Milk Quality and Economic Sustainability in Dairy Farming: A Systematic Review of Performance Indicators

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Abstract: The dairy industry plays a vital role in the global food system, providing a wide range of dairy products that are consumed by millions of people worldwide. Dairy farming provides a daily source of income, creating employment opportunities not only on farms, but also in transportation, milk processing, and the agricultural supply and services sectors. The increasingly pressing challenges and the high competition in the dairy industry, particularly in saturated markets, emphasize the importance for farms to undertake a comprehensive economic sustainability analysis that extends beyond mere yield monitoring. Empirical studies have found a weak adoption of robust performance measurement and control systems in dairy farms. Given the intricate macroeconomic landscape in developed nations and the imperative to address the multifaceted challenges of the industry, this study employs a systematic literature review (SLR) to evaluate whether academic research offers adequate guidance on economic performance indicators. The study finds out that the current repertoire of indicators, while relevant and partially related to quality attributes, fails to encapsulate the intricate interplay of variables and the nature of economic sustainability, highlighting the need to adopt additional indicators into the dimensions of operational efficiency and effectiveness, strategic investments, and financial strength.

Keywords: economic sustainability; performance indicators; dairy industry; milk quality

1. Introduction

The dairy industry plays a vital role in the global food system [1], providing a wide range of dairy products that are consumed and enjoyed by millions of people worldwide [2]. The dairy sector stands out due to its efficiency in converting non-human consumable crops into high-quality food products for human consumption. Dairy cows, through a symbiotic relationship with rumen bacteria, convert indigestible plant resources into milk [3], which provides essential nutrients and much more for human livelihood [2]. By-products of human food processing, such as distiller grains and soybean meal, serve as supplements for dairy cattle, enhancing nutrient utilization and minimizing waste. Furthermore, dairy animals' digestive systems contribute to the decomposition process, generating high-quality fertilizer that enriches the soil. The dairy industry possesses unique characteristics that set it apart from other sectors of agriculture: firstly, milk consists of approximately 87% water, which equates to a commodity with substantial mass that is produced daily, 365 days a year [4]; secondly, milk is perishable and has a limited shelf life [5]; and, thirdly, the dairy industry plays a fundamental socioeconomic role, providing a daily source of income, creating employment opportunities not only on farms but also in transportation, milk processing, and agricultural supply and services sectors. Therefore, the dairy industry exhibits notable distinctions from other primary sector products; furthermore, it is equally imperative to recognize the disparities within the industry itself [4]. These distinctions are particularly prominent between mature markets like the countries located in Europe and

North America, also called "developed countries", and emerging markets such as China, India, and Brazil, categorized as "developing countries" [6]. Developed countries have witnessed a shift towards larger, more mechanized dairy farms with higher milk yields per cow [7]. These farms often employ modern technologies, such as automated milking systems and computerized herd management, to optimize production and efficiency [8]. In contrast, developing countries typically rely on traditional methods of milk production, with limited access to modern equipment and technologies [9]. The small herd sizes and limited resources can result in lower milk yields per cow compared to larger operations [10]. Additionally, the infrastructure and support systems for dairy farming vary across countries. Developed countries generally have well-established dairy co-operatives, processors, and marketing channels that facilitate the efficient collection, processing, and distribution of milk. In developing countries, the dairy industry often faces challenges related to infrastructure, storage, and transportation [11]. The limited access to refrigeration facilities and inadequate road networks can hinder the timely collection and transportation of milk from farms to processing units. As a result, the milk quality and freshness may be compromised, impacting the overall efficiency of the dairy value chain. The dairy industry demonstrates notable variations also in consumption patterns and demand for products [12]. In developed nations, there is generally a high per capita consumption of dairy products, including milk, cheese, butter, and yoghurt, but a steady (or in some cases decreasing) consumption trend is projected in the coming years. Therefore, these markets are often denoted as "saturated". In developing nations, on the other hand, the per capita consumption is lower but is projected to increase considerably due to population growth and rising incomes [13].

A recent publication identified four global trends impacting the dairy industry: the growing awareness of the ecological impacts and the nutritional qualities of dairy products; the alternative milk disruption; the shifting geographies and scales of production and consumption from the North to South; and the intensification of capital, land, and animals. The authors highlighted that these trends represent opportunities for developing countries, while they are areas of challenge in advanced economies [14]. Consequently, the approaches that have been used to address these challenges must necessarily be different according to the type of country in which the farm operates and the other external factors in which it is involved [13,14].

The increasingly pressing challenges and the high competition in the industry, particularly in saturated markets, emphasize the importance of undertaking comprehensive economic sustainability analyses [15]. The analysis should encompass considerations of quality dimensions, extending beyond mere yield monitoring [16]. For over 50 years, the accounting literature emphasized the relationship between the introduction of management control systems and the level of competition within the sector, highlighting the essential role of the resulting control in achieving superior economic performance [17]. In that respect, the managerial literature today still highlights the importance for companies to develop performance indicators [18]. These indicators are variables that qualitatively or quantitatively express the efficiency and effectiveness, or both, of a part or whole process, or system, against a given standard or target [19]. Regardless, it is fundamental to note that the implementation of a management control system does not automatically guarantee an improved performance; rather, performance outcomes are intricately tied to how these systems are designed, developed, and utilized [20]. The evaluation of economic sustainability must encompass a comprehensive analysis of various business aspects, including the overall effectiveness, efficiency of economic and financial decisions, and prospects for continuity [21]. Specifically, this analysis involves considering a system of balances across (at least) three dimensions [21,22]:

- Income Balance: This dimension focuses on generating an income that is congruous both quantitatively, considering factors such as imputed charges and business risk, and qualitatively, in terms of meeting expected levels of profitability. The main information regarding the revenues and expenses of a company can be found in the "income

statement" (or "Profit and Loss" statement). The income statement typically consists of several key categories, including operating revenues, other revenues, operating costs (such as cost of goods sold, general and administrative expenses, research and development costs, etc.), financial costs (such as interest expenses, accruals, and deferrals), and taxes [23].

