farming is their only activity. For the control variable on scholarly, the low level represents those who reached elementary school, and the high level represents the respondents who started the undergraduate course. For the control variable associated with revenue, the low level represents receipts up to 50 thousand reais, and the high level is above 200 thousand reais.

Figure 3 presents each item by research construct. Items with factor loadings below 0.5 were not reported except for the item referring to the economic practice of sustainability, which was chosen to remain as mentioned above.

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Items	Factor loadings
Sustainability – Economic (SUS1). (Chakrabarti, 2023).	
We develop practices for crop growth.	0.51
We develop actions aimed at controlling and managing business risks.	0.45
We develop practices to increase planting/cultivation production.	0.67
We have developed practices to optimize processes (e.g., accelerate planting/pest control) in our business.	0.82
Sustainability – Environmental (SUS2) (Chakrabarti, 2023).	
We develop practices in accordance with environmental legislation.	0.56
We have developed practices for product disposal.	0.90
We promote the recovery, conservation, and sustainable management of environmental resources.	0.66
We develop practices for environmental preservation (e.g., less use of pesticides).	0.65
Sustainability – Social (SUS3) (Chakrabarti, 2023).	
We develop practices for social inclusion.	0.53
We develop practices to comply with labor standards.	0.72
We develop practices for occupational health in the field.	0.64
We develop professional management practices and human resources.	0.62
Life-Cycle Assessment - Introduction (LCA1) (Yasunori; Masahiko, 2010).	
We develop economic performance indicators before cultivation.	0.76
We carry out studies of the soils until the harvest of the products.	0.73
We develop a prior market study of the product to be cultivated/that we wish to cultivate.	0.89
We develop studies of the environmental impacts of our harvest (e.g., RIMA).	0.55
Life-Cycle Assessment - Growth (LCA2) (Yasunori; Masahiko, 2010).	
We develop a growth study of our products after the beginning of the process (eg growth in planting/cultivation).	0.68
We develop a follow-up study plan during the growth stage of our products.	0.66
We develop technology investment projects during the growth stage of our products.	0.57
We develop practices to improve the market entry of our products during their growth stage.	0.67
Life-Cycle Assessment - Maturity (LCA3) (Yasunori; Masahiko, 2010).	
We develop innovation practices to ensure the maturity of our product in the market.	0.82
We develop a productivity study of our products.	0.79
We develop a study to improve our products and processes in the maturity stage.	0.66
We develop partnerships for the maintenance of qualified workforce in the maturity stage.	0.63
Life-Cycle Assessment - Decline (LCA4) (Yasunori; Masahiko, 2010).	
We develop practices for the discontinuation of the product in the market.	0.82
We develop analysis of the life cycle of our products after the end of their cycle.	0.79
We develop techniques to prepare for the next generation of products when we notice poor returns in the market.	0.66
Product Development Process – Pre-Development (PDP1) (Ortega; Carlos, 2020).	
We carry out market prospecting for the selection of the product to be cultivated.	0.71
We carry out labor prospecting for cultivation in the initial stage of production.	0.52
We carry out studies of the quality of the soils for the cultivation of the product in the initial stage of production.	0.56
We develop a production method at the initial stage of production.	0.81
Product Development Process – Development (PDP2) (Ortega; Carlos, 2020).	
We develop practices for the standardization of cultivation during its production.	0.71
We develop production processes and means during cultivation.	0.64
We develop good production/cultivation practices during production.	0.62
We develop ways to improve process efficiency during production.	0.68
Product Development Process – Post-Development (PDP3) (Ortega; Carlos, 2020).	
We monitor the consumption of our products after the sale.	0.71
We carry out studies on the reuse of our products after the sale.	0.64
We carry out studies of new markets for our products after the sale.	0.62
Market Performance (MP) (Ortega; Carlos, 2020).	
The response to the market has improved in the last 3 years.	0.76
We have managed to keep it on the market for the last 3 years.	0.57
Customer loyalty has increased in the last 3 years.	0.49
Demand has increased in the last 3 years.	0.71

Figure 3. Measurement Validation. Source: Authors.

4.3. Variable Operationalization, Reliability, and Validity of Measures

To analyze the unidimensionality, a confirmatory factor analysis (CFA) was performed. Our model showed the goodness of fit as the reference values for comparative fit index (CFI), Root mean squared error of approximation (RMSEA), average variance extracted (AVE), composite reliability (CR), and Cronbach's alpha fell in the acceptable values [45], as shown in Figure 4.

Construct	AVE	CR	Alpha	RMSEA	CFI	TLI
Sustainability - Economic (SUS1)	0.40	0.71	0.66			
Sustainability - Environmental (SUS2)	0.49	0.79	0.83	0.070	0.964	0.936
Sustainability - Social (SUS3)	0.40	0.72	0.71			
Life-Cycle Assessment - Introduction (LCA1)	0.55	0.83	0.78			
Life-Cycle Assessment - Growth (LCA2)	0.42	0.74	0.74	0.078	0.951	0.930
Life-Cycle Assessment - Maturity (LCA3)	0.54	0.82	0.84			
Life-Cycle Assessment - Decline (LCA4)	0.51	0.75	0.70			
Product Development Process - Pre-Development (PDP1)	0.43	0.75	0.81			
Product Development Process - Development (PDP2)	0.44	0.76	0.78	0.072	0.971	0.951
Product Development Process - Post-Development (PDP3)	0.66	0.85	0.84			
Performance – Market Performance	0.41	0.73	0.67	0.051	0.985	0.971
Performance – Operational Performance	0.44	0.78	0.78			

Figure 4. CFA Metrics. Source: Authors.

