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Driving Sustainability in Dairy Farming from a TBL Perspective: Insights from a Case Study in the West Region of Santa Catarina, Brazil

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Abstract: All companies in agribusiness supply chains need to be aware of the best use of available resources, which demands an integrated assessment of environmental, economic and social aspects, i.e., the Triple Bottom Line (TBL). Such analysis allows us to get a more balanced and complete understanding of the real performance of companies, supply chains and industries. Companies in the upstream of agribusinesses supply chains present some limitations, but can contribute significantly to the overall sustainability of the entire value chain. The objective of this research was to understand the role of the drivers of sustainability in dairy farming from a TBL perspective, such as assistance to producers and the value chain, and the use of better technology and management practices. A sample of 54 rural farms in the dairy supply chain of the western region of Santa Catarina, Brazil, was used to test four hypotheses about what can drive sustainability. Furthermore, first- and second-order structural equation models using SMART PLS software were used for the analysis of the data. The results obtained show that social sustainability is positively influenced by the use of good management practices, and the latter, as well as public policies, positively influence economic sustainability. Furthermore, it was found that improvements in production techniques positively influence environmental sustainability, and this is mostly influenced by the use of good management practices, and less so by policies directed at the supply chain. Finally, from the analysis of the second-order variable for sustainability, it was highlighted that the economic dimension prevails in the eyes of the farmers, as the main dimension of sustainability, and that environmental aspects are still neglected.

Keywords: sustainability; Triple Bottom Line (TBL); agribusiness; dairy farming; structural equation model; Brazil; survey

1. Introduction

The increase of global demand and production raises concerns about achieving an economically and environmentally sustainable food supply. The growth of the human population, and consequently the increase in the demand for food, has made agriculture a dominant form of land exploitation,

which has evolved towards a series of agribusinesses characterized by high levels of productivity in globalized markets and supply chains. Furthermore, the high demand and the growing intensity of agriculture have been causing a series of changes in the production chain, with the aim of providing speed in the production processes [1]. Such pressure on land resources impacts not only on the agricultural sector, but also on the society and the environment [2].

As a result, sustainable development has roused the interest of practitioners and researchers from different fields of study and industries [1,2] specifically in terms of new product development [3], manufacturing industries [4], trade-offs between sustainable development goals [5], development of trading [6] and logistics services [7], innovation in new services [8] and customer service [9]. Sustainable development practices are a major challenge [10], because the inherent multidisciplinary nature of this issue requires integration and balance among environmental, social and economic dimensions [2].

Sustainable development in agriculture requires the use of production methods, through the entire supply chain, which should be environmentally friendly and socially responsible, without compromising customers' requirements and expectations, or the business' long-term economic sustainability [11]. Thus, there are many objectives to be achieved, such as long-term profit with good use and preservation of natural resources, high levels of productivity through optimized supply chains and minimal impact through negative externalities, and satisfaction of the customer's needs and producers' expectations, namely farmers and companies in rural communities, balancing in a sustainable way demand and supply [12,13].

This complexity asks for an effective measurement of performance in the agribusiness, that will consider the different dimensions of sustainability [10]. However, there is a lack of performance measures and performance models that fully meet the three dimensions of sustainability [4]. Most of the indicators found in the literature are flawed, and the existing research on the agricultural sector is essentially related to economic aspects. In addition, regional and local particularities should be considered in such performance measurement models [14]. There are some studies, mainly in developed countries, especially in Europe and the United States [4], but there is a need for additional research to incorporate regional, cultural, economic, political and governmental factors of different locations and contexts, in developing countries in particular [15]. Indeed, it is necessary to assess sustainability while taking into consideration specific regional issues.

In this research project, the sustainability of dairy farming in the western region of Santa Catarina, Brazil, was analyzed considering the Triple Bottom Line (TBL) perspective. This region has 21 municipalities over a territorial extension of 2955 square kilometers, and has more than 300 thousand inhabitants. It is a region composed predominantly of small rural family companies. Brazil is one of the largest producers of cow's milk in the world; in 2016 it was responsible for 5.3% of the total world production, followed by China (6%), India (8.6%), and the United States (14.7%) [16]. There are production units spread across the country, employing more than 3 million people through the supply chain, and this accounts for approximately 20% of the country's agribusiness GDP [17]. The production of 35 billion liters in 2019, together with the goal of reaching 41 billion liters by 2023, makes milk an important product for the Brazilian economy [18].

Indeed, milk production in Brazil doubled between 2000 and 2010, reaching 2.44 billion liters, and the State of Santa Catarina has become the fourth-largest producer of milk in Brazil [19]. This increase is justified by the increase in the number of lactating cows, and the migration of small producers of poultry and pigs who suffered from economic crises in such sectors. Small properties are responsible for 87% of the milk produced in Santa Catarina, which is the main source of income for more than 50 thousand families [19]. The western region is responsible for more than 70% of the production of the State of Santa Catarina, and approximately 40 thousand families depend exclusively on the income generated by the dairy activity [20]. Thus, its social impact is considerable.

Nevertheless, it is worth noting the lack of research in the context of milk producers and rural farming. This is especially relevant because the dairy supply chain generates a significant number of jobs and a significant amount of income, being fundamental for the economy of the entire region,

and has been contributing to inhibiting the rural exodus. Indeed, the milk (and its derivatives) supply chain is very important and interesting because it plays an important role in the supply of food for the population, and generates jobs and income to the region, particularly the low density and rural areas [21].