- Capital Balance: The capital balance pertains to the correlation between different categories of investments and capital sources in terms of their return time and maturity. It ensures that the allocation of capital is aligned with the expected returns and investment horizons. The main information concerning the assets and liabilities of companies at a specific point in time is typically presented in the "balance sheet" document. Traditionally, the balance sheet is divided into two sections: assets and liabilities. The assets are further categorized as non-current and current assets, while the equity items are presented next, followed by the liabilities, which are also classified as non-current and current liabilities [23].

- Financial Balance: The financial balance emphasizes the harmonious relationship between income and the expenditure of financial resources, particularly in the immediate and short-term perspective. It involves managing cash flows effectively to maintain stability and meet financial obligations [23]. The financial statement, also known as the "cash flow statement" or "statement of cash flows", presents the primary information regarding the cash inflows and outflows of a company during a specific period. The main components of the financial statement are cash flows from operating activities, cash flows from investing activities, and cash flows from financing activities [24].

To maintain equilibrium across these three dimensions, businesses need to gain a comprehensive understanding of their performance and make informed decisions to ensure long-term economic sustainability and success [25].

As well argued by Fiorillo and Lo Zoppo [26], for companies operating within the primary sectors, the implementation of performance measurement systems entails measuring relevant indicators and identifying deviations between planned objectives and actual results. The performance measurement system must be used as a dynamic tool [27]; indeed, by closely monitoring vital performance indicators like production levels, resource allocation, and financial outcomes, farm managers can accurately assess their progress towards established goals. This systematic approach enables them to proactively identify any deviations or inefficiencies, facilitating prompt corrective actions to address them [26]. Despite the dairy sector's intricate macroeconomic landscape and the well-established usefulness of performance measurement and control systems in the management literature, several empirical studies have highlighted their limited adoption in business practices [28–30]. Acknowledging this empirical gap, this review aims to assess the adequacy of economic performance measurement systems for dairy farms in developed countries discussed in academic research by answering the following research questions:

1. What are the predominant themes and areas of focus in the literature regarding economic performance indicators within the dairy industry?
2. How do dairy farms typically assess their economic sustainability, and what dimensions of performance are commonly considered?
3. Are there emerging trends or changes in the use of performance indicators in the dairy sector, and is the focus on milk quality goals one of the drivers of these changes)?
4. How do dairy farms balance the need for efficiency and productivity with considerations of profitability and long-term financial viability?
5. What are some potential areas of improvement or expansion in economic sustainability methodologies for dairy?

This study would contribute to academic and empirical discussions by examining whether the indicators found in the academic literature accurately capture the dynamics and outcomes observed in dairy farms. It investigates whether these indicators are suitable for implementation in company contexts or if there is a need to develop a more comprehensive set of indicators based on academic research.

2. Materials and Methods

This study employed a literature analysis to identify the most frequently utilized economic and managerial performance indicators within dairy enterprises. The analysis involved two main steps: firstly, systematically searching for peer-reviewed publications and screening the relevant ones; and, secondly, applying a co-occurrence analysis of texts in titles and abstracts, to gain an initial understanding of the existing knowledge and providing specific guidance for categorizing the performance indicators [31]. Only then were the economic–financial performance indicators manually selected from the relevant publications and categorized based on the results of the co-occurrence analysis. The review protocol was retrospectively registered in a public registry to enhance transparency and ensure adherence to predetermined methodologies. The registration details can be accessed at https://doi.org/10.17605/OSF.IO/6F592 (accessed on 15 May 2024).

2.1. Systematic Literature Review

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) method, introduced in 2009, offers valuable guidance in developing high-quality systematic reviews that are less susceptible to bias from subjective factors [30,31]. Numerous observational studies have shown that the use of the PRISMA method is associated with more comprehensive literature reviews [30,32–34]. In this study, the PRISMA method was utilized to conduct a systematic review of the literature on performance indicators used by dairy farms. Due to the inductive nature of the present research, broad selection criteria have been employed to ensure that potentially relevant findings would not be overlooked. The rationale behind this decision was that it is less problematic to code a more comprehensive set of items and subsequently eliminate some during the analysis phase, rather than having to start the entire analysis again to include additional constructs and items [34].

Specifically, the search was carried out for words referring to milk production by dairy farms (farm* AND milk OR milk quality), words referring to the economic–financial sphere (management and economic OR financ*), and references to indicators, not strictly performance (indicator OR parameter OR management and control OR price or profitability OR valu* OR performance OR budget OR kpi). Moreover, a wildcard character (*) was used during the initial search to generate more results; for example, farm* generates results that included "farm", "farms", "farming", "farmer", "farmers", etc. Based on PRISMA guidelines, an electronic database of abstracts and citations (SCOPUS) was used to search the titles, abstracts, and contents of the papers. The search is conducted in January 2023 and is limited to works published after 1 January 2000.

This initial search yielded 238 results. However, the focus of this research is specifically on performance indicators of dairy enterprises in developed countries. To achieve this, an automatic filter was applied, limiting consideration to articles published in North American countries (Canada and the US) and continental European nations with a Human Development Index (HDI) surpassing 0.8 [35].

A total of 155 papers were subjected to the screening phase. During this phase, the process involved conducting a search for full-text articles and reviewing individual abstracts. Further selections were made to exclude specific works based on the following criteria:

- Not English or fully available text;
- Papers, although published in North America or continental Europe, focused on cattle farming in developing nations. For instance, the study conducted by Lankaster et al. [36], published in the American journal PLoS, examined the pastoral system in Tanzania;
- Some papers did not contain any references to economic, financial, or managerial aspects, despite the main topic being cattle farming. For this reason, several studies concerning the clinical implications of mastitis were consequently excluded;

- The production or commercialization of milk was only a peripheral aspect of certain papers, as their focus was on other topics. For example, the study by Di Cerbo and Palmieri [37] explored the probiotics market and was excluded;
- Some papers are primarily focused on animals other than cattle, particularly pigs.

