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EXPLORING ACADEMIA'S ROLE IN ENHANCING THE RESILIENCE OF MALAYSIA'S CATTLE SUPPLY CHAIN THROUGH THE QUADRUPLE HELIX MODEL

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Abstract:

This bibliometric study explores the role of academicians as catalysts in maintaining Malaysia's cattle supply chain industry through the lens of the Quadruple Helix model, which integrates academia, industry, government, and civil society. Utilizing bibliometric analysis, the research examines trends in scholarly publications from 2001 to 2025, focusing on productivity, subject areas, influential authors, and international collaborations. Data extracted from Scopus reveals a growing interest in the Quadruple Helix framework, with a significant surge in publications post-2020, particularly in fields such as Business, Management, and Accounting (19.7%), Social Sciences (15.4%), and Economics (12%). Notably, Agricultural and Biological Sciences remain underrepresented (1.7%), highlighting a critical research gap. The study identifies Elias G. Carayannis as the most cited author, emphasizing his foundational contributions to Quadruple Helix theory. Geographically, Indonesia leads in publications (11.08%), while Malaysia accounts for only 2.99%, underscoring the need for localized research. Keyword analysis reveals themes like sustainability, entrepreneurship, and innovation ecosystems, yet lacks an agriculture-specific focus. Co-authorship networks highlight strong European collaborations, with Malaysia showing emerging ties in Southeast Asia. The findings advocate for enhanced academic-industry-government-civil society partnerships to address challenges in Malaysia's

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cattle supply chain, offering a roadmap for future research and policy interventions.

Keywords:

Academician, Quadruple Helix, Cattle Supply Chain

Introduction

The cattle supply chain industry in Malaysia faces numerous challenges, including logistical risks and supply chain disruptions, which impact the overall performance and sustainability of the sector (Aizat Md Sin et al., 2024). To address these issues, the Quadruple Helix model, integrating academia, industry, government, and civil society, offers a comprehensive framework for fostering innovation and enhancing supply chain management (Widjajanti & Sugiyanto, 2020). Within this framework, academicians play a pivotal role by contributing knowledge, research, and technological advancements that can drive improvements in the cattle supply chain. This paper explores the role of academicians as catalysts in maintaining Malaysia's cattle supply chain industry through the Quadruple Helix model.

The Quadruple Helix model expands on the traditional Triple Helix model by incorporating civil society alongside academia, industry, and government. This inclusion emphasizes the importance of cultural and societal perspectives in innovation processes (Carayannis & Campbell, 2011a). By fostering collaboration among these four pillars, the model creates a dynamic and adaptive innovation ecosystem capable of addressing complex challenges in various sectors, including agriculture and livestock (Aggarwal & Sindakis, 2020). In this context, the cattle supply chain can benefit from a holistic approach that combines technical, social, and institutional knowledge.

Academicians are crucial in this model as they provide the foundational knowledge and research necessary for innovation. Their involvement can lead to the development of new technologies and practices that enhance supply chain efficiency and sustainability (Widjajanti & Sugiyanto, 2020). For example, in Malaysia’s cattle industry, academicians contribute by researching supply chain risk management and designing frameworks to mitigate these risks (Aizat Md Sin et al., 2024). Through partnerships with industry and government, these innovations can be translated into practical, scalable solutions that improve performance and ensure long-term sustainability (Afzal et al., 2018; Anwar & Priyono, 2016).

Academicians play a crucial role in enhancing the performance of Malaysia's cattle supply chain industry, particularly through the application of the Quadruple Helix model, which integrates academia, business, government, and the local community (Aizat Md Sin et al., 2024). Their involvement has been instrumental in mitigating logistical risks and improving management practices to support the resilience and survival of MSMEs in an ever-changing economic landscape (Mardiatmi et al., 2024). By contributing strategic insights and supporting decision-making processes, academicians help strengthen the foundations of the livestock sector, ensuring greater sustainability and operational efficiency. Furthermore, the implementation of the Quadruple Helix model has been shown to stimulate innovation and foster the development of small industries through the creation of an innovation ecosystem (Widjajanti & Sugiyanto, 2020).

