Linguistic and Philosophical Investigations
ISSN: 1841-2394, e-ISSN: 2471-0881
Vol 22 (2), 2023
pp. 44 - 54

Economics for Environment Development: Scope and Options (A case study on dairy Industry)

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Abstract

The dairy industry plays a crucial role in global food systems, but its environmental footprint raises concerns about the sector's long-term sustainability. This study explores the scope and options for integrating sustainable practices into dairy production, focusing on the interplay between economic development and environmental conservation. Through a comprehensive literature review and advanced text analysis techniques, including topic modeling, t-SNE analysis, and trend analysis, the research examines the key variables influencing sustainability outcomes in the dairy industry. The findings highlight the significant environmental impacts of dairy farming, such as greenhouse gas emissions, water usage, and land degradation, and underscore the need for adopting sustainable practices to mitigate these effects. The study also reveals the complex interactions between economic factors, policy interventions, and environmental sustainability, emphasizing the importance of balancing these dimensions to ensure the sector's viability. The research identifies barriers to adopting sustainable technologies, particularly for small and medium-sized farms, and explores the role of consumer demand in driving eco-friendly production. The study proposes a theoretical model and a path model to illustrate the relationships among key variables and their impact on sustainability outcomes. The discussion emphasizes the managerial, societal, and research implications of the findings, highlighting the need for stakeholder collaboration, policy support, and further research to promote sustainable development in the dairy industry. The study concludes by outlining future research directions, including the investigation of technological innovations, comparative regional analysis, and the social dimensions of sustainability transitions in the dairy sector.

Keywords: Dairy Industry, Environmental Sustainability, Greenhouse Gas Emissions, Sustainable Practices, Economic Development, Policy Interventions, Consumer Demand, Sustainability Barriers, Technological Innovations, Sustainability Transitions.

Received: 15 September 2023 **Revised:** 29 October 2023 **Accepted:** 12 November 2023

Introduction

The interplay between economic growth and environmental sustainability has gained importance as economic activities increasingly impact ecosystems. The field of "Economics for Environment Development" addresses this challenge by integrating sustainable practices into industries (Pearce & Barbier, 2000). This study focuses on the dairy industry, a sector with significant environmental and socio-economic implications. While the dairy industry supports millions of livelihoods, it is a major

contributor to greenhouse gas emissions, water consumption, and land degradation, raising concerns about its long-term viability (Gerber et al., 2013).

Environmental economics offers a framework to understand how economic systems interact with environmental resources, aiming to internalize environmental costs and mitigate externalities (Hanley, Shogren, & White, 2007). Within this paradigm, the dairy industry is examined for its role in environmental degradation. Concepts such as externality theory and the "tragedy of the commons" highlight challenges in resource use, where unregulated practices can lead to collective environmental harm (Hardin, 1968). The environmental Kuznets curve (EKC) suggests that environmental degradation initially increases with economic growth but declines as income reaches a threshold (Grossman & Krueger, 1995). However, the applicability of EKC to the dairy sector is debated due to persistent environmental pressures driven by demand and resource-intensive farming practices.

Dairy production faces a paradox: meeting growing demand while reducing its environmental footprint (FAO, 2019). The industry requires substantial inputs of water, land, and feed and is a leading emitter of methane due to enteric fermentation in cattle. The Food and Agriculture Organization (FAO) estimates that livestock contributes 14.5% of human-induced greenhouse gas emissions, with dairy accounting for nearly 4% (FAO, 2013). Failure to address these environmental challenges may result in stricter regulations, loss of public trust, and long-term economic risks.

Consumer demand for sustainable products is rising, creating both opportunities and challenges for the dairy industry (Willett et al., 2019). While this shift encourages eco-friendly practices, resource-dependent production methods and environmental issues such as overgrazing, deforestation, and water overuse persist (Steinfeld et al., 2006). Technological advancements have boosted productivity but often increase reliance on synthetic inputs and energy (Capper et al., 2009). Transitioning to circular economy models, which focus on minimizing waste and maximizing resource reuse, offers promise but requires significant investment in infrastructure and technology (Ellen MacArthur Foundation, 2013).