As a result, a total of 65 studies were included in the review and subsequently underwent meta-analysis. The outcomes of this process are depicted in Figure 1, which illustrates the results within the flow diagram framework proposed by PRISMA 2020.
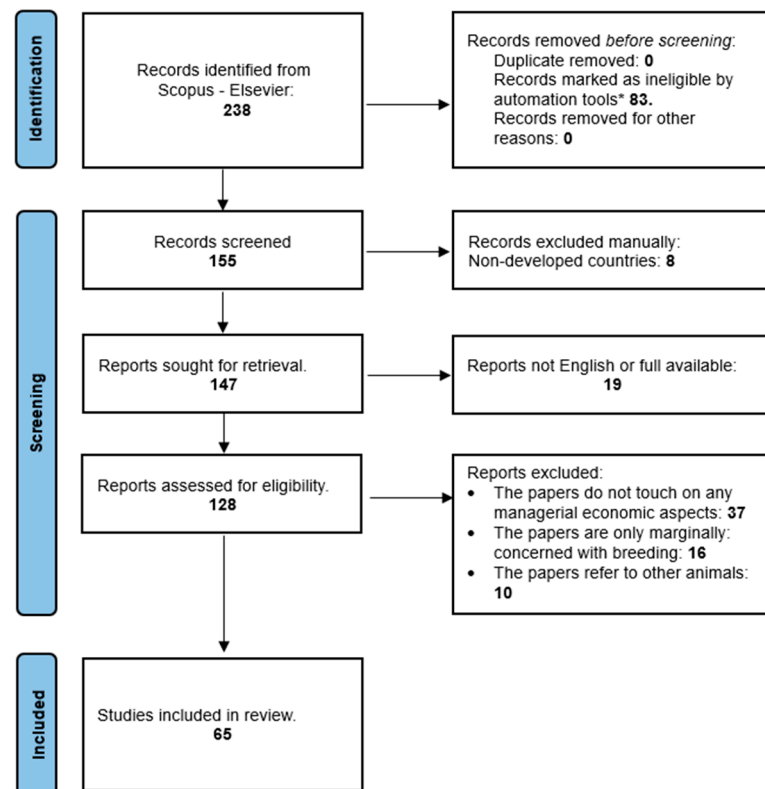
Figure 1. PRISMA flowchart systematically guides selection: numbers denote included (2° column) and excluded (3° column) papers at each stage (1° column). * An automatic filter was applied, restricting consideration to nations with a Human Development Index exceeding 0.8.

Efforts were made to broaden the scope by expanding search terms and including databases in the initial search strategy. Any discrepancies encountered during the selection process were diligently addressed through active discussions among the research team. While the objective was to incorporate an international perspective into the analysis, it was decided that we should focus on a single database known for its high-quality research contributions. This approach was chosen to maintain the rigor and reliability of the included studies, ensuring their suitability for the review's objectives. Consequently, emphasis was placed on prioritizing the quality assurance of the selected papers rather than pursuing an extensive but looser analysis. The resulting inclusion of 65 papers, representing 20 countries of research, reflects the meticulous selection process and the adherence to stringent inclusion criteria. However, it is essential to acknowledge that this limited scope may have excluded valuable studies from other databases. Considering this outcome, there is a possibility that incorporating additional databases could have broadened the geographic representation and provided insights from a more diverse range of countries [38]. This potential avenue for further exploration and inclusivity underscores the dynamic nature of research and the importance of considering alternative sources for a more comprehensive understanding of the subject matter.

Moreover, in applying the PRISMA method for the identification and selection of relevant literature, review papers were intentionally included to ensure a comprehensive analysis. This inclusion allows for a broader synthesis of existing research [39,40], offering extensive insights into widely recognized and validated economic and managerial performance indicators within the dairy industry. Acknowledging the inherent limitations associated with review papers, including potential interpretative biases and the prospect of redundant citations [41], their inclusion was deemed indispensable to providing a holistic understanding of the research landscape [42].

The title, abstract, authors, publication year, journal, country of publication, field of knowledge, research question, methodology, and main results were extracted for each paper. Prior to proceeding with the manual identification and categorization of different economic and non-economic performance indicators within each paper, a co-occurrence analysis was conducted.