To have consistency in the CFA, it is necessary to pay attention to the metrics: Root Mean Square Error of approximation (RMSEA), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Average Variance Extracted (AVE), Cronbach's Alpha, Composite Reliability (CR) and Factor Loading.

The mean square error of approximation is a parsimony-adjusted index, where values closer to zero represent good fits. The value of RMSEA, typically used, varies between 0.03 and 0.08; thus, it is noted that all values of the constructs are in this range.

The comparative fit index (CFI) compares the fit of a target model with the fit of an independent or null model. Values greater than 0.90 are recommended; thus, it is observed that adherence was obtained for all constructs [46].

The non-normed fit index (TLI) is preferable for small samples and has reference values above 0.90 (BYRNE, 1994) or greater than 95 [47]. Therefore, all constructs showed adherence.

The extracted mean-variance (AVE) is a measure of the amount of variance that is captured by a construct in relation to the amount of variance due to a measurement error. The literature recommends an AVE of up to 0.5. Note that for each item of the construct, the majority had an AVE below 0.5, except for PDP3, LCA1, LCA 3 and LCA4; however, they were close to 0.5. Cronbach's Alpha is a reliability measure that ranges from 0 to 1, with values of 0.60 and 0.70 considered as the lower limits of acceptability. It measures the correlation between answers in a questionnaire by analyzing the answers given by the respondents, presenting an average correlation between the questions [48]. Therefore, it is noted that all items of the constructs are above the lower limit. The Composite Reliability is a measure of internal consistency in the scale items, as well as Cronbach's Alpha [49]. Note that the CR value was adequate as it presents values above 0.70.

Figure 5 presents the correlation matrix between the independent variables of the model. The independent variables are those belonging to the Sustainability, LCA and PDP constructs. As the Performance construct is the response variable, it was not reported in the matrix. The control variables were included in the analysis to verify the existence of a relationship with the variables. The acronyms for the control variables were reported as Control 1, Control 2, Control 3, Control 4, and Control 5, representing, respectively, banana producer, scholarity low, scholarity high, revenue low and revenue high. The independent variables of the constructs were reported as SUS1, SUS2, SUS3, AVC1, AVC2, AVC3, AVC4, PDP1, PDP2 and PDP3, which represent, respectively, Economic, Environmental, Social, Introduction, Growth, Maturity, Decline, Pre- development, development, and post-development.

This figure shows the correlation coefficients for the different variables. It is a powerful tool for summarizing a large dataset and identifying and visualizing patterns in the data provided. The

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relationships that were significant, i.e., had p-values lower than 0.05 or lower than 0.01, were reported in parentheses next to their respective coefficients. In addition, Figure 5, the descriptive statistics of the model were reported, using the techniques of mean and standard deviation. Input values were non-standard values of variables. Data normality was tested by kurtosis and Asymmetry techniques, also reported at the end of Figure 5.

Analyzing the results as the control variables, we can see that Control variable 2 had a negative correlation and significance with control variables 3, 4, and 5. While control variable 4 had a positive correlation and significance with Control variable 3. Control variable 5 had a negative correlation and significance with the LCA1, PDP1, and PDP2 constructs.

The SUS1 construct had a positive correlation and significance with all other constructs except for PDP3. While all other constructs (SUS2, SUS3, LCA1, LCA2, LCA3, LCA4, PDP1, PDP2, and PDP3) showed positive correlation and significance with all others.

Therefore, it was possible to observe how the constructs are strongly correlated when combined pairwise.

The average of the control variables presented values between 0 and 1 due to the nature of the answers being binary. While the mean for the independent variables was around 3, since non-standard values were used, that is, from the Likert scale from 1 to 5. And the construct with the greatest deviation was the LCA3 construct.

The normality of the independent variables was examined using the metrics of Skewness and Kurtosis values. Besides them, there are other methods such as Shapiro-Wilk, Kolmogorov-Smirnov (K-S), and Anderson-Darling (for small samples). The results suggest that our independent variables are normally distributed since all values are between [-2.58, +2.58], which represents 0.01 of significance [45], except for the “Control_4”, however, this will not be a problem since it is a control variable and not a main model variable.

4.4. Response Bias

In order to analyze the consistency of the model, the Harman's test was applied [50] A Harman's post hoc factor analysis is commonly used to see if the variation in the data can be largely attributed to a single factor. Harman's test is used to collect data for both dependent and independent variables. An analysis is performed using EFA on all items of the constructs to verify the total variance. If the total variance extracted by a factor exceeds 50%, common method bias is present in the study [45], [50].

As a result, it was possible to notice that the extracted variance was not greater than 50% (48.9%), thus indicating that there is no presence of multicollinearity in the construct. Therefore, we can conclude that response bias should not be an issue of concern in the study.

4.5. Endogeneity and Robustness Checks

Endogeneity is an issue that we should be concerned about in regression analysis because if the independent variables are not exogenous, they are strongly correlated to the error term. Endogeneity occurs when one or more independent variables are affected by other variables within the model. In addition to bias, another major problem that can arise is inconsistency, in which case our estimates did not converge to the population parameter [51]. It is impossible to eliminate 100% of endogeneity in the model; however, it is possible to mitigate its existence in the econometric model [51].

For the selection of the endogenous variable, it is necessary that it has no direct influence on Y (model dependent variable). Instrumental variables are exogenous variables used in the model to correct other variables that should be independent but are endogenous. Therefore, an instrumental variable is a third variable used in regression analysis when we have the presence of endogenous variables.