In this particular context, the sustainability assessment is relevant to measuring the social, economic and environmental impacts of dairy farming, making it possible to design, implement and evaluate effective and efficient strategies that consider all the actors involved from multiple perspectives [22,23]. The remaining content of the paper is as follows. Section 2 presents the main concepts that made it possible to design the research construct, and establish the different hypotheses tested through the structural equation models. Section 3 explains the methodological aspects of the research. The results and findings are presented in Section 4. Finally, Section 5 aims to provide some discussion of the findings, as well as to highlight the main conclusions and opportunities for further research.

2. Drivers and Dimensions of Sustainability

The assessment of agricultural sustainability asks for the development of constructs that highlight the different dimensions and drivers of sustainability [24]. Furthermore, the impact of such drivers must be measured and understood in order to develop a good knowledge of this phenomenon within each particular context, namely, we must consider the different industries, supply chains and locations. Thus, in this research, the role of different drivers of sustainability in dairy farming activities, found in the literature, was evaluated through a set of hypotheses and the use of a structural equation models.

The sustainability of dairy activity is closely linked to the dimensions of sustainability discussed in the literature, i.e., economic, social and environmental. Family farming is very important in this context because it represents a significant amount of labor in rural areas, using balanced production practices with less industrial inputs, and consequently generating less harmful liabilities to the environment [25]. However, the drivers of sustainability in rural activities encompass a series of demographic, natural, socioeconomic, political, institutional and management factors [26].

Rural sustainability asks for political initiatives that promote effective dialogue between rural producers and policy tools, in terms of regulation and the use of economic instruments, among other public policies that benefit agricultural activity [27]. Moreover, the use of innovative technologies can promote changes in production which may significantly help agricultural sustainability [28]. Indeed, sustainable agriculture practices are commonly considered to exist when the rural producer uses improved production techniques and practices that promote a more effective consumption of inputs [29]. Additionally, [30] indicates that there is a need for greater awareness in small- and medium-sized rural producers regarding the benefits that management practices can bring to the success of their activities. For instance, [31] proved that the existence of some formal management processes (e.g., strategic planning and more robust management control systems) contributes to the financial sustainability of small rural properties.

In this sense, it is necessary to understand the role and behavior of the drivers of sustainability, and their impact on the different dimensions of sustainability, to develop effective public policies for agriculture [26]. Some drivers proved to be prevalent in the sustainability of agricultural activities, such as public policies [26,27], improvements in production techniques [28,29], and management practices [26,30,31]. Thus, these aspects becoming important factors to be researched.

2.1. Dimensions of Sustainability

Sustainability must be understood from a multidimensional perspective, namely, from three fundamental dimensions: economic, social and environmental [13]. Sustainability means taking into account people, the planet and profit [32], or in other words, the social dimension, the environment and the economy [33]. These dimensions, called the Triple Bottom Line, have been widespread and accepted as the main pillars of sustainability assessment [32].

A study of global livestock production systems points out that in the future, production will be increasingly affected by the competition for natural resources, particularly land and water, as well as food competition in the context of a carbon-constrained economy. For instance, the demand for beef products may be strongly moderated by environmental and socioeconomic factors, such as concerns about human health, green production systems, and changes in socio-cultural values [34].

Global livestock production has increased substantially since the 1960s, with dairy production standing out. In 2019, global milk production reached 852 million tons. In South America, milk production was estimated at 61.8 million tons in 2019 [35]. The increase in milk production, combined with concerns about the sharp growth in global demand [36], raises concerns about achieving an economically and environmentally sustainable food supply. Thus, farmers are pushed to use production systems and practices that make the best use of available resources from an economic perspective, but that also minimize the potential environmental and social impact of the entire supply chain [37]. Indeed, sustainability also includes social values and social impacts [37].

Thus, the TBL presents an integrated assessment that considers relevant environmental, economic and social aspects. This allows for a more balanced and more complete understanding of companies' performances. These concepts were devised by John Elkington in the mid-1990s, and are related to a construct that expresses the relevance of the environmental agenda in order to integrate economic, social and environmental dimensions into the traditional measurement of business performance [32]. In general terms, the TBL model suggests that organizations consider, in addition to short-term financial results, the impact on environmental resources for future generations.

The economic pillar is fundamentally reflected in the organization's financial results [32]. The understanding of the economic pillar implies considering physical, financial, human, and intellectual capital, in the short and the long term, but other concepts, such as social and natural capital, can also be included [32]. Economic sustainability enables the efficient use and management of production resources, as well as an effective flow of public and private investments [38]. As such, economic sustainability also encompasses an efficient allocation and distribution of natural resources [22] from an economic perspective [33].

The social pillar is related to the search for greater fair income distribution, in a way that favors social inclusion, decent life, and generalized access to social resources and services [22]. Social sustainability deals with the consolidation of processes that promote equity in the distribution of goods and income, in order to substantially improve the rights and conditions of most of the population, reducing the differences between people's living standards [38]. The social pillar highlights social well-being, envisioning the reduction of social inequalities through, for example, the empowerment of women and minorities [32].