2.2. Co-Occurrence Analysis and Clustering Development

As mentioned earlier, a co-occurrence analysis was conducted to deepen the understanding of the text and to identify categories for the indicators. This analysis, applied to extensive text, helps pinpoint main themes and topics providing a visual map of the search field [43]. The co-occurrence analysis of text in titles and abstracts was performed with VOS viewer 1.6.19 software, utilizing the full counting method, with a minimum occurrence threshold set at 8 times. Aligning against best practices in the use of this tool [44], common words such as "paper", "term", "number", and "research" were excluded from the results. Figure 2 displays the outcomes of the co-occurrence analysis, specifically the distribution of themes across all publications.
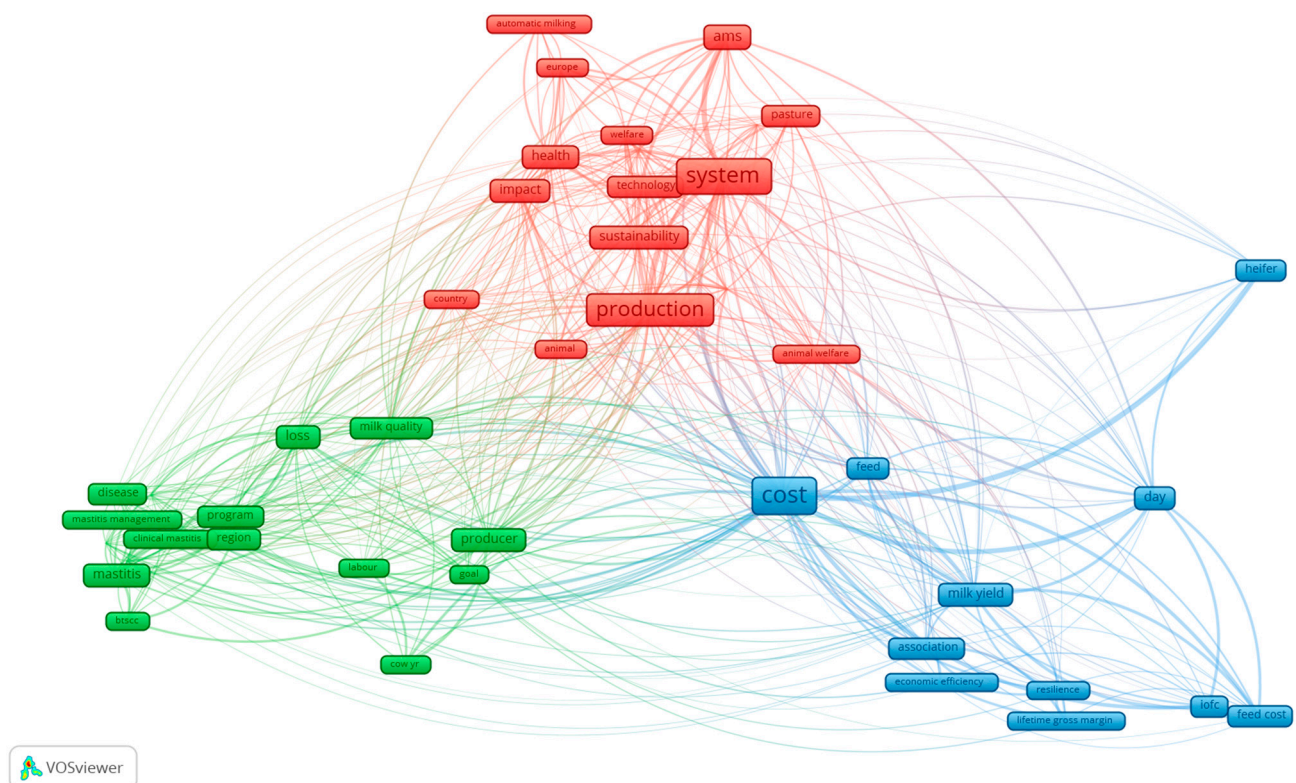
Figure 2. Analysis of co-occurrence in titles and abstracts.

The analysis reveals the research community's focus can be traced to three main categories, specifically, as follows:

- The red cluster (Cluster 1) comprises terms linked to productivity, specifically pertaining to the composition of the production structure and output dynamics within dairy farms. Notably, keywords such as "production", "productivity", and "system" prominently emerge within this cluster.
- The blue cluster (Cluster 2) underscores the research emphasis on factors associated with operational efficiency. In this regard, it is important to emphasize that the crucial node of this cluster is the word "cost", which is the primary aspect that farms work on to improve operational efficiency.
- The green cluster (Cluster 3), relatively smaller in size, indicating lower term frequency and weaker connections with other terms, features the crucial node "milk quality". Additionally, several terms are closely related to specific quality attributes, such as "mastitis", "program", "veterinary", and "losses".

After gaining a preliminary understanding of the topics receiving the most attention from the scientific community of dairy sectors, a logically structured framework for categorizing results was formulated. This framework aligns with the findings of the co-occurrence analysis and incorporates insights from the economic and managerial literature, resulting in the establishment of distinct categories and subcategories of indicators (as depicted in Table 1):

- Productivity Indicators: Developed based on the identified red cluster in the co-occurrence analysis, this category encompasses indicators related to output dynamics [45] of dairy farms. Subcategories were created based on the measured output, such as herd performance, quantity, and quality of milk, as well as a residual category for other occasionally studied outputs in the literature.
- Efficiency Indicators: Developed based on the identified blue cluster in the co-occurrence analysis, this category groups indicators that measure the operational efficiency of dairy farms. Following the approach proposed by the literature [46], this category includes elements that influence profit generation from the farm's revenues. Subcategories were created that reflect the main components of the income statement, such as milk revenues, other revenues, cost of goods sold, etc. Additionally, a residual subcategory was created for cases where individual papers did not differentiate between costs and revenues.
- Profitability Indicators: This category, not derived from a cluster, was created to identify profitability indicators used in the industry literature. As a matter of fact, farm profitability, which is different from but depends on productivity and efficiency, summarizes a farm's economic gain [47].
- Other (Capital and Financial) Indicators: This category was created to account for the elements and indicators of capital and financial nature that are examined in the field.

Table 1. Categories and subcategories of economic and non-economic indicators.

Productivity	Efficiency	Profitability	Other (Capital and Financial)	Non-Economic
Herd performance	Cost of goods sold	-	-	Animal health and welfare
Milk production	Consumption			Environmental information
Milk quality	Milk income			Land use and quality
Other	Other cost			Other milk attributes
	Fixed cost			Farm characteristics
	Other income			Farmer characteristics
				Management practices
				Forage quality
				Ethical aspects

For comprehensiveness, based on the identified green cluster, non-economic indicators mentioned in the literature were also considered. In order to streamline data collection,

interpretation, and comprehension, the indicators were divided into subcategories. These were delineated based on economic–managerial practices for the efficiency and profitability categories [23,46], while industry-specific practices were employed for the productivity category [48].

3. Results

The studies selected through the systematic literature review possess distinct attributes that enhance the overall comprehension of the research field. By incorporating a wide array of methodologies, geographic locations, and research emphases, the selected studies provide valuable perspectives and insights into the topic at hand. The incorporation of studies from diverse sources ensures a broad spectrum of viewpoints, augmenting the reliability and validity of the findings. In the coming section, the presentation of the characteristics of the studies included in the review is conducted. Following this, descriptive information regarding the economic and financial aspects identified in the industry literature from dairy enterprises in advanced economies is provided.