To test for endogeneity and self-selection bias we run the two-stage least squares (2SLS) regression approach using Stata 16. We instrument all our independent constructs related to PDP in our model during the hierarchical regression stages. We selected banana producers' operational performance to instrument our independent variables; this variable was chosen because it has no

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direct link to the independent variable on marketing performance. According to the tests, the independent variables showed that our measuring instrument is strong (p-value < 0.05 and the minimum F-value was 9.91, so above 3, as the literature recommends).

ıdent ːs	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Control_1	-														
Control_2	0.139	-													
Control_3	-0.186	-0.321 (p=0.001)	-												
Control_4	-0.106	-0.193 (p=0.043)	0.238 (p = 0.012)	-											
Control_5	0.167	-0.256 (p=0.007)	0.035	-0.170	-										
SUS1	0.167	0.156	-0.138	-0.105	-0.044	-									
SUS2	-0.124	-0.028	-0.020	0.068	-0.138	0.420 (p=0.000)	-								
SUS3	0.028	0.054	-0.019	0.168	-0.172	0.467 (p=0.000)	0.386 (p=0.000)	-							
LCA1	-0.162	0.101	0.009	0.061	-0.225 (p=0.018)	0.398 (p=0.000)	0.627 (p=0.000)	0.607 (p=0.000)	-						
LCA2	-0.131	0.082	0.043	0.098	-0.163	0.367 (p=0.000)	0.444 (p=0.000)	0.638 (p=0.000)	0,.73 (p=0.000)	-					
LCA3	0.075	0.173	-0.032	0.026	-0.171	0.481 (p=0.000)	0.389 (p=0.000)	0.670 (p=0.000)	0.565 (p=0.000)	0.697 (p=0.000)	-				
LCA4	0.036	0.144	-0.027	0.005	-0.179	0.326 (p=0.001)	0.356 (p=0.000)	0.550 (p=0.000)	0.589 (p=0.000)	0.646 (p=0.000)	0,.88 (p=0.000)	-			
PDP1	-0.67	0.120	0.021	0.082	-0.257 (p=0.007)	0.455 (p=0.000)	0.534 (p=0.000)	0.650 (p=0.000)	0.663 (p=0.000)	0.695 (p=0.000)	0.702 (p=0.000)	0.614 (p=0.000)	-		
PDP2	-0.079	0.062	-0.057	0.125	-0.240 (p=0.012)	0.543 (p=0.000)	0.544 (p=0.000)	0.482 (p=0.000)	0.588 (p=0.000)	0.609 (p=0.000)	0.528 (p=0.000)	0.559 (p=0.000)	0.669 (p=0.000)	-	
PDP3	-0.034	0.023	-0.030	0.114	-0.052	0.083	0.248 (p=0.009)	0.286 (p=0.002)	0.429 (p=0.000)	0.276 (p=0.004)	0.415 (p=0.000)	0.373 (p=0.000)	0.255 (p=0.007)	0.111	-
Mean	0.6455	0.3455	0.1636	0.1091	0.1909	3.8295	3.9477	3.6341	3.7614	3.6727	3.7455	3.4606	3.7659	3.8182	2.3697
SD	0.48056	0.47769	0.37164	0.31318	0.39482	0.61324	0.69739	0.85179	0.77325	0.80262	0.9055	0.86733	0.82206	0.7434	0.0856
Skewness	-0.617	0.659	1.844	2.543	1.595	0.019	-0.266	-0.901	-0.962	-1.199	-0.848	-0.522	-0.5	-0.684	0.25
Kurtosis	-1.65	-1.595	1.425	4.547	0.553	0.158	-0.496	1.069	1.256	1.347	-0.066	0.014	0.013	0.942	-1.100

Figure 5. Bivariate Correlation Matrix. Source: Authors.

Therefore, we verified whether the independent variables should be treated as endogenous and would need to be instrumented as proposed in the 2SLS regression model. We performed Stata's stat endogenous procedure using Durbin and Wu-Hausman statistics to assess the consistency of the estimators. The test showed that the hypothesis that the independent variable is exogenous could not be rejected during the regression estimation because all p-values were greater than 0.05.

To ensure the consistency of the model, we perform a robustness check on the model. We performed whether the results of our regression analysis could vary by (i) removing control variables, (ii) including a new construct, and (iii) analyzing individual predictors.

In the first approach, we removed control variables 1, 2, 3, 4, and 5 to check if our predictors are influenced by demographics. We found stable results because they did not show significant changes in the coefficients of our model; in addition, all significance relationships remained the same without the presence of control variables.

For the second approach, we included a construct called Operational Performance that has RMSEA = 0.051, CFI = 0.985, AVE = 0.44, Cronbach = 0.78 and CR = 0.78. The construct items were: (i) Productivity has increased in the last three years (0.76), (ii) Cultivation methods have improved in the last three years (0.56), The production period between start and end (Lead time) has improved in the last three years (0.48), and Harvest assertiveness has improved in the last three years (e.g., we planted 100 and harvested them all) (0.80). We expected to obtain a significant effect of the new construct with the PDP and LCA phases as it associates with the production over the last three years. The approach showed a direct effect of the new construct with the PDP phases and partially with the LCA phases.

The third approach was contemplated by the individual analysis of the relationship of effects between each construct; in Figure 5, we found consistency with our main results. The control variables did not show significance, in general, when compared with the predictor variables. In

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comparing the predictor variables, we found a strong relationship of significance, in general, between them.