The environmental pillar is focused on eco-efficiency, which means the supply of goods and services at competitive prices, satisfying human needs and providing life quality, at the same time as an effort being made to progressively reduce—to a level that is bearable for the planet—the ecological impacts and intensity of resource consumption, considering the product's entire life cycle [32]. The environmental dimension refers to actions that prevent damage to the environment, such as reducing the emission of pollutants and preserving biodiversity, and replacing the consumption of non-renewable resources by renewable ones [38]. Environmental sustainability can be achieved through the preservation or recovery of the planet's resource capacity, through socially just and economically viable technological developments, applying restrictions to the consumption of fossil fuels, the reduction of the volume of waste and pollution, as well as the reduction and optimization of consumption by industrialized countries [32,33].

2.2. Public Policies and Assistance to Producers

Although local governments may not interfere directly in global markets, they have a fundamental role in global food production, working with small producers to ensure sustainability and social inclusion through public welfare policies [39]. Combined with public incentive policies,

the strengthening of the agricultural production chain asks for partnerships between public and private organizations, universities and non-governmental organizations, companies and non-profit organizations, among others, which may contribute actively to the design of effective public policies by acting with the local community [40].

These policies aim to promote investments (particularly direct foreign investment) in rural infrastructure and local businesses, technology transfer, and research and development, in order to improve production processes and increase crop productivity. They can also provide farmers with knowledge and skills to produce food competitively in a sustainable manner [11]. Likewise, capacity-building policies aim to train and enable farmers to use sustainable practices efficiently, thereby improving their productivity without compromising food quality, security and safety [16].

Public policies can be very important in this context. For example, in recent years, there has been a significant increase in household income in rural areas in Brazil due to public support policies, especially those directed towards small farms [41]. Much of this achievement is due to the financial resources made available by public entities that provided access to new production practices and technology in rural areas [42].

The increase in family income can also be obtained through technical assistance, providing the rural producer with cutting-edge and advanced technical knowledge [43]. In the case of dairy farming, the technical assistance provided by public policies has been mainly related to better management of the herd and animal nutrition [44]. In this sense, the increase in household income plays an important role in sustainability, since the economic pillar enables the efficient allocation and management of resources, allowing investments to be made in the other dimensions of the sustainability tripod [38].

In order to reach global agribusiness supply chains, products from rural areas need to be produced and distributed through a quick and efficient flow, avoiding waste, inefficiency and idle capacity. In Brazil, road transport is the main mode of transportation, and a massive public investment is needed that aims at providing good conditions for the transportation of products from rural locations to industrial plants, and from these to the markets [45].

Thus, the following research hypothesis was formulated:

Hypothesis 1 (H1). *Public policies and assistance to producers increase the sustainability of dairy farming.*

2.3. Public Policies for the Supply Chain

Globally, agricultural activity is considered to be one of the largest consumers of water throughout the production chain, which can have major implications for the environment [36]. The increase in the world population will significantly affect water consumption, creating competition for this resource between agriculture, industries and cities [46].

The human use of water resources has increased sixfold in the 20th century. This represents twice the rate of population growth, which makes it unsustainable. Some research also shows that water should be considered the highest global priority, more important even than the effects of climate change. Current production systems are responsible for an important share of such pressure on water production [47].

Because of the high consumption of water resources, and the production of wastes and effluents, rural activity (especially the dairy chain) has a significant negative impact on water pollution. Studies in California and Washington have revealed that between 10% and 20% of freshwater sources have exceeded acceptable nitrate concentrations per liter of water. Pollution was even greater in the areas of California hosting the entire dairy supply chain. In these regions, high levels of contamination were found in a third of the reservoirs [48].

Public policies for the management of water and land resources aim to ensure sustainable agricultural practices that minimize the impacts of high levels of productivity, namely, the conservation and improvement of natural resources. In this sense, public policies can establish rules and monitor

the use of water resources, creating conditions to increase the efficient use of the water and minimize soil pollution [35].

Local policies directed towards small farms can be extremely important for the sustainability of dairy farming. For example, local government, recognizing the characteristics of each region, can design incentives and specific actions that benefit local supply chains, such as projects for the acquisition by schools of family farming products [49].

Thus, the following research hypothesis was formulated:

Hypothesis 2 (H2). *Public policies for the supply chain increase the sustainability of dairy farming.*

2.4. Improvements in Production Techniques

Dairy farming has achieved great results in recent years due to technological improvements that have enabled the development of modern facilities for milking, storage, and the transportation of materials and products to industrial plants [50]. The significant advances in genetics, nutrition and the management of the dairy herd have provided unforeseen results. In the last 60 years, milk production has increased more than four times [37].

The main changes in the production processes occurred in the post-World War II period [51]. A study carried out in the United States identified that in the year 1944, the average annual production was just over 2000 kg of milk per animal, but in the beginning of the 21st century, the average annual milk production per animal reached 9000 kg [37]. Furthermore, recent research shows that the average production has increased to more than 10,000 kg of milk per animal [48]. This significant increase in production per animal can have significant effects on the environment, since about 90% of the global warming related to the dairy production chain occurs in the field.

Globally, cattle are responsible for around 18% of greenhouse gas emissions [51]. In Brazil, the average annual milk production is extremely low—around 1500 kg of milk per animal. This result is largely due to poor genetics and a low-protein diet [49]. A study carried out with data from 1980 revealed that 55% of the increase in production is due to genetic improvements, in particular the use of breeds with higher daily productivity, such as Holstein cows [52].

A herd with well-fed cows, combined with animal health practices, such as the control of foot-and-mouth disease and daily mastitis exams, can contribute to a good quality of milk, which consequently guarantees a higher income [49]. Besides, good hygiene during the process can help in avoiding the contamination of the product and of the workers who work in the milking process [48].