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Despite these contributions, academicians face several challenges in their efforts to sustain and enhance the cattle supply chain. These include vulnerabilities in the live animal trading sector, which expose weaknesses and threats that can undermine business continuity. In addition, structural obstacles such as weak institutional frameworks, inadequate research and development funding, and limited collaboration between universities and industries hinder the full realization of academic potential in the sector (Nwaichi et al., 2025). These issues echo challenges faced in other contexts, such as the implementation of the Triple Helix model in Nigeria, and are similarly relevant to the Malaysian context, pointing to the need for improved institutional support and policy alignment.

Academicians are also driving forces behind technological innovations in Malaysia's cattle supply chain industry. The Quadruple Helix framework has facilitated the advancement of digitization among SMEs, with Sharia-compliant fintech emerging as a notable solution for addressing the disruptions caused by the COVID-19 pandemic. Moreover, the interactive dynamics among academicians, business stakeholders, and government entities highlight the critical role of universities in transferring knowledge, technology, and innovation to the broader community (Anwar & Priyono, 2016). Although current abstracts offer valuable insights into these contributions, direct economic evaluations remain limited. Nevertheless, the findings underscore the importance of continued research and collaborative efforts to enhance the sustainability, innovation, and competitiveness of Malaysia’s cattle supply chain industry.

Several studies highlight the successful application of the Quadruple Helix model across different sectors. In particular, the model has proven effective in promoting the digitalization of SMEs, showcasing the tangible impact of academic contributions on business activities and management practices [8]. In Indonesia, its implementation in small industries has demonstrated that intensive collaboration among the four pillars can result in innovative problem-solving and improved industry outcomes (Widjajanti & Sugiyanto, 2020). These examples illustrate the model’s versatility and its potential to drive sustainable development and competitiveness within Malaysia’s cattle supply chain industry.

Despite its strengths, the Quadruple Helix model is not without challenges. Power imbalances between stakeholders and insufficient interaction among the pillars can hinder effective collaboration (Barbosa-Gómez et al., 2023). To overcome these obstacles, strategic investments in capacity-building and improved coordination are essential (Nwaichi et al., 2025). Enhancing the model’s effectiveness requires stronger partnerships between academia and industry, more supportive government policies, and greater engagement from civil society (Aggarwal & Sindakis, 2020; Mardiatmi et al., 2024). When these conditions are met, the Quadruple Helix model can serve as a powerful tool to address systemic issues in Malaysia’s cattle supply chain, with academicians playing a central role in catalyzing innovation and ensuring the sector’s resilience and sustainability.

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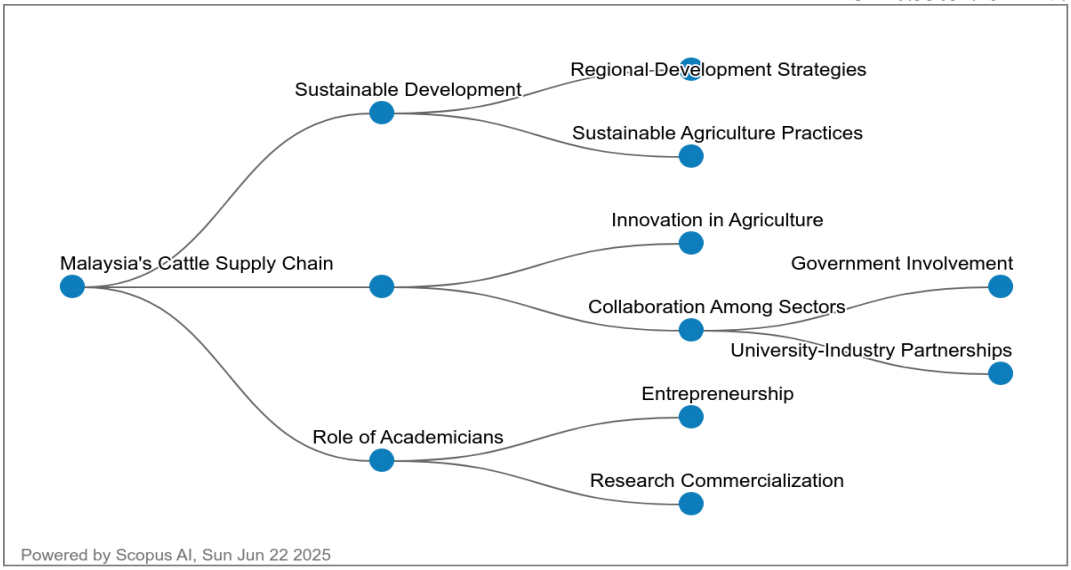