4.6. Data Analysis

We performed a hierarchical least squares regression set on the model to test the hypotheses. We normalized our independent variables using a mean-centering Z-score to test for all relationships (Figure 6). In the first stage of the hierarchical regression, we analyzed all the direct effects of the control variables (Control1, Control2, Control3, Control4, Control5) and the sustainability construct in its economic (SUS1), environmental (SUS2) and social (SUS3) practices in the Product Life Cycle in all its phases of introduction (LCA1), growth (LCA2), maturity (LCA3) and decline (LCA4).

In the second stage of the hierarchical regression, we analyzed all the direct effects of the control variables and the PDP in its three phases of pre-development, development, and post-development (PDP1, PDP2 and PDP3).

In the third stage of the hierarchical regression, we analyzed all the direct effects of the control variables, Sustainability, and the LCA on the PDP. In the fourth stage of the hierarchical regression, we analyzed all the direct effects of the control variables, the sustainability variables, the LCA variables, and the PDP variables on market performance. No direct relationship was made from the Market Performance variables because it is a set of dependent variables in the model. Thus, our model has five control variables and ten independent variables.

We checked the assumptions of normality, linearity, and homoscedasticity in our regression analysis. We analyzed normality via Kurtosis and Skewness values. Linearity was investigated by plotting partial regression for the independent variables, while homoscedasticity was visualized by examining standardized residual plots against predicted values. Figure 6 presents the results of the hierarchical regression. Figure 7 presents the effects of mediation. The mediation analyzed in this paper is between the sustainability variables and the PDP variables being mediated by the LCA variables leading to market performance.

To present the mediation of effects, we use Process macro from [52]. To assess the mediation of effects, we calculated the indirect effects of the relationships as suggested by [53]. Process analysis allows us to bootstrap to examine the condition of indirect effects. Bootstrapping is a resampling method used to approximate the normal distribution in the sample to a statistical survey. With this, it allows for calculating the population mean from a sample redistribution (Central Limit Theorem). This is a more robust and powerful procedure than Sobel's z-test for testing the mediation of effects [54]. We set 5,000 bootstrap samples in the sample as [53] suggest.

5. Results

We used ten independent variables divided into the Sustainability, LCA, and PDP constructs in a hierarchical analysis of each model. We performed a model with four hierarchical stages, where the first stage included the analysis of the direct effect of the control variables and Sustainability on the LCA. The second stage included the analysis of the direct effect of the control variables and Sustainability in the PDP. The third stage included the analysis of the effect of the control variables, Sustainability, and LCA on the PDP. And the fourth stage included the analysis of the direct effect between the control variables, Sustainability, LCA and PDP on market performance.

The model's dependent variable was Market Performance, which included four items. From Figure 6 we can see that all models were significant when analyzing the p-value at levels 0.01, 0.05, and 0.1, with R square changing significantly when analyzing the p-value at levels 0.01 and 0 .05 at all stages in the hierarchical process.

As a final result of the step of each model, we had the following metrics: LCA1 construct ($F= 17.548$, $p<0.01$), LCA2 ($F= 11.559$, $p<0.01$), LCA3 ($F= 13.358$, $p<0.01$) and LCA4 ($F=6.878$, $p<0.01$), PDP1 construct ($F=15.558$, $p<0.01$), PDP2 ($F=11.824$, $p<0.01$), PDP3 ($F= 1.755$, $p<0.1$) and the Marketing Performance construct ($F= 4.658$, $p<0.01$). All showed significant values at p-value levels 0.01 and 0.1, as for the F-value, only PDP3 is below 3, the others all showed acceptable values.

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Unstandardized coefficients were reported in Figure 6 because all scale values were standardized with Z-score because they represent standardized effects.

Figure 7 presents the estimates of standardized errors, significance level, and their corresponding lower (LLCI) and upper level (ULCI) confidence intervals. All values found were within the 95% confidence interval, showing the efficiency of the indirect effects of bootstrapping, except in the analysis between SUS3 and PDP2, and SUS1 and PDP3, mediated by LCA, as there was no mediation since they were left out. in the lower and upper range. Finally, Figure 8 summarizes the evaluation of the hypotheses. It is concluded that hypothesis H1 was supported in the research, and hypothesis H2 was partially supported.

Analyzing Figure 6, regarding the first stage of the 12 possible combinations between the constructs in model 02, 8 were significant. Significant relationships were between SUS2, SUS3 and LCA1, SUS2, SUS3 and LCA2, SUS1 and SUS3 and LCA3, SUS2 and SUS3 and LCA4.

As for the second stage of the nine possible combinations between the constructs in model 02, 7 were significant. Significant relationships were between SUS2, SUS3, and PDP1, SUS1, SUS2, SUS3, and PDP2, and SUS2, SUS3, and PDP3.

As for the third stage of the 21 possible combinations between the constructs in model 03, 12 were significant. Significant relationships were between SUS2, SUS3, LCA2, LCA3 and PDP1, SUS1, SUS2, LCA2, LCA4 and PDP2, SUS1, LCA1, LCA2, LCA3, and PDP3. As for the fourth stage of the 14 possible combinations between the constructs in model 04, 7 were significant. Significant relationships were between SUS1, LCA2, LCA4, PDP2, PDP3, and MP.

The F test is a statistical test that is used in hypothesis testing to check whether the variances of two populations or two samples are equal or not. The general significance F test indicates whether the regression model provides a better fit than a model that does not contain independent variables. Analyzing the value of F in the first stage, all models (only level 2 models since it is the combination of model 01 variables) were significant with p-values lower than 0.01. For the second stage, all models (level 2 models only, as mentioned above) were also significant, with the model referring to the variables PDP2 and PDP3 at a level of 0.05, and PDP1 at a level of 0 ,01. For the third stage, all models (level 3 models, as it includes the combination of models 1 and 2) were significant at a level of 0.01. For the fourth stage, the model (model at level 4 only, as it includes models 1, 2, and 3) was significant at the level of 0.01. Therefore, we can confirm that all models were significant when considering the constructs in the big picture.