3.1. Characteristics of Included Studies

It is interesting to note that the proportion of publications from a particular country seems to mirror the corresponding proportion of milk quantity produced by it. The majority of publications (over 27%) were found to be written in the United States, which is the leading milk-producing nation among "developed economies" and the second largest globally after India [15]. However, if we consider the combined countries in the European continent, it becomes evident that this continent produces more milk compared to the United States alone (30% for Europe versus 13.8% for the US). Similarly, the total number of publications originating from Europe is significantly higher than those produced in North America (including the United States), as depicted in Figure 3.
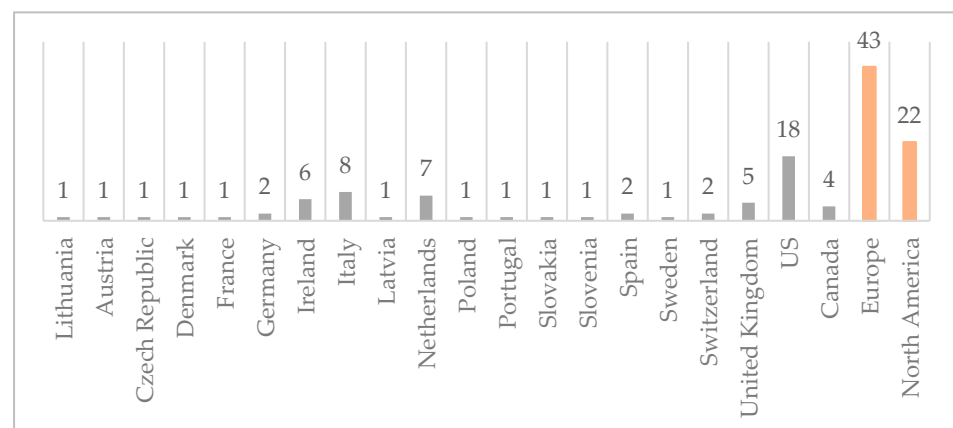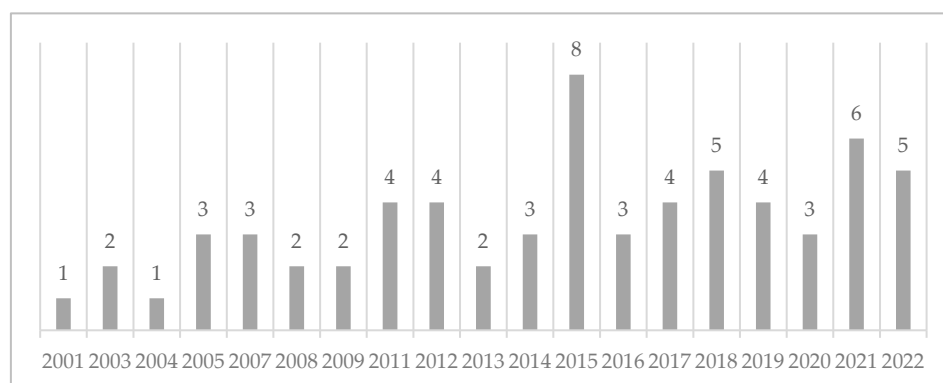

Figure 3. Frequency of publication per country (in grey) and continent (in orange).

Regarding the year of publication, it is noteworthy that most of the analyzed works were published in 2015, as depicted in Figure 4. Additionally, there has been no discernible increase in publications in recent years, precluding the assertion that the study of performance indicators in agricultural enterprises has witnessed a surge in research attention. Although the literature is chronologically distributed, the following paragraphs will analyze how the focus on specific performance indicators has changed.

Regarding the methodology, the scrutinized literature revealed a clear predominance of quantitative studies (*n* = 46). In more detail, over two-thirds of the analyzed works consisted of quantitative empirical studies, while twenty per cent (13) were literature reviews. The remaining papers encompassed the following methodologies: exploratory case study (4), conceptual paper (1), and mixed methods (1). This comprehensive approach

ensures that conclusions are grounded in empirical data while also benefiting from the broader perspectives offered by review papers.

Figure 4. Frequency of publication per year.

The analysis of contributing journals revealed the involvement of 41 different publications in the subject under scrutiny, highlighting the widespread significance of the theme across diverse knowledge domains [38]. Among the examined publications, almost half (30) were found in the top six journals in the field of animal sciences, with the "Journal of Dairy Science" being the primary contributor, accounting for more than a quarter of the analyzed papers (17). Table 2 provides a comprehensive overview of the journals with the highest representation of studies included in the review.

Table 2. Frequency of publication per journal.

Academic Journal	N° of Papers	Percentage
Journal of Dairy Science	17	26.2%
Journal of Agricultural Science	5	7.7%
Sustainability (Switzerland)	2	3.1%
Animal	2	3.1%
Tropical Animal Health and Production	2	3.1%
Irish Journal of Agricultural and Food Research	2	3.1%
Other journals	35	53.7%
Total	65	100%

The examination of the fields of knowledge covered by the analyzed papers, as depicted in Table 3, further emphasizes the relevance of the topic in various research areas. Veterinary and animal sciences, along with agricultural sciences, emerged as the predominant focus of the published studies. Economic and managerial sciences, on the other hand, constituted a smaller proportion (less than 10%) within the subject matter. This inductive analysis preliminarily suggests that the performance evaluation of dairy farms is predominantly examined through a veterinary or agronomic lens, rather than a managerial or financial perspective.

Table 3. Frequency of publications by field of knowledge.

Field of Knowledge	N° of Papers	Percentage
Veterinary and Animal Sciences	30	46.2%
Agricultural Sciences	15	23.1%
Environmental Sciences	6	9.2%
Economics and Management	5	7.7%
Medicine	3	4.6%
Food Sciences	3	4.6%

Table 3. *Cont.*

Field of Knowledge	N° of Papers	Percentage
IT Sciences	2	3.1%
Biology	1	1.5%
Total	65	100%

3.2. Performance Indicators Results

Through a manual process of identifying both economic and non-economic performance indicators, a total of 869 indicators were identified across the 65 papers analyzed. On average, each paper incorporated or reported more than 13 performance indicators. Table 4 presents the frequency of selected indicators within the previously defined categories and the percentage distribution.

Table 4. Indicator distribution summary: categories, and absolute, percentages, and relative frequencies.