Figure 1: Mind Maps For The Malaysian Cattle Supply Chain Based On The Quadruple Helix Model.

This mind map outlines the key components of Malaysia's cattle supply chain within the Quadruple Helix framework, emphasizing sustainable development through academic research, regional strategies, and innovative agricultural practices. It highlights the critical role of academicians in driving knowledge transfer and technological advancements, supported by government policies and cross-sector collaboration. The integration of university-industry partnerships, entrepreneurship, and research commercialization further strengthens the ecosystem, while sustainable practices ensure long-term viability. By aligning these elements, such as academia, industry, government, and civil society, the model fosters a resilient and innovative cattle supply chain, addressing both current challenges and future opportunities in Malaysia's agricultural sector.

Research Question

1. What is the number of publications by year from 2001 to 2025?
2. What are the influences and subject area productivity of the topic?
3. What are the top 10 most-cited articles?
4. What are the top 10 countries based on several publications?
5. What are the popular keywords related to the study?
6. What is co-authorship based on countries' collaboration?

Methodology

Bibliometric analysis represents a quantitative research approach aimed at assessing scholarly productivity and uncovering trends within defined research domains. By applying statistical techniques to a collection of academic literature, this method reveals patterns related to authorship, publication frequency, and citation behavior (Marvi & Foroudi, 2023). Its application has become increasingly prominent across disciplines such as business, management, and health sciences, owing to its capacity to illuminate the historical progression of knowledge and the evolving structure of scientific inquiry (Öztürk et al., 2024) (Koo & Lin, 2023) (Lim et al., 2024). The process generally involves several core steps, including the

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extraction of data from bibliographic sources like Scopus or Web of Science, followed by visualization and mapping using tools such as VOSviewer and Bibliometric software (Lim et al., 2024) (Hallinger & Kovačević, 2022) (Foudah et al., 2024).

This methodology can be utilized at multiple analytical levels, ranging from broad, macro-level assessments of entire academic fields to more focused, micro-level evaluations of individual researchers' contributions (Costas et al., 2009; Costas et al., 2010). It incorporates a variety of indicators, categorized into dimensions such as research productivity, scholarly impact, and collaborative activity (Costas et al., 2009; Costas et al., 2010). These indicators serve to identify prevailing trends, research voids, and factors contributing to academic success (Costas et al., 2009; Costas et al., 2010; Siu et al., 2025). Although bibliometric analysis is widely adopted, there remains a pressing need for standardized reporting protocols to enhance consistency and validity, particularly in fields like health and medical sciences (Koo & Lin, 2023). In conclusion, bibliometric analysis stands as a critical instrument for tracing the development of academic disciplines and shaping the direction of future scholarly investigations (Tomé, 2024; Mezquita et al., 2024; Zhang et al., 2018).