R square is a statistical measure that represents the proportion of the variance of a dependent variable that is explained by an independent variable. The model with the highest R squared in the sample was in the third stage in the variable PDP1 (0.65), followed by PDP3 (0.60) of the same stage and LCA1 of the first stage (0.58).

The adjusted R squared is a corrected measure of goodness of fit for linear models. As for the ranking of the proportion of explanation of the independent variables, it was the same presented for the R square. In general, no major differences were found between the R-squared and the adjusted R-squared in the models.

Finally, the last metric was the R-changed. It represents how much the model improved with the addition of more predictor (independent) variables in the hierarchical regression. In the first and second stages, with only two models, where model 01 represents the presence of only the control variables, the R-changed was not significant, however, when we add the independent variables, the model becomes significant. In stages 2 and 3, it is noted that in the first models, with only the control variable, the models were not significant; however, from model 02 onwards, when we insert independent variables, the model becomes significant.

With this, all analysis requirements were checked in the database to perform the regression analysis. Finally, multicollinearity was evaluated for our independent variables [45]. To assess the mediation of effects, we calculated the indirect effects of the relationships as suggested by [53]. Figure 7 presents the results.

pendent iable	1st main stage								2nd main stage					
	LCA1		LCA2		LCA3		LCA4		PDP1		PDP2		PDP3	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
ımy01	-0.224	**-0.197(0.000)**	-0.186	**-0.214(0.099)**	0.167	0.090	0.095	0.077	-0.051	-0.074	-0.077	-0.125	-0.073	-0.020
ımy02	0.137	0.155	0.164	0.151	0.262	0.220	0.184	0.177	0.155	0.144	0.016	-0.013	0.067	0.102
ımy03	0.020	0.109	0.084	0.156	0.065	0.151	0.050	0.113	0.091	0.181	-0.163	-0.069	-0.165	-0.127
ımy04	0.075	-0.137	0.198	-0.042	0.089	-0.155	-0.008	-0.244	0.129	-0.084	0.252	0.216	0.441	0.238
ımy05	**-0.343 (0.09)**	-0.110	-0.219	-0.001	-0.335	-0.097	-0.358	-0.155	-0.462**(0.032)**	-0.229	**-0.392(0.045)**	-0.239	-0.042	0.113
1		0.014		0.035		**0.134(0.091)**		0.000		0.090		**0.263(0.000)**		-0.136
2		**0.339 (0.000)**		**0.166(0.0160)**		0.112		**0.153(0.063)**		**0.239(0.000)**		**0.220(0.001)**		**0.217(0.069)**
3		**0.331 (0.000)**		**0.434(0.000)**		**0.497(0.000)**		**0.415(0.000)**		**0.388(0.000)**		**0.124(0.056)**		**0.282(0.022)**
.1														
.2														
.3														
.4														
1														
2														
3														
ılue	1.626	**17.548 (0.000)**	1.080	**11.559(0.000)**	1.223	**13.358(0.000)**	0.980	**6.878(0.000)**	1.680	**15.558(0.000)**	1.628	**11.824(0.000)**	0.398	**1.755(0.095)**
	0.073	0.582	0.049	0.478	0.056	0.514	0.045	0.353	0.075	0.552	0.073	0.484	0.019	0.122
ısted R^2	0.028	0.548	0.004	0.437	0.010	0.476	-0.001	0.301	0.030	0.517	0.028	0.443	-0.028	0.053
ıge in R^2	0.073	**0.509 (0.000)**	0.049	**0.429(0.000)**	0.056	**0.459(0.000)**	0.045	**0.308(0.000)**	0.075	**0.477(0.000)**	0.073	**0.411(0.000)**	0.019	**0.103(0.010)**

andardized beta coefficients are reported. since the main variables were standardized previous to regression.