Nevertheless, the impact on overall sustainability of the use of advanced technology and production processes in dairy farming is unclear, or can be ambiguous. Indeed, improvements in the farm's profitability due to the implementation of new technologies might be easily calculated; however, it is more difficult to measure consumer acceptance of products resulting from the introduction of new technologies, as well as the social and environmental impact of such improvements from a lifecycle and complete supply chain perspective [46].

Thus, the following research hypothesis was formulated:

Hypothesis 3 (H3). *Improvements in production techniques increase the sustainability of dairy farming.*

2.5. The Use of Management Practices

In several industries and regions in Brazil, cooperatives play an important role. Cooperatives operating exclusively in the milk production chain encompass various activities, that range from the production of feed, and the production of machinery and tools, to acting in the distribution channels of industrialized products. Some offer training to producers, as well as technical assistance, and help in the design and implementation of projects that promote sustainable practices [49].

Although dairy farming is a very globalized activity, the dairy supply chain is very specific to each country. In the case of Brazil, a large part of the production is linked to farms that use relatively simple and low-cost technology, and reduced production knowledge. Thus, there is room for improvement through training programs and technical assistance, which can be considered the main pillars of a process of change towards new and more competitive standards in the industry [49].

Dairy production cooperatives aim at the economic and social integration of rural and small producers, providing farmers with competencies to control the flow of production, ultimately preventing excess and falling prices, as well as facilitating easier access to cheaper and better inputs. Furthermore, cooperatives can guarantee important social benefits, such as participation in leftovers, a sense of fairness, and producer recognition [53].

Management practices are very important because it is not only a matter of investing in financial resources. Indeed, it is not enough to simply adopt technology and increase productivity. It is necessary to produce quality products at competitive prices for the right markets [17]. Production costs must be well managed and understood, considering the use of sophisticated technologies, complex production processes, extended value chains, and a higher amount of indirect costs. Appropriate cost accounting, capital budgeting and investment appraisal techniques and tools should be used in such complex business environments. For example, the opportunity cost of fixed capital is often not considered by producers, but it may impact considerably the economic sustainability of the business [44].

Thus, the following research hypothesis was formulated:

Hypothesis 4 (H4). *The use of good management practices increases the sustainability of dairy farming.*

3. Materials and Methods

The research was conducted with the collaboration of the Association of the Municipalities of the western region of Santa Catarina, Brazil, which is composed of the Municipalities of Aguas de Chapecó, Aguas Frias, Arvoredo, Caxambu do Sul, Chapecó, Cordillera Alta, Coronel Freitas, Formosa do Sul, Guatambu, Irati, Jardinópolis, Nova Erechim, Nova Itaberaba, Pinhalzinho, Planalto Alegre, Quilombo, Santiago do Sul, São Carlos, Serra Alta and União do Oeste. Thus, the population of this study is composed of approximately 4304 farms, which, among several activities, are milk producers.

These municipalities are important in the context of this research because they have a strong vocation for agribusiness. The State of Santa Catarina is the main producer of poultry and pork in Brazil, and the fourth in milk production, producing approximately 2.9 billion liters of milk per year. The western region is responsible for the production of 2.2 billion liters per year, i.e., approximately 75% of the State's production [54].

For the data collection, two meetings were held at rural producers' cooperatives and some visits were made to farms in order to contact more respondents. The final sample consisted of 54 rural farms that operate in the dairy farming. The data were collected over four months and include approximately 290 dairy farm owners. From those contacts, visits were made to the farms to apply the questionnaire and explain the purpose of the research, resulting in the methodological approach of a structured interview based on a questionnaire (presented in the Appendix A). On average, the response time was approximately between 30 and 40 min. After a brief explanation of the purpose of the questionnaire, general information was collected concerning the respondent and the farm, and 37 questions were used to get information concerning the farmers' perceptions on sustainability in the farming activities.

Table 1 presents the reflective latent variables, which were developed from the related observable variables.

Table 1. Research construct.

Latent Variables	Description of Observable Variables	Likert Scale
Public Policies (Producer)	Five questions assessed the rural milk producer's perceptions concerning the degree of involvement of public institutions in technical assistance, offering credit or supporting credit conditions, and training.	1 Totally unsatisfied to 5 Totally satisfied
Public Policies (Supply Chain)	Three issues assessed the perception of the producers concerning the degree of involvement of public institutions and legislation that benefit the dairy sector, and water resources management policies to face the drought.	1 Totally unsatisfied to 5 Totally satisfied
Improvements in Production	Seven questions assessed the producers' perceptions concerning the quality of the equipment, conditions of comfort of the animals, nutrition control, monitoring of animals' health and the quality of the milk, hygiene, and conservation of the milking parlor and food.	1 Totally unsatisfied to 5 Totally satisfied
Management Practices	Six questions assessed the perception of producers concerning participation in lectures, training, cooperatives, and unions that assist in the exchange of management information, planning activities, financial control and cost analysis, and the use of software and hardware for management purposes.	1 Never to 5 Always
Social Sustainability	Six questions assessed the perception of producers concerning the social impact measured by the quality of life, well-being, mental health, housing conditions, socialization with other people, physical appearance, and access to the media.	1 Totally unsatisfied to 5 Totally satisfied
Environmental Sustainability	Five questions assessed the perception of producers concerning the environmental impact of the storage of solid and liquid wastes, and the disposal of pesticide packaging, the use of chemical and pesticide fertilizers, and the use of the land for dairy farming.	1 Never to 5 Always
Economic Sustainability	Five questions assessed the perception of producers concerning the economic impact measured by production capacity, investment appraisal analysis, increase in production, and satisfaction with income.	1 Totally unsatisfied to 5 Totally satisfied

Source: Adapted from [55–58].