Data Search Strategy

Based on the bibliometric search conducted in Scopus using the query TITLE-ABS-KEY (academician OR quadruple AND helix AND performance OR business), a total of 237 documents were retrieved. This result reflects a broad scholarly interest in topics related to academicians, the Quadruple Helix model, and their impact on performance or business outcomes. However, the structure of the search string with loosely grouped Boolean operators suggests that the documents may span a wide thematic range. Many may not directly address the cattle supply chain or even the Malaysian context specifically but instead cover general applications of academic contributions and innovation frameworks in various industries and regions. Still, this dataset serves as a foundational starting point for understanding how academia is being positioned as a driver of socio-economic development within collaborative models like the Quadruple Helix.

Table 1: The Search String

Scopus	**TITLE-ABS-KEY (academician OR quadruple AND helix AND performance OR business)**

In terms of research trends, this bibliometric finding may indicate an increasing global acknowledgment of academia's role in fostering innovation and improving performance through partnerships with industry, government, and civil society, core principles of the Quadruple Helix model. While not all 237 documents may directly reference Malaysia's cattle industry, a closer analysis (e.g., keyword co-occurrence, citation patterns, and country affiliations) can help identify clusters of studies that align more closely with agri-food systems and livestock development. This trend supports the relevance of your research focus, highlighting the need to explore more targeted studies that discuss how Malaysian academic

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institutions are collaborating with stakeholders to enhance the cattle supply chain, address food security challenges, and build sustainable agricultural systems.

Data Analysis

VOSviewer is a specialized software tool developed for constructing and visualizing bibliometric networks, encompassing relationships such as citation, bibliographic coupling, co-citation, and co-authorship (Li & Wei, 2022) (Van Eck & Waltman, 2009) (van Eck & Waltman, 2010) It has become a widely utilized instrument in scientometric studies and domain analyses due to its robust capabilities in processing bibliographic data and its continuous enhancements over time (Li & Wei, 2022). The software is freely accessible and has been integrated into platforms such as Digital Science's Dimensions, thereby facilitating broader access to co-authorship and citation network visualizations (Li & Wei, 2022; Van Eck & Waltman, 2009).

One of VOSviewer's key strengths lies in its ability to generate advanced graphical representations of bibliometric maps, enabling researchers to efficiently interpret large and complex datasets (Van Eck & Waltman, 2009). It also includes built-in text mining functions that allow for the construction and visualization of co-occurrence networks based on key terms extracted from scientific publications (Li & Wei, 2022). Moreover, VOSviewer Online extends its usability by allowing researchers to embed interactive visualizations into web-based platforms (Li & Wei, 2022). The software has been employed in a wide array of applications, including monitoring the evolution of specific research domains such as lactic acid production (Cárdenas-Arias et al., 2023) and multi-input transfer function analysis, as well as identifying thematic trends in areas like corporate governance and leadership.

VOSviewer is also known for its intuitive and user-friendly interface, making it accessible to users with varying levels of technical expertise (Van Eck & Waltman, 2009) (van Eck & Waltman, 2010). Its scalability is demonstrated by its capacity to manage extensive datasets, such as constructing co-citation maps of up to 5,000 scientific journals (van Eck & Waltman, 2010). The software supports multiple types of bibliometric analyses, including co-authorship networks, keyword co-occurrence patterns, and citation analysis (Malmqvist et al., 2019; Sahu & Chakma, 2024; Hasan et al., 2024). However, a technical limitation is that it requires structured metadata input, which may hinder its use when such data is unavailable or improperly formatted (Malmqvist et al., 2019). Another concern noted in the literature is the tendency for users to interpret visualizations directly without performing essential data cleaning and disambiguation, which may compromise the accuracy of results (Li & Wei, 2022). An important methodological feature of VOSviewer is its application of the association strength (AS_{ij}) normalization method for co-occurrence data. This is calculated as:

$$AS_{ij} = \frac{C_{ij}}{w_i w_j}$$

This formula quantifies the strength of association between items i and j as the ratio between the observed frequency of their co-occurrence and the expected frequency assuming independence. This approach enhances the reliability of visualized relationships within the dataset.