Independent Variable	3rd main stage									4th main stage			
	PDP1			PDP2			PDP3			MP			
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 4
Dummy01	-0.051	-0.074	-0.041	-0.077	-0.125	-0.078	-0.073	-0.020	-0.032	-0.040	-0.126	-0.073	-0.052
Dummy02	0.155	0.144	0.043	0.016	-0.013	-0.073	0.067	0.102	-0.094	0.037	-0.015	-0.018	-0.004
Dummy03	0.091	0.181	0.101	-0.163	-0.069	-0.122	-0.165	-0.127	-0.231	-0.066	-0.028	-0.045	-0.021
Dummy04	0.129	-0.084	-0.019	0.252	0.216	0.271	0.441	0.238	0.438	0.142	0.182	0.130	0.053
Dummy05	**-0.462(0.032)**	-0.229	-0.192	**-0.392(0.045)**	-0.239	-0.211	-0.042	0.113	0.276	0.047	0.080	0.039	0.079
SUS1		0.090	0.051		**0.263(0.000)**	**0.271(0.000)**		-0.136	-0.218*		**0.243(0.000)**	**0.217(0.000)**	**0.182(0.001)**
SUS2		**0.239(0.000)**	**0.149(0.028)**		**0.220(0.001)**	**0.155(0.019)**		**0.217(0.069)**	-0.063		-0.039	-0.027	-0.068
SUS3		**0.388(0.000)**	**0.141(0.063)**		**0.124(0.056)**	-0.043		**0.282(0.022)**	-0.082		0.032	0.006	0.000
LCA1			0.054			-0.026			**0.703(0.000)**			-0.050	-0.108
LCA2			**0.166(0.075)**			**0.237(0.010)**			**-0.492(0.004)**			**0.201(0.010)**	**0.178(0.026)**
LCA3			**0.211(0.035)**			-0.120			**0.612(0.001)**			0.123	0.066
LCA4			0.038			**0.243(0.004)**			-0.012			**-0.268(0.000)**	**-0.313(0.000)**
PDP1													0.114
PDP2													**0.124(0.063)**
PDP3													**0.086(0.085)**
F-Value	1.680	**15.558(0.000)**	**15.448(0.000)**	1.628	**11.824(0.000)**	**12.122(0.000)**	0.398	**1.755(0.095)**	**4.186(0.000)**	0.199	**3.829(0.001)**	**4.686(0.000)**	**4.685(0.000)**
R^2	0.075	0.552	0.656	0.073	0.484	0.600	0.019	0.122	0.341	0.009	0.233	0.367	0.428
Adjusted R^2	0.030	0.517	0.614	0.028	0.443	0.550	-0.028	0.053	0.260	-0.038	0.172	0.289	0.336
Changed in R^2	0.075	**0.477(0.000)**	**0.104(0.000)**	0.073	**0.411(0.000)**	**0.116(0.000)**	0.019	**0.103(0.010)**	**0.219(0.000)**	0.009	**0.223(0.000)**	**0.134(0.001)**	**0.061(0.023)**

Figure 6. Results of Regression Analysis. Source: Authors.

Interactions (LCA as mediators)	Bootstrap outcome			95% confidence interval		Total and direct effects	Sig.	Conclusion
	Mean	SD	Sig.	LLCI	ULCI			
SUS1-> LCA1 -> PDP1	0.0833	0.0438	0.0126	0.0044	0.1757	Total Effect	0	
SUS1 -> LCA2 -> PDP1	0.605	0.0382	0.0735	-0.0084	0.1447			Complete
SUS1 -> LCA3 -> PDP1	0.1373	0.0557	0.0033	0.0362	0.255	Direct Effect	0.1482	
SUS1 -> LCA4 -> PDP1	0.0071	0.0369	0.7996	-0.0625	0.0882			
SUS2 -> LCA1 -> PDP1	0.078	0.0642	0.1174	-0.047	0.2087	Total Effect	0	
SUS2 -> LCA2 -> PDP1	0.0807	0.0444	0.0464	0.0062	0.1802			Partial
SUS2 -> LCA3 -> PDP1	0.1192	0.0443	0.0007	0.0377	0.2099	Direct Effect	0.017	
SUS2 -> LCA4-> PDP1	0.0063	0.0371	0.8325	-0.0577	0.0923			
SUS3 -> LCA1 -> PDP1	0.1184	0.0573	0.0194	0.0062	0.234	Total Effect	0	
SUS3 -> LCA2 -> PDP1	0.085	0.0643	0.1449	-0.0284	0.2248			Partial
SUS3 -> LCA3 -> PDP1	0.1771	0.0708	0.0062	0.0327	0.3121	Direct Effect	0.0468	
SUS3 -> LCA4 -> PDP1	0.0081	0.0602	0.862	-0.0951	0.1414			
SUS1-> LCA1 -> PDP2	0.0389	0.0473	0.2353	-0.0394	0.1497	Total Effect	0	
SUS1 -> LCA2 -> PDP2	0.0796	0.0408	0.0184	0.0096	0.1656			Partial
SUS1 -> LCA3 -> PDP2	-0.059	0.056	0.197	-0.1735	0.0521	Direct Effect	0	
SUS1 -> LCA4 -> PDP2	0.0738	0.0462	0.0091	0.0009	0.1799			
SUS2 -> LCA1 -> PDP2	0.0063	0.0878	0.9162	-0.1394	0.208	Total Effect	0	
SUS2 -> LCA2 -> PDP2	0.1004	0.0482	0.0186	0.0173	0.2034			Partial
SUS2 -> LCA3 -> PDP2	-0.0044	0.0422	0.9026	-0.0895	0.0766	Direct Effect	0.0007	
SUS2 -> LCA4 -> PDP2	0.0673	0.0487	0.0336	-0.0028	0.1841			
SUS3 -> LCA1 -> PDP2	0.1014	0.0732	0.0671	-0.0412	0.2484	Total Effect	0	
SUS3 -> LCA2 -> PDP2	0.1145	0.0715	0.0748	-0.0167	0.2658			
SUS3 -> LCA3 -> PDP2	0.0078	0.0798	0.9112	-0.1449	0.1684			No mediation
						Direct Effect	0.6065	
SUS3 -> LCA4 -> PDP2	0.0932	0.0725	0.0704	-0.238	0.257			

Figure 7. Indirect effects (bootstrapping outcome). Source: Authors.

Analyzes of the Sustainability constructs were carried out, in all its practices, economic (SUS1), environmental (SUS2) and social (SUS3), and the PDP construct, in all its phases, pre-development (PDP1), development (PDP2) and post-development (PDP3), being mediated by the LCA construct, in all its phases, introduction (LCA1), growth (LCA2), maturity (LCA3) and decline (LCA4), generating a total of 36 combinations.

The first combination between SUS1 and PDP1 being mediated by the LCA construct in all its phases, significance was obtained only in the combinations, [SUS1-> LCA1 -> PDP1] and [SUS1 -> LCA3 -> PDP1], as they presented significant p-value and the zero point it is not included in the lower (LLCI) and upper (ULCI) confidence level ranges. However, when analyzing the direct effect of the combinations, it is observed that the p-value was not significant, which is concluded as complete mediation since the direct effect of the variable x was not significant, and the mediation was significant. The same analysis was repeated for the other combinations.