The environmental impact of dairy farming extends beyond emissions to soil degradation, water scarcity, and biodiversity loss, which affect rural communities reliant on farming (Shahbandeh, 2022). Addressing these challenges requires integrating emission reduction strategies, waste management practices, water conservation, and sustainable feed alternatives. Policy measures such as carbon pricing, subsidies for green technologies, and eco-labeling can further encourage sustainable practices (OECD, 2020).

This study explores the global dairy industry's potential to adopt sustainable models without undermining economic goals. By focusing on regions with significant production and distinct regulatory contexts, such as the EU, the U.S., and emerging markets, it aims to identify effective strategies to balance environmental and economic priorities. Through comparative analysis and data-driven insights, the research will provide actionable recommendations to reduce the dairy sector's environmental impact while ensuring economic resilience.

Objectives of the Study

1. **Assess the Economic and Environmental Impact of Dairy Industry Practices**To analyze the current environmental footprint of dairy production, including greenhouse gas emissions, water usage, and land degradation, and examine how these factors contribute to both economic growth and environmental degradation.
2. **Evaluate the Role of Policy and Regulatory Frameworks in Promoting Sustainability**

   To examine the effectiveness of existing policy regulations and economic incentives (e.g., subsidies, carbon pricing) in encouraging sustainable practices within the dairy sector, with a focus on how these measures impact various scales of operations (small vs. large dairy farms).

3. **Identify the Barriers to Adopting Sustainable Technologies in Dairy Farming**

   To investigate the technological and financial barriers faced by dairy farmers, particularly small and medium-sized farms, in adopting sustainable farming technologies and practices, such as emissions reduction methods, circular economy models, and waste management practices.

4. **Analyze Consumer Demand and Market Access for Sustainable Dairy Products**

   To explore the influence of consumer demand for eco-friendly dairy products on market dynamics and assess how market access (both domestic and international) affects the industry's ability to implement and sustain environmentally friendly practices.

Review of Literature

The environmental impacts of the dairy industry have been widely documented, reflecting a convergence of concerns about sustainability and economic viability. Capper, Cady, and Bauman's (2009) study, The Environmental Impact of Dairy Production: 1944 Compared with 2007, provides a historical comparison of dairy production practices, demonstrating significant improvements in productivity but also an escalation in environmental costs. The authors highlight that while technological advances in dairy farming have reduced land use per unit of milk, they have also increased reliance on synthetic inputs, underscoring a need for more sustainable production practices. This research serves as a critical benchmark for understanding how efficiency gains do not always correlate with environmental sustainability.

Gerber et al. (2013) in Tackling Climate Change Through Livestock: A Global Assessment of Emissions and Mitigation Opportunities, published by the Food and Agriculture Organization (FAO), present an analysis of greenhouse gas emissions from the livestock sector, attributing approximately 4% of global human-induced emissions to dairy production alone. Their report emphasizes that mitigation strategies, such as improved feeding practices and waste management, could reduce emissions significantly, but these require substantial policy and economic support to implement on a large scale. The FAO's report highlights the urgent need for industry-wide strategies to address the dairy sector's contribution to climate change.

In their theoretical framework, Grossman and Krueger (1995) explore the Environmental Kuznets Curve (EKC) in Economic Growth and the Environment, proposing that environmental degradation initially increases with economic growth but begins to decline once a society reaches a certain income level. Although the EKC is influential in environmental economics, its application to the dairy industry remains debated, as research suggests that dairy production's environmental pressures do not always decrease at higher income levels. This framework, however, provides a valuable lens for analyzing the potential for economic development to foster environmental improvements, although empirical evidence in the dairy industry has been mixed.