Categories	Abs. Frequencies	% Total	%Economic Indicators
Efficiency	332	38%	48%
Productivity	271	31%	39%
Profitability	67	8%	10%
Other (Capital and Financial)	17	2%	3%
Non-Economic	182	21%	-
Total	869	100%	100%

It is evident that the literature predominantly focuses on efficiency, which pertains to the ability of an agricultural company to maximize the utilization of productive inputs [46], and productivity, which relates to output dynamics [49]. These two categories encompass nearly 70% of the identified indicators in the literature. Moreover, in terms of economic indicators alone, they account for over 87% of the analyzed information. Notably, there is a presence of specific indicators related to profitability, although they represent only 8% of the total indicators used.

Conversely, the category of "other (capital and financial)" indicators, encompassing items such as "debt", "investments", and "WACC", has a very low frequency, accounting for only 3%. Therefore, indicators associated with financial and capital dimensions receive limited analysis within the dairy sector's literature. As argued in the "Discussion" section, the absence of a capital and financial analysis poses a significant weakness in evaluating the performance of dairy farms, particularly considering their high levels of indebtedness within the primary sector [50].

However, it is important to note that the results regarding this cluster of "non-economic" indicators are heavily influenced by the criteria used for paper selection and fall outside the scope of the investigation. Therefore, although the "non-economic" indicators appear (at least) three times more frequently than profitability indicators, they will not be analyzed in detail.

3.2.1. Productivity Indicators

In this cluster, all the elements found in the literature related to the outcomes produced by dairy farms are included [51–53]. Table 5 presents the absolute frequencies and percentages of the mentioned elements, classified into different subcategories.

Table 5. Productivity indicator subcategories: type, and absolute and percentage frequencies.

Productivity Subcategories	Abs. Frequencies	% Total
Herd performance	140	52%
Milk production	90	33%
Milk quality	34	13%
Other	7	3%
Total	271	100%

Contrary to expectations, the subcategory with the highest frequency does not pertain to the amount of milk produced (constituting 33% of the total), but rather focuses on aspects associated with herd performance (making up 52% of the total). Even so, it is necessary to point out that this result is because there are considerably more indicators related to herd performance (25 indicators) than those related to milk quantity production. Consequently, even though the subcategory of milk quantity production has a lower frequency of indicators, the variable "milk yield" stands out as the most commonly addressed element in the literature when discussing dairy farm productivity. Other notable productivity elements include "herd size" (33), "somatic cell count" (23), and "culling rate" (14).

When analyzing the level of productivity in dairy farms, less attention is given to milk quality aspects. Only 13% of the total productivity indicators evaluate milk quality characteristics, such as the percentage of fat (15) or protein (14). The remaining productivity indicators mainly refer to the output of agricultural products necessary for animal nutrition.

3.2.2. Efficiency Indicators

This cluster comprises elements identified in the literature that impact the operational efficiency of dairy farms [46]. Table 6 presents the frequencies of different subcategories.

Table 6. Efficiency indicator subcategories: type, and absolute and percentage frequencies.

Efficiency Subcategories	Abs. Frequencies	% Total
Cost of goods sold	171	54%
Consumption	41	12%
Milk income	39	12%
Fixed cost	18	5%
Other cost	42	13%
Other income	21	6%
Total	332	100%

As emerged from the co-occurrence analysis, even by a manual analysis, it is evident that the most analyzed aspect in the literature is represented by the elements composing the cost of goods sold (54% of the total). In detail, it is worth noting that, in line with extensive discussions in the literature [46–48], the most analyzed cost item is the "feed costs" (cited 43 times), followed by "labour costs" (27) and "veterinary costs" (18). Interestingly, albeit to a lesser extent, some academic attention also focuses on consumption (12% of the total), considering it separately from the price at which resources are paid. Even in terms of consumption, the most analyzed items are "feed" (14) and "labour" (8). As expected, milk revenue is also well-represented in the literature (12% of the total), with the main mentioned items being "milk price" (20) and revenue based on "price and quantity sold" (17). It is important to note that the literature's attention to fixed costs (6% of the total), encompassing items such as "machinery costs" (6) and facilities (4), is lower compared to "other costs" (10% of the total), which includes elements like "opportunity costs" (5) and "administrative costs" (1). The limited analysis of fixed costs will be addressed in the subsequent section as an additional weakness in performance evaluation, particularly considering the rigid asset structure of dairy farms [54].

3.2.3. Profitability Indicators

With the aim of understanding which indicators of economic sustainability are being used by dairy farms, profitability indicators were also distinguished. In this case, as observed earlier, no subcategories were created, but the identified indicators, along with their absolute frequencies and relative percentages, are directly presented (Table 7).

Table 7. Profitability indicators: type, and absolute and percentage frequencies.

Profitability Indicators	Abs. Frequencies	% Total
Gross margin	24	36%
Net margin	18	27%
Income over feed cost	8	12%
Other with less than 5 frequencies	17	25%
Total	67	100%

Among the spectrum of profitability indicators, the most recurrently utilized is the gross margin. This indicator is typically calculated by deducting variable costs from the combined revenues of the farm, encompassing both milk and other sources of income. However, the methodological variations used to determine the "gross margin" are evident. For instance, Pečnik and Žgajnar [55] omit details regarding the collection of variable costs, while Oudshoorn et al. [56] concentrate solely on variables such as feed, medical treatment, and fertilizer costs. In contrast, Wilson [57] broadened the calculation of the gross margin to encompass a wider array of costs, including irrigation expenses, seed costs, and various loosely defined expenses.

The net margin, which is another crucial profitability indicator, enhances the evaluation process by encompassing the overall difference between total revenues and the complete range of costs incurred. The net margin serves as a more comprehensive measure of economic performance compared to the gross margin, as it takes into consideration activities beyond operational aspects. However, its calculation necessitates a more extensive set of data. For instance, Wilson [57] extends the scope of the gross margin by incorporating fixed expenses like contracted labour outlays, machinery expenditures, land-related costs (including opportunity costs or rent), and family labour charges to ascertain the net margin. This complexity in calculation might contribute to the relatively lower frequency of this indicator within the literature.