The drivers of sustainability have been broken down into four latent variables. Thus, the questions related to public policies, directed to the producer, seek to capture the perception of rural producers about the support of public institutions in the development of rural properties and dairy farming. Questions concerning public policies directed towards the supply chain capture the perception of the rural producer regarding the contribution of public institutions to the development of a more sustainable local milk supply chain, particularly in terms of the management and use of water resources, which are very important in this context. Furthermore, the factor related to production improvements highlights producers' perceptions of the use and impact of efficient milk production techniques. Finally, the perceptions of rural milk producers concerning the use of management practices that help in the financial control and efficient management of resources of dairy activities were also captured.

It is noteworthy that the latent variables presented in Table 1 were built from the questions mentioned above, measured using a 5-point Likert scale, called observable variables. Indeed, the latent variables used in the structural equation model were not directly observed, but were formed, through confirmatory factor analysis, from the observable variables measured directly. Therefore, the independent variables are formed by the latent factors, and the dependent variables are related to the latent factors of social sustainability, environmental sustainability and economic sustainability. This allowed us to measure the relationship among drivers and sustainability from a Triple Bottom Line perspective. The drivers of sustainability are related to public policies, improvements in production techniques and management practices, which were highlighted in previous studies [26–31].

The data were analyzed via partial least squares structural equation modeling using SmartPLS3 software. For this, two complementary models were used, the first on the relationship between the drivers and each of the dimensions of sustainability (i.e., social, environmental, and economic), and the other on the relationship between the drivers and sustainability measured as a second-order variable. Previous studies also used complementary models, first considering only the relationships between first-order variables in order to capture the individual effects of the latent variables, and then grouping the relevant latent variables into a second-order variable to capture possible joint effects [59,60].

The formation of the second-order variable resulted from the multiple interactions and covariances among the relevant latent variables [61]. This approach is very robust, as demonstrated in other similar

works [59,60,62–65]. Despite the importance of assessing sustainability from different perspectives, using the TBL approach, it is equally important to measure sustainability as a more complex and integrated phenomenon, which requires a higher degree of abstraction, obtained by joining the TBL dimensions that may compose it [66]. In this way, a single measure for sustainability makes it possible to observe the magnitude of each dimension of the Triple Bottom Line with regards to sustainability as a whole, and makes it possible to analyze the impacts and global contributions of the various drivers of sustainability.

The structural equation modeling seeks to explain the relationships between multiple variables. Such equations describe all the relationships between the constructs involved in the analysis, particularly the unobservable factors or latent factors represented by the multiple variables [67,68]. The structural equation can be used conceptually to answer any research question involving the direct or indirect observation of one or more independent variables, or one or more dependent variables. In this research, it is the most appropriate technique, considering that the main objective is to determine and validate the causal process of a proposed theoretical model. It is therefore a confirmation technique that determines whether the target model is valid.

4. Analysis of Results

A structural equation model is developed in two major steps: the measurement model and the structural model. The measurement model has the purpose of verifying whether the items of each construct accurately measure their respective concept, while the structural model defines the relationships between the variables [60].

To verify that the set of items accurately measures the proposed concept and validate the measurement model, it is necessary to use appropriate statistical techniques. In that sense, several preliminary tests were performed in order to validate the structural equation model. Table 2 shows the reliability and validity tests of the construct.

Table 2. Construct reliability and validity test.

Variables	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted
Public Policies (Producer)	0.749	0.750	0.826	0.445
Public Policies (Supply Chain)	0.813	0.851	0.887	0.724
Improvements in Production	0.787	0.805	0.824	0.422
Management Practices	0.766	0.804	0.801	0.406
Social Sustainability	0.764	0.769	0.829	0.452
Environmental Sustainability	0.750	0.733	0.822	0.487
Economic Sustainability	0.738	0.747	0.826	0.489

Source: research data.

The dimensions of the construct were assessed using the convergent validity tests, internal consistency reliability, and composite reliability. Convergent validation assesses the degree to which two measures of the same concept are correlated. The criterion proposed by Fornell and Larcker [69], which indicates convergent validation when the mean-variance extracted is greater than 40% [70], was used to check convergent validity. Therefore, the results indicate that the latent variables showed an extracted indicator of mean-variance greater than 40%, proving the convergent validation of the construct.

Reliability measures the internal consistency between the measured values of the items. Reliability is high if the Cronbach's alpha and composite reliability are greater than 0.70 [60]. The results obtained indicate values higher than 0.70 in all latent variables, confirming the reliability of the constructs. In addition, the internal consistency proved to be very good, as determined by the rho_A test, which is higher than 0.60 in all variables. Therefore, all the adjustment indices for the measurement model have acceptable levels.

Besides this, discriminant validity is supported by the good fit of the model. This indicates that any strong cross-loading does not deteriorate the good fit of the model [67]. Attention must be paid to

discriminatory validation, which checks the degree to which a latent variable is truly different from the others. Table 3 shows the discriminant validity via the Heterotrait–Monotrait ratio of the construct used in the structural equation model.

Table 3. Discriminant validity using the Heterotrait–Monotrait ratio.