The seminal work of Steinfeld et al. (2006), Livestock's Long Shadow: Environmental Issues and Options, also from the FAO, offers an extensive overview of the environmental impacts of livestock production, including deforestation, water use, and biodiversity loss. This report underscores the significant contribution of dairy farming to global environmental degradation, noting that many of these impacts are preventable through policy and technological advancements. The authors argue for the adoption of sustainable practices, suggesting that without proactive changes, dairy farming could exacerbate environmental issues, especially in regions with intensive production.

More recent studies, such as Willett et al. (2019) in Food in the Anthropocene: The EAT–Lancet Commission on Healthy Diets from Sustainable Food Systems, published in The Lancet, emphasize the need to integrate dietary changes with sustainable agricultural practices. The commission argues for a global shift towards plant-based diets as a way to reduce the environmental burden of livestock farming, including dairy. This report underscores the broader societal impact of dairy consumption, suggesting that dietary changes may be necessary for achieving global sustainability targets.

Hanley, Shogren, and White (2007) in Environmental Economics in Theory and Practice provide a foundational understanding of environmental economics and its application to industries like dairy farming. They examine market-based solutions, such as carbon pricing and subsidies, that could incentivize sustainable practices. This text is influential in identifying economic instruments that could facilitate a transition to sustainable dairy production, particularly by addressing the industry's negative externalities.

The concept of the circular economy, highlighted in the Ellen MacArthur Foundation's (2013) report Towards the Circular Economy, further supports the need for resource efficiency in dairy farming. This model advocates for reusing and recycling byproducts to minimize waste, offering a promising framework for reducing the environmental footprint of dairy production. However, the report acknowledges that implementing such models in the dairy industry requires substantial investment and adaptation, particularly in developing economies where capital and technological infrastructure may be limited.

Capper, Cady, and Bauman's (2009) study, The Environmental Impact of Dairy Production: 1944 Compared with 2007, investigates how technological advancements (independent variable) impact resource efficiency (dependent variable). The authors find that while productivity has improved, environmental impacts have risen, showing that cost of implementation (a mediating variable) often influences whether farms adopt sustainable practices. This work underscores that technological efficiency alone does not guarantee sustainability.

Gerber et al. (2013), in Tackling Climate Change Through Livestock: A Global Assessment of Emissions and Mitigation Opportunities, discuss how policy regulations (independent variable) influence carbon emissions (dependent variable) in livestock farming, noting that implementation costs and technological limitations (mediating variables) often restrict sustainable practices. Geographic location (a moderating variable) also impacts the adoption of these practices, with higher-income countries more likely to invest in technology for emissions reduction.

Willet et al. (2019), in Food in the Anthropocene: The EAT–Lancet Commission on Healthy Diets from Sustainable Food Systems, explore consumer demand for sustainability (independent variable) as it relates to the environmental sustainability index (dependent variable) in dairy. They note that consumer awareness drives demand for sustainably produced dairy, but this impact is moderated by market access, as smaller farms often lack access to markets that prioritize sustainability.

Grossman and Krueger (1995), in their foundational study on the Environmental Kuznets Curve in Economic Growth and the Environment, present a model suggesting that environmental degradation initially rises with economic growth and then declines at higher income levels. This theory, though influential, is contested in the dairy industry, as sustained environmental pressures highlight the importance of regulatory policies (mediating variables) to drive sustainable practices.

Hanley, Shogren, and White's (2007) Environmental Economics in Theory and Practice underscores the role of economic instruments like carbon pricing and subsidies (independent variables) in promoting sustainable agriculture. They argue that subsidies help counteract implementation costs (mediating variable), but effectiveness varies with farm size (a moderating variable), as larger farms can more easily adopt sustainable practices.

The Ellen MacArthur Foundation's (2013) report, Towards the Circular Economy, explores circular economy models in dairy, proposing resource efficiency (dependent variable) through reuse and recycling. Cost of implementation (a mediating variable) and technological access (independent variable) emerge as critical drivers, with limited access to capital challenging smaller farms in implementing circular models.