A compelling trend surfaces in the form of the "Income over Feed Cost" indicator, which has gained traction in recent years. This metric measures residual income after accounting for purchased and internally produced feed costs. Notably, Atzori et al. [58] adopt a comprehensive approach, incorporating all income sources from farming—ranging from milk sales to calf sales and slaughter-related income. In contrast, Buza et al. [52] focus exclusively on income stemming from milk sales when calculating this indicator. Notably, all eight publications employing this indicator were published after 2012. This trend underscores the dynamic nature of economic evaluation within the dairy sector, reflecting both evolving methodologies and changing priorities.

3.2.4. Other (Capital and Financial) Indicators

Consistent with the recommendations outlined in the literature regarding the dimensions of economic sustainability [21,22] to be assessed for a business, this category consolidates all the profitability, capital, and financial indicators documented in the literature that have not been classified within the preceding clusters. Table 8 presents the limited results obtained.

Table 8. Other (Capital and Financial) indicators: type, and absolute and percentage frequencies.

Profitability Indicators	Abs. Frequencies	% Total
Debt	2	12%
Investments	2	12%
Economic Breeding Index	2	12%
WACC	1	6%
Production risk	1	6%
Discount rate	1	6%
Milk demand	1	6%
Milk pay-out	1	6%
Equity rate	1	6%
Tax rate	1	6%
Inflation rate	1	6%
Deflation rate	1	6%
Wage rate	1	6%
Interest rate	1	6%
Total	17	100%

In addition to noting the low absolute frequencies of these terms in the literature, it is also interesting to observe that these 17 additional indicators related to assets and financial aspects are found in nine publications, all published in the last decade. Therefore, it seems that these aspects have emerged only in recent years, although still very modestly.

4. Discussion

The purpose of this study was to provide a comprehensive review of the economic sustainability indicators in the dairy industry. A systematic literature review and co-occurrence analysis were employed to identify and categorize them. The majority of the data came from primary quantitative studies, ensuring a robust empirical foundation for the conclusions. However, review papers were included in order to provide a comprehensive synthesis of existing research and highlighting indicators that are widely recognized and validated across different studies. For the discussion, it is noteworthy to observe the relative frequency with which different indicators are used within the academic literature, rather than their absolute values. The absolute values are significantly constrained by the criteria employed for the identification and selection of papers using the PRISMA method.

Before discussing the indicators that analyze overall farm performance, it is important to note that many of the reviewed studies focus on approaches, methodologies, and technologies that aim to increase the productivity or profitability of the farms. As a result, many publications tend to focus primarily on the economic effects that individual innovations can have on dairy farms, rather than delving into the comprehensive economic and financial performance of the entire enterprise. For instance, studies conducted by Luini et al. [59], Dillon et al. [60], and DeLong et al. [61] examine the marginal effects on production levels and profitability achieved through the introduction of new techniques to combat animal diseases, particularly mastitis. Others explore the cost–benefit analysis of implementing automated systems for both milking processes and health monitoring in dairy farms [46,57,62]. Buza et al. [52], Tabacco et al. [63], and Schaub et al. [64] even analyze the marginal economic impact of different feeding techniques on milk production and profitability, using indicators such as the gross margin and net margin. Therefore, although many studies cite and utilize performance indicators related to productivity, efficiency, and profitability, it is necessary to emphasize that these analyses are not always conducted at a comprehensive level but often focus on individual interventions.

When evaluating the overall economic performance of a farm, a comprehensive analysis of various business aspects, including the overall effectiveness, efficiency of economic and financial decisions, and continuity prospects, must be conducted [65]. Specifically, this analysis entails considering a balanced system across three dimensions: income, capital, and financial [21,22]. The need to simultaneously consider these three economic dimen-

sions is a fundamental concept widely discussed in traditional economic and managerial literature for over fifty years [61–64].

Regarding the dairy industry, after conducting a thorough systematic literature review, it is not possible to assert that all three dimensions are equally evaluated when analyzing the economic and financial performance, both for individual improvement interventions and at the farm level. As observed, the dairy literature primarily focuses on indicators related to the income dimension, providing huge evidence on indicators that assess both the outcomes generated by farms (productivity indicators) and the efficiency of resource utilization in producing those outcomes (efficiency indicators). In this regard, it is important to highlight that the income performance of dairy farms is analyzed in each of its dimensions, considering both the input resources and output production [65,66].

This information, as widely discussed in the management literature [66–68], offers valuable insights that inform the development of effective business strategies [69,70]. As stated by Marginean et al. [71], "Identifying the contribution of every group of expenses to the formation of results is necessary when the company's management seeks to improve the financial strategy. The extent to which each type of expense contributes to the formation of results is thus important when decisions regarding policy stabilization are made to minimize expenses". However, Marginean et al. [71] also highlight that relying solely on the income analysis provides a myopic view of farm performance when the capital and financial dimensions are not taken into consideration. For example, a farm may be more efficient than another because it has made significant investments in acquiring better machinery. However, the improved efficiency may not justify the purchase of that machinery, rendering the effort (financial and asset-related) futile. Without a financial and asset perspective, this piece of the puzzle remains unseen, leading to the potential misinterpretation of the economic performance of various farms.

The systematic literature review revealed that the absolute frequencies of profitability indicators are comparatively lower than those of efficiency and productivity. Not only that, these indicators are not related to the asset dimension of the dairy farm. Both the net margin and gross margin can be considered good indicators to obtain an idea of the economic margins [72] generated by the activities of the dairy farm during a single financial year. However, these indicators alone overlook important information. The net margin and gross margin do not provide indications of the amount of investment made by the farm to achieve a specific goal. These indicators also fail to indicate a farm's financial capacity. While they allow for an understanding of the generated economic margins, they do not reveal when these margins transform into cash flows [73].

Indicators that analyze economic margins in relation to revenue, such as the net margin and gross margin, generate information that "could almost always have positive or negative relevance for the evaluation of the company; therefore, it is necessary to consider the underlying phenomena in order to express a judgment on the economic sustainability" [73]. As already widely discussed in the management literature, the economic viability of a business requires evaluating financial and capital information, such as the size of assets and the commercial working capital. The need to evaluate income results in light of the financial and asset dimensions becomes even more important in the presence of a rigid asset structure [74] (where long-term assets significantly outweigh short-term assets), and a high level of financial indebtedness [75]. This scenario is particularly prominent in dairy farms, especially those located in more developed nations [50].