It is important to highlight that two groups did not present any mediation, namely: the combinations of SUS3 and PDP2 being mediated by LCA in all its phases (LCA1, LCA2, LCA3, LCA4) and the combinations of SUS1 and PDP3, being mediated by LCA also in all its phases. Finally, Figure 8 presents the results of the hypotheses and the research conclusions.

Hypotheses	Outcome	Supported relationship
H1: Sustainability Organization -> Product Development Process (PDP)	supported	SUS1 -> PDP1 (B=0.090, P=0.396), SUS1 -> PDP2 (B=0.263, P=0.000), SUS1 -> PDP3 (B=-0.136, P=0.286), SUS2 -> PDP1 (B=0.239, P=0.000), SUS2 -> PDP2 (B=0.220, P=0.001), SUS2 -> PDP3 (B=-0.217, P=0.069), SUS3 -> PDP1 (B=0.388, P=0.000), SUS3 -> PDP2 (B=0.124, P=0.056), SUS3 -> PDP3 (B=-0.282, P=0.022).
H2: Sustainability Organization -> Life-Cycle Assessment (LCA) -> Product Development Process (PDP)	Partially Supported	SUS1 -> LCA1 -> PDP1 (P=0.0126) SUS1 -> LCA3 -> PDP1 (P=0.033) SUS2 -> LCA2 -> PDP1 (P=0.0464) SUS2L -> LCA3 -> PDP1 (P=0.007) SUS3 -> LCA1 -> PDP1 (P=0.0194) SUS3 -> LCA3 -> PDP1 (0.0062) SUS1 -> LCA2 -> PDP2 (P=0.0184 SUS1 -> LCA4 -> PDP2T (P=0.0091) SUS2 -> LCA2 -> PDP2 (P=0.0186) SUS2 -> LCA1 -> PDP2 (P=0.0004) SUS2 -> LCA2 -> PDP3 (P=0.0071) SUS2 -> LCA3 -> PDP3 (P=0.0008) SUS3 -> LCA1 -> PDP3 (P=0.0002) SUS3 -> LCA2 -> PDP3 (P=0.0117) SUS3 -> LCA3 -> PDP3 (P=0.0084)

* It was possible to conclude that hypothesis 1 was supported in this study, however, as for hypothesis 2, it was partially supported. In the next section (Discussion) the main insights of the results of the hypotheses in it were specified.

Figure 8. Hypotheses Evaluation. Source: Authors.

6. Discussion

The literature does not focus on carrying out a systemic approach to the areas of PDP, LCA and sustainability and how these relationships can contribute to market performance in case of rural producers in southern Brazil.

The existing literature on sustainability has focused on evaluating the three sustainability practices (economic, environmental, and social) in business development without considering aspects of product development or even the phases of the product life cycle [16]. It is possible to notice these gaps in [55] who evaluated the relationship between national participations of green entrepreneurial activity and sustainability practices. Also, in [56] who explored the relationship of sustainability reporting with corporate reputation in the context of public policies and in [57] who analyzed the relationship between information technology and sustainability practiced by G-7 economies. Therefore, it is noted that this study aimed to fill this gap between developing an empirical analysis of sustainability practices and the PDP and LCA. Although our study is aimed at an analysis of obtaining market performance of rural producers in the southern region of Brazil, it is possible to contribute, in terms of theoretical and empirical progress, by analyzing in an integrated way these three important areas for the development of market performance.

The existing literature on PDP also presents a gap in terms of integration with the areas of Sustainability and the phases of the LCA [16]. This becomes evident in [58] who analyzed the relationship of Lean practices in the assembly of factories with the product development process and the information technologies used. Also, in [59] who investigated the impact of product customization on the perceived satisfaction of the sellers' relationship and on the subsequent expectations of relationship continuity.

This gap becomes more worrying when [16] investigated the literature on LCA, since most papers related to this area do not portray the importance of product development and its environmental impacts throughout its life cycle. The focus of the literature on LCA was focused on the application of economic factors, that is, only the economic practice of sustainability. To exemplify this drawback in the literature, [60] applied a cost and life cycle assessment to estimate the economic costs of gasoline generators used to generate electricity in urban areas of Sub-Saharan Africa. Therefore, previous studies focus on evaluating these areas separately and not integrated from a systemic approach, in this way, this study contributed to further expand the application of empirical methods associated with an integrated view of the areas of sustainability, PDP and LCA and how they drive market performance.

In the study, we identified that hypothesis H1 ("Sustainability has a positive association with the Product Development Process (PDP) leading the company to Market Performance"), was supported from quantitative analysis using CFA and least squares regression (OLS) hierarchical, for sustainability in socio-environmental practices at all stages and for the three pillars of the PDP in the development stage. Therefore, this means that sustainable practices support product development (presented in the 2nd main stage) and, later, we confirm that the development and post-development phase influence market performance (presented in the 4th main stage). We also identified that this makes sense, as the pre-development phase is the product planning stage that has no direct effect on the market performance of rural producers. The development phase concerns production and the post-Development phase deals with customer contact and maintenance, having a direct relationship with market performance. With this, we conclude that H1, in general, was supported. We had only one exception for economic practices in the pre-development and post-development phase of rural products.