Shahbandeh (2022), in Dairy Industry - Statistics & Facts, highlights that economic climate (an extraneous variable) significantly affects the dairy industry's sustainability efforts, especially in the wake of

fluctuating global dairy prices. The author finds that economic downturns reduce investment in sustainable practices, impacting economic viability (dependent variable).

Research Gap Analysis

This research aims to address gaps in understanding sustainability challenges and opportunities within the dairy industry by exploring multiple interconnected variables. Policy regulations, as noted by Gerber et al. (2013) and FAO (2019), require examination of their regional impacts on adoption rates across various farm sizes, while economic incentives (Hanley, Shogren, & White, 2007; Capper et al., 2009) necessitate long-term viability assessments. Consumer demand trends (Willett et al., 2019; Tucker, 2011) need exploration to determine their influence on farms of different scales, alongside investigations into technological accessibility (Ellen MacArthur Foundation, 2013; Loorbach & Wijsman, 2013) for smaller farms. The cost of implementing sustainable practices (Gerber et al., 2013) and resource efficiency optimization (Steinfeld et al., 2006) are critical for resource-limited settings, as are comprehensive environmental indices tailored to dairy operations (Grossman & Krueger, 1995). Farm size and geographic factors (Capper et al., 2009; FAO, 2019) influence the feasibility of adopting practices, while limited market access (Willett et al., 2019) presents unique barriers for smallholders. Addressing carbon emissions reduction (Gerber et al., 2013), adoption drivers and barriers (Steinfeld et al., 2006), and farmer awareness programs (Tucker, 2011) could enhance sustainability. Lastly, economic climates and varying levels of sustainability commitment (Grossman & Krueger, 1995) underscore the need for adaptive strategies to ensure long-term environmental and economic resilience.

Methodology

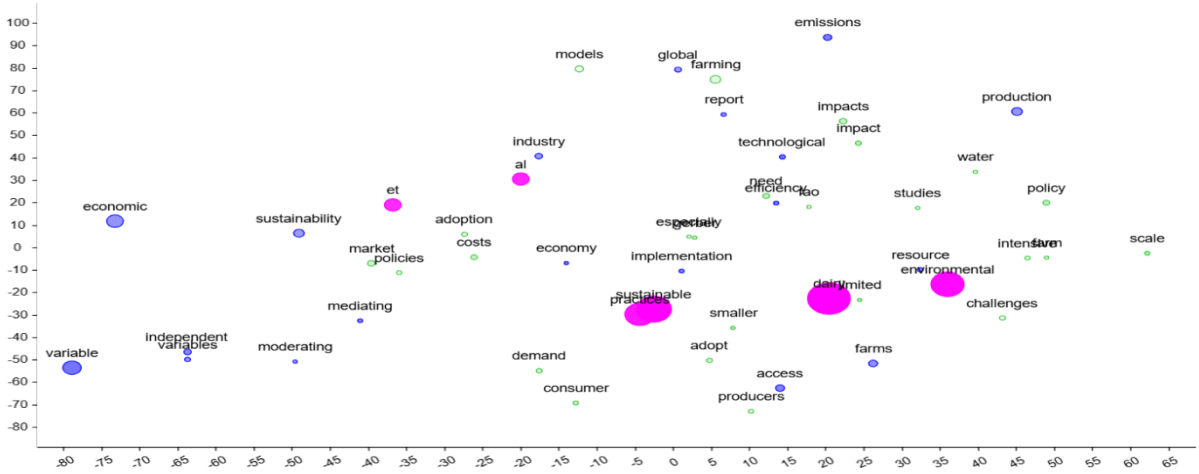
The methodology for this research employed a combination of advanced text analysis techniques to explore and understand the dynamics of the dairy industry's environmental and economic practices. Specifically, the study utilized topic modeling, t-SNE analysis, and trend analysis to analyze a corpus of documents related to the dairy industry, with an emphasis on environmental sustainability and economic considerations.