To prevent any potential confusion among those less acquainted with the managerial literature, it is deemed useful to emphasize that, while some studies suggest that a rapid assessment of a farm's economic performance may be achieved through profitability indicators alone, these indicators are consistently contextualized within the papers to encompass both income and capital dimensions. Widajatun et al. (2020) [76] estimate economic sustainability using only profitability indicators, but they juxtapose the firm's profits (either gross or net) with the scale of productive assets. However, the systematic literature review

has revealed that profitability indicators used by dairy farms take into consideration only the income balance aspect.

It is also necessary to point out that a wide profitability indicator used by dairy farms is income over feed cost (IOFC) [47,53,72–76] which measures what remains of milk income after subtracting the feed cost of lactating cows on a per-cow-per-day basis or per hundredweight basis. Many sources [73,76] even consider this indicator as a "better metric for evaluating profit margins". However, this indicator still provides a partial expression of the generated economic margins as it only considers feed costs. Moreover, when analyzing the IOFC indicator in depth, it is noticeable that the numerator (income) can be disaggregated into milk price multiplied by the quantity of milk, and the denominator (feed cost) can be disaggregated into feed price multiplied by the quantity used. Different studies [77,78] have widely demonstrated that livestock farms have very little control over the purchase price of feed and the sale price of milk. Therefore, the farm can influence the quantities of milk produced and feed consumed but not the prices. Thus, if prices are considered as an exogenous lever to the farm, IOFC mainly indicates efficiency rather than economic profitability.

The systematic literature review revealed a wealth of evidence that underscores the multifaceted relationship between milk quality and dairy farm productivity. The literature delves into several indicators of milk quality, including, but not limited to, fat and protein percentages [64] and somatic cell counts [79] offering insights into the intricate interplay between product attributes and overall farm performance (always limited to the income dimension alone). The emphasis on milk quality is not surprising, given its far-reaching implications for both economic returns and consumer satisfaction. However, the exploration of milk quality goes beyond isolated indicators to broader considerations, such as animal health conditions. This holistic perspective recognizes the inherent interconnectedness of various aspects within the ecosystem of a dairy farm. In particular, several recent studies have ventured into analyzing how milk quality is closely linked to dairy animal welfare. Villettaz-Robichaud et al. [80] demonstrated that the milk production genetic index, a useful quality indicator, has a positive relationship with animal welfare.

In light of the extensive analysis conducted in this study, several promising directions for future research emerge, each contributing to a deeper understanding of economic sustainability within the dairy industry. Firstly, there is a critical need to expand the scope of performance indicators beyond traditional income-focused metrics to encompass the holistic economic landscape of dairy farms. This entails a comprehensive assessment that integrates financial and capital dimensions alongside productivity and efficiency analyses. By incorporating these additional dimensions, researchers can offer nuanced insights into the interplay between investment decisions, asset management strategies, and overall farm performance. Additionally, given the dynamic nature of the dairy industry and evolving market conditions, there is a compelling need for longitudinal studies that track the long-term impact of various interventions and management practices on farm profitability and resilience. By adopting a longitudinal approach, researchers can capture the complex dynamics of economic sustainability and inform strategic decision-making for dairy stakeholders. Ultimately, by embracing these future research directions, scholars can contribute to the advancement of knowledge in dairy farm economics and empower industry practitioners to navigate the challenges and opportunities of a rapidly changing landscape.

5. Conclusions and Future Directions

The pressing challenges within the dairy supply chain, especially within developed countries [14], underscore an unprecedented emphasis on the urgent necessity for dairy farms to adopt a profoundly holistic approach to evaluating their economic sustainability. Beyond the mere yield analysis [81], it is becoming ever more vital for these businesses to undertake comprehensive analyses that embrace a wide spectrum of interconnected indicators. Maintaining a continuous assessment of operational efficiency and effectiveness

(pertaining to the Income Dimension), strategically allocating investments (within the Capital Dimension), and proficiently transforming income into liquid assets (addressing the Financial Dimension), while ensuring the integrity of production quality, stands out as paramount factors demanding meticulous scrutiny [21,22]. These factors form the basis on which dairy farms must focus their attention to maintain their competitive position [82] within increasingly saturated markets [14].

From the systematic literature review on the dairy sector, a compelling incumbent emerges, that calls for the incorporation of a broader spectrum of indicators to comprehensively measure the economic sustainability of the various actors engaged in the supply chain. The current repertoire of indicators, while relevant, fails to encapsulate the intricate interplay of variables and the nature of economic sustainability.

Consequently, it becomes of paramount importance to adopt additional indicators that delve into the dimensions of operational efficiency and effectiveness, strategic investments, and financial strength. This evolution in indicator selection and assessment methodology is not merely a suggestion, but rather an imperative that resonates from the collective insights gleaned from the extensive analysis of existing research. By developing a sector-specific comprehensive set of indicators, the dairy industry can navigate the complex landscape more accurately, better inform decision-making, and strengthen the resilience of the entire supply chain.

Numerous high-competition industrial sectors have already embraced sophisticated management control systems, which serve not only to co-ordinate and optimize operational activities but also to account for (and divulge) the asset and financial dimensions of the enterprise to give a comprehensive understanding of economic sustainability. Further research should consider the application of these indicators, tailoring them to address their specific requirements.

Additionally, an exciting direction for development arises in the formulation of performance indicators that seamlessly align across the various stakeholders involving the dairy supply chain. Extending the application of these indicators to diverse actors, such as milk processors, distributors, and marketing companies, would furnish the entire chain with a comprehensive and shared reference framework. Embracing such an integrated approach bolsters the resilience of individual dairy farms, thereby fortifying the entire supply chain against uncertainties. The positive impacts of this integration extend beyond efficient information and knowledge sharing, opening avenues for attracting new capital investments in the sector. This influx of capital, driven by a deep understanding of performance indicators spanning the entire supply chain, enhances the sector's capacity to innovate, modernize, and grow sustainably.

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