	ECON_SUST	ENV_SUST	IP	PPP	PPSC	MP	SOC_SUST
ECON_SUST							
ENV_SUST	0.401						
IP	0.390	0.530					
PPP	0.631	0.314	0.321				
PPSC	0.226	0.262	0.153	0.316			
MP	0.662	0.330	0.616	0.565	0.177		
SOC_SUST	0.758	0.284	0.315	0.531	0.252	0.497	

IP: Improvements in Production; PPP: Public Policies (Producer); PPSC: Public Policies (Supply Chain); MP: Management Practices; ECON_SUST: Economic Sustainability; ENV_SUST: Environmental Sustainability; SOC_SUST: Social Sustainability. Source: research data.

The most highly recommended criterion to evaluate the discriminant validity is the hetero-reason (HTMT), which compares the mean of the cross correlations between two different latent variables with the mean of the internal correlations of the observable variables themselves, it being necessary to have a HTMT different from 1, and preferably a HTMT < 0.90 [60] or 0.85 [71]. HTMT is a measure of similarity between latent variables that allows the evaluation of discriminant validity, i.e., it shows that two latent variables effectively represent different theoretical concepts. If the HTMT is significantly different from one, discriminant validity can be established. In this case, the discriminant validity was verified for all variables as shown in Table 3.

After the validation of the measurement model, the final step is focused on the results of the structural equation model. Thus, the structural equation model was established based on the influence of the different drivers of social, environmental and economic sustainability (Table 4).

Table 4. Statistics of the first-order structural equation model.

Structural Relations	Original Sample	Sample Mean	Standard Deviation	*t* Statistics	*p* Value
Public Policies (Producer)→ Social Sustainability	0.284	0.253	0.193	1.470	0.142
Public Policies (Producer)→ Environmental Sustainability	0.076	0.067	0.174	0.436	0.663
Public Policies (Producer)→ Economic Sustainability	0.257	0.281	0.124	2.070	0.039 **
Public Policies (Supply Chain)→ Social Sustainability	−0.296	−0.255	0.190	1.556	0.120
Public Policies (Supply Chain)→ Environmental Sustainability	−0.048	−0.062	0.167	0.289	0.772
Public Policies (Supply Chain)→ Economic Sustainability	−0.089	−0.092	0.106	0.844	0.399
Improvements in Production→ Social Sustainability	−0.169	−0.153	0.132	1.285	0.199
Improvements in Production→ Environmental Sustainability	0.490	0.471	0.209	2.346	0.019 **
Improvements in Production→ Economic Sustainability	0.146	0.158	0.143	1.022	0.307
Management Practices→ Social Sustainability	0.476	0.499	0.149	3.194	0.001 *
Management Practices→ Environmental Sustainability	0.012	0.008	0.169	0.069	0.945
Management Practices→ Economic Sustainability	0.476	0.464	0.131	3.625	0.000 *

** Significance level of 5%; * Significance level of 1%. Source: research data.

The results indicate that the use of better management practices positively influence social and economic sustainability in dairy farming. Based on the non-rejection of the fourth hypothesis, the important role that management control can play in the sustainability of rural businesses is proven. This is aligned with the findings of previous research, which highlighted that efficient management practices and effective financial control promote sustainability in rural businesses [17,44];

Furthermore, results suggest the acceptance of the first hypothesis, i.e., public policies directed towards producers have a positive influence on the economic sustainability of dairy farming, supporting jobs and economic conditions in the rural environment [39] and strengthening the local production chain [40].

Finally, the results indicate that improvements of the production techniques used in dairy farming may influence significantly the environmental sustainability of rural businesses. This suggests the acceptance of the third hypothesis, which relates production techniques to the sustainability of dairy farming. Indeed, improvements in production techniques have led to significant changes in milk storage and milk transport facilities, contributing to the sustainability of rural properties [50].

Complementarily, a structural equation model that considers sustainability as a second-order variable, measured from the multiple interactions and covariances among the social, environmental and economic sustainability latent variables, was also developed. The relationship between the drivers and sustainability considers the Triple Bottom Line dimensions in an aggregated way. Table 5 shows the statistics related to the second-order structural equation model.
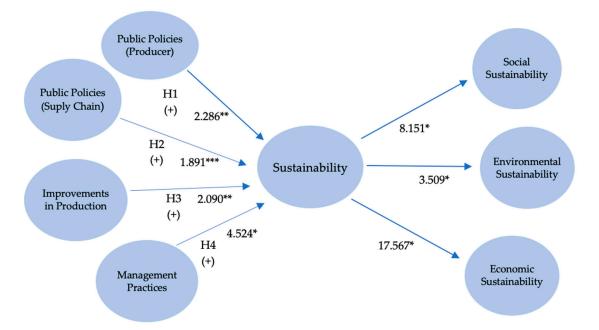
Table 5. Statistics of the second-order structural equation model.