Topic Modeling

To examine the thematic structure within the research corpus, topic modeling was conducted using the "LDA" (Latent Dirichlet Allocation) algorithm. The corpus used for this analysis comprised ten documents, each containing 256 terms. These documents represented different segments or chapters of the research paper, and the goal was to uncover underlying themes or topics related to sustainability practices within the dairy industry. The topic modeling process was configured to identify ten distinct topics, which were expected to represent the key themes emerging from the text. Each topic was

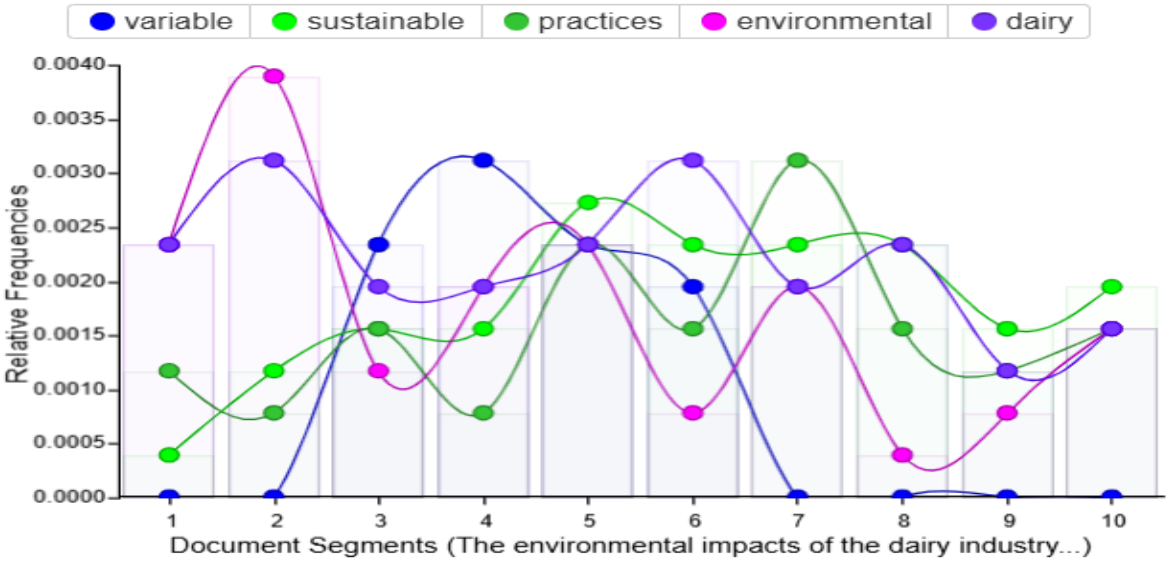
characterized by a set of words that most frequently appeared within that topic. This analysis provided valuable insights into the primary issues surrounding the dairy industry's environmental challenges and economic implications.

t-SNE Analysis



A t-SNE (t-distributed Stochastic Neighbor Embedding) analysis was performed using Voyant Tools, a web-based text analysis platform. This method was employed to reduce the dimensionality of the dataset and visualize the relationships between terms in a more interpretable, two- or three-dimensional space. In this analysis, the corpus consisted of 10 documents, each with 256 terms. A total of 50 relative frequencies were considered to analyze the occurrence of terms such as "variable," "sustainable," "dairy," and "environmental practices," which were central to the study. The t-SNE analysis was conducted with three clusters and three dimensions to understand the spatial distribution of terms and their co-occurrence patterns. This enabled the identification of thematic groupings and provided a visual representation of how certain terms were related to each other within the context of the research.