As for hypothesis H2 ("Life cycle assessment (LCA) mediates the relationship between Sustainability and Product Development Process (PDP) leading the company to Market Performance"), we identified that in the pre-development phase of the PDP, dealing with of field products (bananas) the LCA maturity stage mediates sustainability. While economic practices are fully mediated, environmental, and social practices are partially mediated. We conclude that rural families that develop sustainable practices may have reduced results in the replanning of their products if these products are already at a mature stage in the market. The same phenomenon can be observed for economic and social practices in the product introduction stage and for environmental practices in the growth stage. In addition, we identified that in the PDP development phase, we concluded that rural families that develop economic and environmental practices with their products in the market growth phase may have reduced (but still significant) results if their product is in the development phase. The same is true for economic practices in the Decline phase. As for the post-development phase of the PDP, we concluded that when companies invest in environmental and social practices, there is a complete mediation of the effect, where these practices lose strength if the product is in the introduction and maturity phases in the market. This fact can be confirmed in the day-to-day of organizations, as only economic practices are relevant to performance and this means that with these stages in which the business is still incipient or is mature in the market, they end up reducing the socio-environmental effects. On the other hand, when the product is in the growth phase in the market and the families are dealing with post-development, we have a complete competitive mediation, that is, the sign of the growth effect is inverted (negative), this means that if the families develop socio-environmental practices in the growth phase, and will be mediated by this phase which, consequently, will bring negative results in post-development. As the product post-development stage is mainly related to after-sales, the development of socio-environmental practices during this stage can lead to higher costs for rural producers, which may have undesired (negative) results in after-sales practices. Therefore, we conclude that hypothesis H2 was supported in the maturity phase mediating sustainability in economic, environmental, and social practices and in the pre-development phase. It was also supported in the introductory phase by mediating environmental and social and pre-development practices. In addition, it was possible to observe that it was supported in the growth phase mediating environmental practices and in the pre-development

 doi:10.20944/preprints202404.0133.v1

phase. We can see that H2 was also supported in the growth phase mediating economic and environmental practices, and in the development phase. In addition, we had support for H2 in the decline phase mediating economic practices and in the development phase. Finally, this hypothesis was also supported in the introduction, growth, and maturity phase, mediating the environmental and social practices, and in the post-development phase.

In summary, this study empirically contributed to show rural producers (bananas) that hypothesis H1 was supported in the research and hypothesis H2 was partially supported, allowing them to manage their activities in a strategic and competitive way in the rural market.

7. Conclusions

Our study consolidated a theoretical model through an empirical validation of Sustainability, LCA, PDP and Market Performance. As a contribution to the academy, according to [16] it was observed from the systematic review of the literature that there are no articles referring to an analysis using the systemic approach based on frameworks between the areas of Sustainability, LCA, PDP and Market Performance of banana producers in southern Brazil.

A Post Hoc test was performed to validate the positive association of the hypotheses of this research through robustness analysis and endogeneity test. We also demonstrate that sustainability practices have a positive association with the phases of the Product Development Process. Furthermore, we saw that the LCA phases partially mediate the Sustainability constructs and the Product Development Process phases that lead to the Banana producers' Market Performance.

The results presented are directly related to the theoretical lens that was used in this research on the systemic approach based on frameworks. Different areas of research were analyzed, which we can understand as subsystems, according to the principle of this theoretical lens, where the objective was to understand how they are related and how together they can improve the marketing performance of rural producers in the banana sector in Brazil, contradicting what has been observed in recent years regarding an isolated analysis of the PDP seen only as an operations support department, where we know that decisions and mistakes in the PDP have a direct impact on the performance capacity in organizations.

Our study contributions to the sustainable development goals (SDG) proposed by the 2030 Agenda for Sustainable Development of the United Nation [61]. The ONU and its partners work to achieve their sustainable development goals, composed of 17 ambitious and interconnected goals, which envision the main challenges to achieve the development of partner countries and, consequently, the world. In summary, the goals represent a call for the world to develop actions that end poverty, protect the environment and climate, and bring peace and prosperity to people.

Our study is directly related to objective 12, which deals with “Responsible Consumption and Production”, more specifically items 12.2 and 12.6 which deal, respectively: “By 2030, achieve sustainable management and efficient use of natural resources” and “Encourage companies, especially large and transnational companies, to adopt sustainable practices and integrate sustainability information into their reporting cycle.” It was identified in our study that sustainable practices help in product development and the stages of development and post development of the product have a direct effect on the market performance of banana producers.

Our study has the limitation of considering only rural banana producers in the southern region of Brazil, however, according to [61] 70% of the sum of products and services generated by agribusiness come from the agricultural sector. Although banana production has growth projections for the coming years, other branches could be explored in terms of research. Therefore, our study is a first step towards expanding this analysis in the agricultural field in future studies.

Furthermore, we suggest analyzing the introduction of new constructs and verify the other hypotheses and relationships that can influence the dependent variable of market performance. In addition, analyze the introduction of moderating variables in the construct and analysis of structural equations with information in neural networks.

Author Contributions: Conceptualization, Lourenço, F. and Gonçalves, M. C; methodology, Dias, I., Canciglieri Junior, O.; validation, and Benitez, G.; formal analysis, Benitez, G.; investigation, Gonçalves, M. C.; resources, Nara, E.; data curation, Lourenço, F.; writing—original draft preparation, Gonçalves, M. C,; writing—review and editing, Dias, I.; visualization, Dias, I.; supervision, Nara, E. and Canciglieri Junior, O; project administration, Nara, E. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Fundação Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) and Pontifícia Universidade Católica do Paraná (PUCPR).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: Not applicable.

Conflicts of Interest: The authors declare no conflicts of interest.

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