	Original Sample	Sample Mean	Standard Deviation	*t* Statistics	*p* Value
Public Policies (Producer)→ Sustainability	0.253	0.252	0.111	2.286	0.023 **
Public Policies (Supply Chain)→ Sustainability	−0.204	−0.157	0.108	1.891	0.059 ***
Improvements in Production→ Sustainability	0.292	0.348	0.139	2.090	0.037 **
Management Practices→ Sustainability	0.479	0.434	0.106	4.524	0.000 *
Sustainability→ Social Sustainability	0.854	0.844	0.105	8.151	0.000 *
Sustainability→ Environmental Sustainability	0.496	0.577	0.141	3.509	0.000 *
Sustainability→ Economic Sustainability	0.886	0.882	0.050	17.567	0.000 *

*** Significance level of 10%; ** Significance level of 5%; * Significance level of 1%. Source: research data.

The results show that public policies directed towards producers, improvements in production techniques and the use of management practices have a positive influence on sustainability. Nevertheless, the impact of public policies directed towards the production chain was not found to be statistically significant. The results suggest that the drivers related to the benefits more directly related to and perceived by rural milk producers, especially those who depend also on their own actions, have a greater impact on sustainability. In contrast, changes in the supply chain may not have the same effect because they result in a less immediate and more indirect effect on farms. The findings indicate that, from all dimensions, economic sustainability is the one that prevails, or is more developed in dairy farming. These results are presented in Figure 1.

Figure 1 shows the results of the structural equation model obtained from the measurement of sustainability as a second-order variable, represented by the first-order factors of social, environmental and economic sustainability. It is proven that the studied drivers really explain strongly and positively the second-order variable of sustainability. They are also important variables for measuring sustainability from a Triple Bottom Line perspective (see Table 4). Further, the results of t-statistics tests indicate that the most important driver of sustainability in dairy activity is the use of good management practices. It should be noticed that public policies aimed directly at rural producers and improvements

in production techniques also contribute positively to sustainability. Nevertheless, public policies directed towards the supply chain do not have a strong effect on the sustainability of dairy farming.

Figure 1. Second-order structural equation model. *** Significance level of 10%; ** Significance level of 5%; * Significance level of 1%. Source: research data.

On the other hand, analyzing the second-order variable, it can be seen that the economic dimension contributes 60% to the perception of sustainability in dairy farming, followed by the social dimension. The environmental dimension makes a much smaller contribution. This indicates that economic aspects still prevail in these companies. Further research can evaluate if these conclusions may be extrapolated to other agricultural activities and businesses, and to other locations. This is aligned with the fact that the most relevant driver of sustainability is the use of management practices, which are directly related to financial and economic control in dairy farms.

5. Discussion and Conclusions

Thus, it was concluded that economic sustainability prevails in dairy farms, and that there are factors that effectively improve sustainability from the perspective of the Triple Bottom Line. These drivers mostly refer to management practices, followed by improvements in production techniques and public policies. In this sense, it is seen that the concern of rural producers with the application of management control tools is very important in promoting sustainability.

The first hypothesis aimed to investigate whether public policies of assistance to producers can contribute to more sustainable dairy farming. The results confirm the hypothesis, indicating that the existence of public policies for technical assistance can positively impact the sustainability of dairy farms. The findings are aligned with previous research that showed that local governments play a significant role in promoting policies and assistance directed towards small producers [39], and promoting partnerships between institutions (e.g., cooperatives) and communities [40]. Furthermore, technical support can be provided or promoted through public policies, contributing to a better infrastructure in rural areas, technological development, and the production of food in a sustainable manner [11]. The findings also corroborate previous work that suggests a relationship between training policies for farmers and the use of sustainable work practices [35].

The second hypothesis aimed to assess whether public policies directed towards the production chain can contribute to the sustainability of dairy farming. In this case, such policies are focused on water resources management, because of its importance for the agribusiness in general, and milk

production in particular. The results allow us to reject the hypothesis, as there was not found a significantly positive relationship between such policies and sustainability. We may say that it was not possible to confirm the existence of competition between agriculture, industry and cities for natural resources [46], or even that the production chain is a major consumer of natural resources [36]. Perhaps, from the perception of rural producers, who have an abundance of natural resources on their farms, issues related to the sustainability of the supply chain as a whole are not so important or intelligible.

The third hypothesis investigates whether improvements in production techniques can contribute to the sustainability of dairy farming. The results of the research confirm the hypothesis, indicating that investment and continuous improvements in production play a positive role in the sustainability of rural businesses in the dairy industry. This result confirms previous evidence, related to the implementation of new technologies in rural areas over the years, such as the use of modern milking, storage, and transport equipment [50], and the significant improvement in herd genetics, management and nutrition [37], as well as animal health [49] and worker hygiene during the milking process [48]. These advances directly affect the social and economic dimensions of the business, increasing the income of milk producers, and preserving the environment by reducing the number of animals to produce equivalent quantities of milk.

The fourth hypothesis aimed to investigate whether the use of management practices in dairy farming can contribute to the sustainability of the business. The results of the research allowed the validation of the hypothesis. The findings confirm studies that have been discussing, for instance, the importance of cooperatives in promoting management training and financial literacy to support investment in profitable projects in dairy farming [49]. These results are aligned with the idea that sustainable practices help to produce more with less economic resources [49]. Furthermore, making rural farms competitive from an economic point of view asks for the use of management practices, and it can be considered fundamental to supporting the development of the other sustainability dimensions [17,32].

On the other hand, the analysis of the second-order variable allowed us to understand that the economic dimension prevails in the eyes of the farmers as the main dimension of sustainability, and that environmental aspects are still neglected. Eventually, further research may evaluate if this situation is different in other agricultural activities and supply chains, and/or if it can be expected to change in the coming years. The drivers of such change are also important, and management practices appear to be important because they have an immediate and direct impact on dairy farming.