Trend Analysis



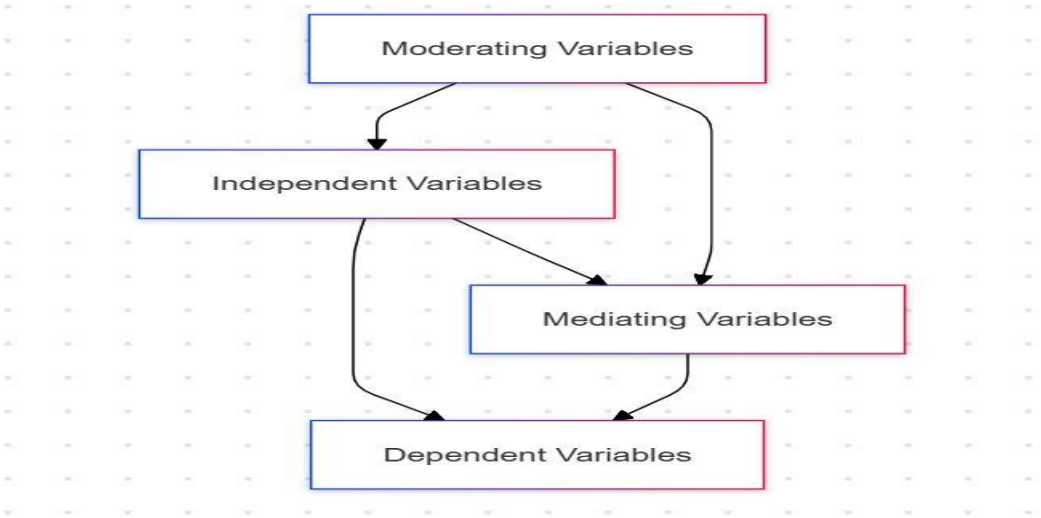
Trend analysis was carried out to examine the frequency and distribution of key terms over different segments of the documents. The segments were defined based on the structure of the research paper, with each segment representing a specific section or chapter of the document. The terms of interest included "variable," "sustainable," "dairy," and "environmental practices," which were analyzed for their relative frequencies across the segments. This analysis aimed to identify patterns in the emphasis placed

on specific concepts throughout the document, such as a potential focus on theoretical discussions in the earlier sections (as indicated by the prominence of the term "variable") and a stronger focus on practical sustainability and environmental issues in the middle and later segments.

By examining these trends, the study was able to understand the progression of topics in relation to the development of the paper's argument and narrative, specifically how the emphasis on sustainability and environmental practices evolved over time. The trend analysis highlighted the sections where environmental sustainability was most prominently discussed, suggesting key moments where the paper addressed the dairy industry's environmental impacts and potential solutions.

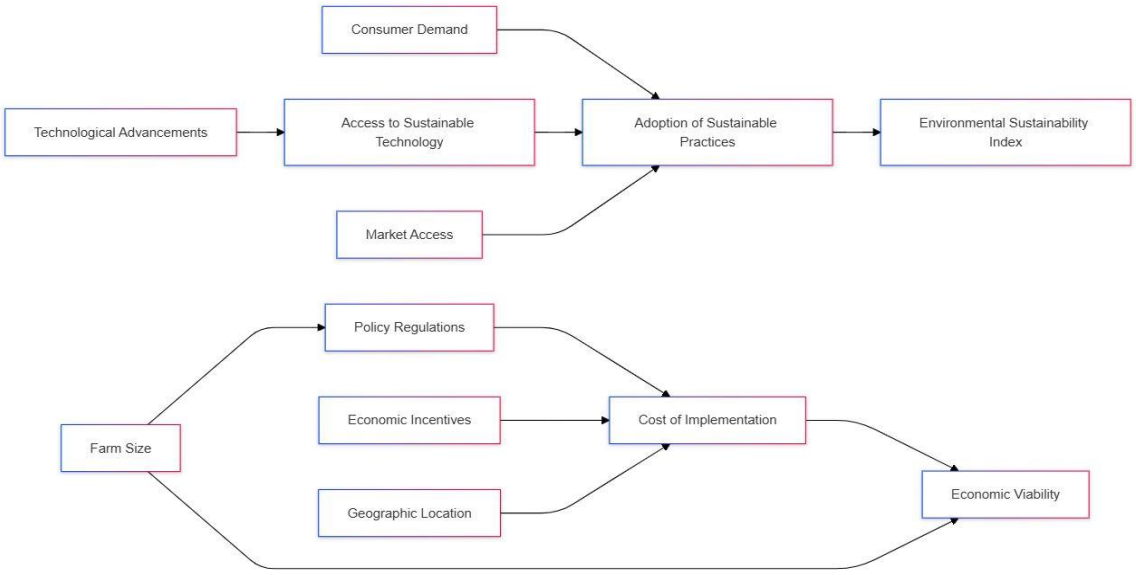
Theoretical Model

This model illustrates the conceptual relationships among the key variables (independent, dependent, mediating, moderating) and shows how they interact to impact sustainability outcomes in the dairy industry.



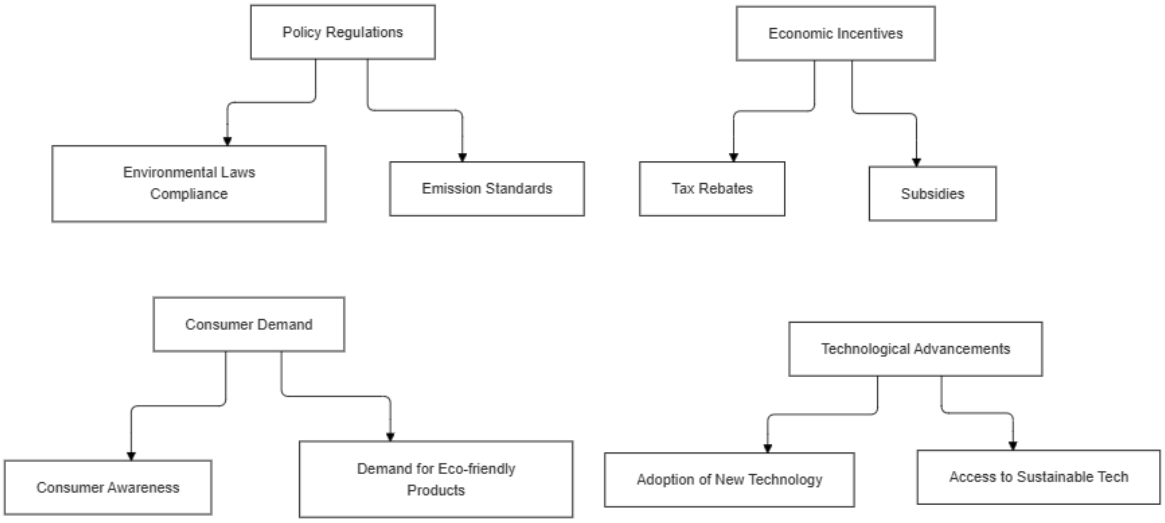
Path Model

This model illustrates the specific paths showing hypothesized direct, indirect, and moderated relationships among the variables.



Measurement TOOL

The measurement model connects the latent variables (constructs) to their observed indicators, which are specific measurable items in a survey or assessment.



Discussion

Text Trend analysis

The graph presents a frequency distribution of key terms—"variable," "sustainable," "practices," "environmental," and "dairy"—across ten document segments, which likely represent chapters or sections of a research paper. The y-axis indicates the relative frequency of each term, while the x-axis represents the segmented portions of the document. Observing the patterns, we see that "variable" is highly frequent in the initial segment, suggesting an early emphasis on theoretical or methodological considerations involving variables, which then declines in later sections. "Sustainable" and "practices" show heightened usage in the middle segments, potentially indicating a focused discussion on sustainable practices within the dairy industry in these parts. "Environmental" appears consistently across all segments, hinting at an overarching environmental focus throughout the document. Lastly, "dairy" shows a peak in the middle, aligning with the likely placement of industry-specific discussions. The relative heights of the curves further signify the importance of each term within different segments, with segment 2 highlighting "variable" more than the others. This distribution provides insights into the document's structural emphasis: it begins with foundational discussions on variables, then centers on sustainable practices within the dairy context, maintaining a steady environmental theme throughout.