Thus, in this research, the use of first and second-order structural equation models was important in analyzing sustainability in dairy farming activities, recognizing the different dimensions of sustainability, namely those highlighted by the TBL approach. It was observed that some factors contribute more to driving sustainability in dairy farming, with different impacts on the economic, social and environmental dimensions. A single variable for evaluating sustainability is also relevant to connecting it with the main triggers and drivers of change. A better and deeper understanding of this process helps industries, companies and governments to design and implement more effective and efficient initiatives and public policies. Namely, it highlights that it is still important to promote actions towards the development of environmental sustainability. The evaluation of dairy farming sustainability can be used to rank and recognize companies, industries and supply chains, giving visibility and market incentives for a higher compromise with sustainability practices worldwide.

The study has some limitations, among which there is the fact that the results cannot be fully generalized as the sample may not be fully representative. Furthermore, the need to collect the data more directly made the process very time-consuming and expensive, and the time needed to reply to the questionnaire was relatively long, complicating the data collection process. These limitations might be mitigated in future research by using, for example, electronic questionnaires, and the active sponsorship of municipalities and cooperatives to facilitate both access to and the collection of the data.

For further research, we suggest an investigation of the impact of other drivers of sustainability in rural farms, such as freestall, and the exclusive use of pasture or mixed production systems, in addition

to studies in other regions and different supply chains. Indeed, the characteristics of the product and the supply chain can affect sustainability differently. It may be particularly interesting to study the supply chain of milk powder, fresh cheese, cheeses in general, and other milk derivatives. Particularly, the sustainability of dairy farms may also be influenced by the breed of the dairy cattle. Indeed, as was evident in some studies, certain breeds produce more milk than others, resulting in lower production costs [37,48] and higher economic sustainability of dairy farming. Thus, further studies can be performed to replicate, complement and extend the findings found here, and to add more knowledge regarding how agribusiness supply chains may progress towards sustainability.

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

Appendix A

QUESTIONNAIRE
Owner identification and address (optional)
Age of the farm manager
Education level of the farm manager
Number of animals
Production system (grazing, freestall, compost barn)
Milk production (daily, monthly and annual)
Destination of milk production [dairy industry; family agribusiness (cheeses and dairy products)]
Overall income (approximately)
Weight of milk production in overall income (approximately)
Farm size (area of land)
Number of farm workers
Public Policies (Producer)
Assess the technical assistance provided to dairy farming.
Evaluate the financing or credit granted to dairy farming.
Evaluate training courses on dairy farming.
Evaluate training in new technologies applied to dairy farming.
Evaluate the conditions of the roads for the transportation of dairy products.
Likert scale from 1—Totally unsatisfied to 5—Totally satisfied
Public Policies (Supply Chain)
Assess how the municipality, regulations and legislation support the development of dairy farming.
Evaluate how water resources are managed in the municipality's watershed.
Assess the availability of water resources for the development of dairy farming.
Likert scale from 1—Totally unsatisfied to 5—Totally satisfied
Improvements in Production
Assess the quality of the infrastructure of the farming property.
Evaluate the quality of the farming property's machinery and equipment.
Evaluate the comfort conditions of the animals in the farming property.
Evaluate the control of animal nutrition in the farming property.
Evaluate the monitoring of the sanitary conditions of the animals and of the quality of the milk in the farming property.
Evaluate the level of hygiene and conservation of the milk (e.g., picket stand, milking parlor) in the farming property.

Evaluate the level of safety stocks of silage, haymaking, etc., for the milk herd on the farming property.

Likert scale from 1—Totally unsatisfied to 5—Totally satisfied

Management Practices

Evaluate your participation in short courses related to dairy farming.

Evaluate the degree of use of planning and financial control in dairy farming activities.

Evaluate the degree of use of cost control in dairy farming activities.

Evaluate the degree of use of software and computerized tools for management activities in dairy farming.

Evaluate your participation in cooperatives and similar associations and groups of milk producers.

Evaluate your participation in activities with other dairy farmers.

Likert scale from 1—Never to 5—Always

Social Sustainability

Assess the level of personal quality of life and well-being and in the context of the farm.

Assess the level of personal mental health and in the context of the farm.

Assess the level of personal housing conditions and in the context of the farm.

Assess the level of personal socialization and in the context of the farm.

Assess the level of personal satisfaction (e.g., physical appearance, good mood) and in the context of the farm;

Assess the level of personal access to media and information (e.g., internet) and in the context of the farm.

Likert scale from 1—Totally unsatisfied to 5—Totally satisfied

Environmental Sustainability

In the farm, to what extent there is a concern about the storage of solid wastes from dairy farming.

In the farm, to what extent there is a concern about the storage of liquid excrements from dairy farming.

In the farm, to what extent there is a concern about the use of fertilizers and pesticides in the pastures for the dairy activity.

In the farm, to what extent there is a concern about the storage of pesticide containers.

In the farm, to what extent there is a concern about less intensive use of the land.

Likert scale from 1—Never to 5—Always

Economic Sustainability

Evaluate the production capacity and gross income of dairy farming in the last 5 years.

Evaluate the profitability of dairy farming by comparing the financial investments and the resources involved, namely, labor force, with the income generated.

Evaluate the projected increase in milk production in the coming years.

Evaluate whether the income provided by dairy farming is sufficient to cover the main expenses of the property, namely, salaries.

Assess whether the income from dairy farming is sufficient to meet all financial needs.

Likert scale from 1—Totally unsatisfied to 5—Totally satisfied

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