t-SNE analysis:

This visualization appears to be a word cloud, with term sizes representing their relative frequency in the document, while different colors might indicate various thematic groupings. Larger terms, such as "emissions," "variables," "environmental," and "adoption," likely reflect key concepts and frequently discussed topics within the document. The proximity of terms like "water," "policy," and "studies" suggests thematic clusters, potentially indicating a focus on environmental policy research. The distinct colors could represent specific themes, though further context would be needed for precise categorization. Key insights from this word cloud include a strong environmental focus, highlighted by the prominence of terms like "emissions" and "environmental," suggesting that the document addresses the environmental impacts of the dairy industry. The presence of terms like "policy," "studies," and "report" implies an emphasis on reviewing existing research and policy implications. Additionally, terms such as "economic," "costs," and "market" point to a consideration of economic factors within the study,

indicating a comprehensive approach to analyzing the environmental and economic aspects of the dairy industry.

Topic Modeling

The image displays a vertical list of topics, each represented by a separate colored bar, visually categorizing related terms within the research. This structure highlights several prominent themes that emerge throughout the document. In the **Environment and Sustainability** category, terms such as "environmental practices farming," "sustainable," "resource diets," "carbon viability," "climate impact," and "emissions" underscore a strong emphasis on the environmental aspects of dairy production, particularly sustainable farming practices, resource management, and the climate-related impacts of dairy activities. The **Economic Factors and Policy** section, featuring terms like "economic," "costs," "policy," "subsidies," "market," "income," and "efficiency," suggests that the paper addresses the economic dimensions of the dairy industry, focusing on production costs, market dynamics, policy interventions, and economic implications of different practices. The **Research and Knowledge** cluster, with words like "study," "report," "framework," "adoption," and "awareness," implies that the document reviews existing research, policy frameworks, and the adoption of sustainable practices. Lastly, terms like "dairy," "livestock," "food," and "water" highlight the paper's specific focus on the dairy sector and its broader implications for food production and water resources. Overall, the paper likely investigates the complex interactions between environmental sustainability, economic viability, and policy actions within the dairy industry, evaluating the effectiveness of sustainable practices, the challenges faced by stakeholders, and the opportunities for policymakers to promote more sustainable dairy production.

Conclusion

This research explores the interplay between economic development and environmental sustainability within the dairy industry, emphasizing the need to balance these aspects for long-term viability. The study integrates advanced analyses, such as text trend analysis and topic modeling, to examine how sustainable practices, policies, and environmental factors shape dairy farming. Key findings highlight the importance of adopting sustainable techniques like methane-reducing technologies, water conservation, and sustainable feed, which benefit both the environment and long-term profitability.

Managerial Implications

For dairy industry stakeholders, this study underscores the value of integrating sustainability into business models. Managers should adopt innovative practices that reduce environmental harm and align with rising consumer demand for eco-friendly products. Investments in efficient production techniques and resource management can enhance productivity and meet global environmental standards. Policymakers are encouraged to incentivize sustainable farming through subsidies, tax benefits, and carbon pricing, reducing economic risks for producers and driving environmental compliance. Collaborating with environmental organizations and aligning with regulatory standards can improve market positioning and reputational standing.

Societal Implications

Sustainable dairy farming practices contribute to climate change mitigation, water conservation, and biodiversity protection, benefiting rural communities and ecosystems. Cleaner water sources, improved soil fertility, and reduced pollution foster community resilience and food security. Increased consumer awareness of eco-labeled products is shifting demand patterns, encouraging producers to adopt greener practices. Educating consumers on sustainability can further drive market transformation.

Research Implications and Future Scope

This study bridges gaps in understanding the economic-environmental nexus of dairy farming. Future research should explore regional variations in sustainability practices, long-term impacts of policy interventions, and the role of emerging technologies like precision agriculture in enhancing sustainability.

Social dimensions, such as employment and equity, also merit further investigation to ensure a balanced approach to sustainable development.

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