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In conclusion, VOSviewer stands out as a powerful and versatile tool for bibliometric research, offering major advantages in graphical visualization, analytical depth, and ease of use. Nonetheless, researchers are advised to conduct rigorous data preparation and apply cautious interpretation to avoid common pitfalls. The software's widespread adoption across diverse research disciplines underscores its significance in contemporary bibliometric studies and its continued relevance for future scholarly exploration (Li & Wei, 2022; Van Eck & Waltman, 2009; van Eck & Waltman, 2010; Malmqvist et al., 2019)

Results and Discussion

Document By Years

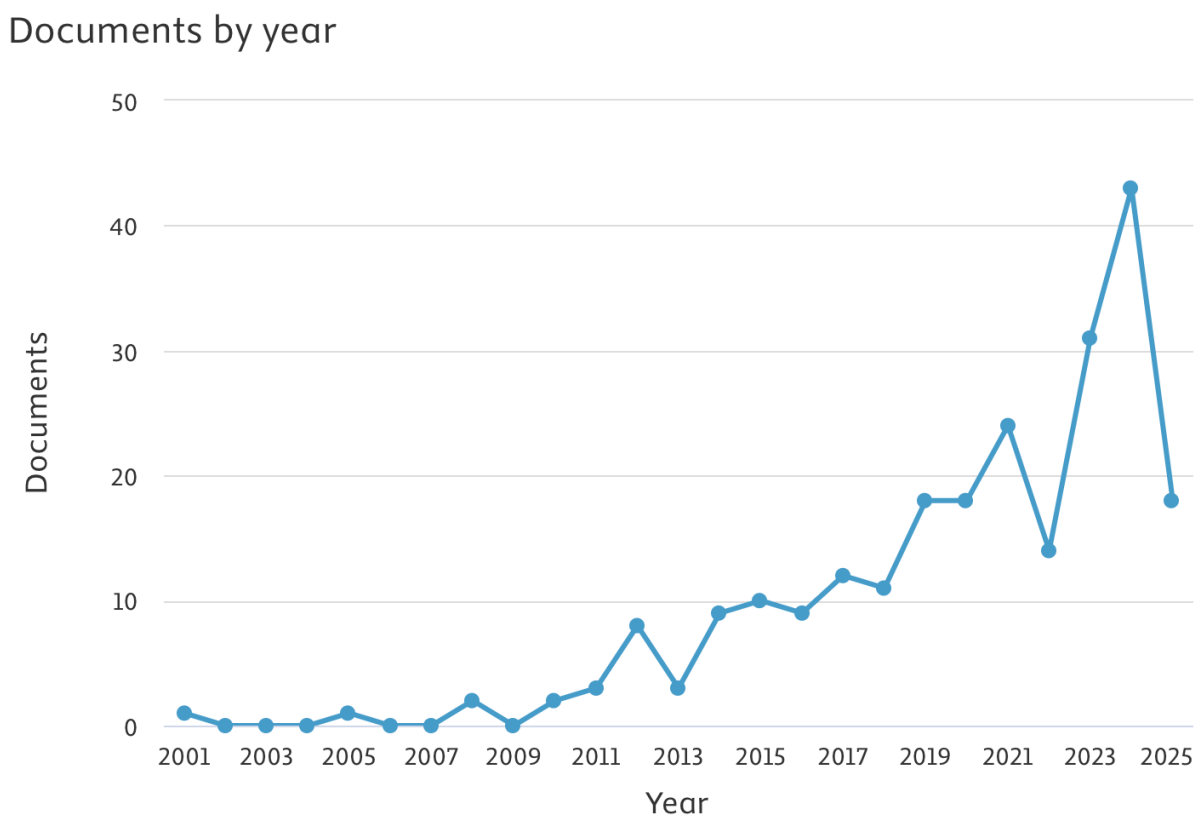

Figure 2: Document By Year

Table 2: Document By Year

Year	Documents
2025	18
2024	43
2023	31
2022	14

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2021	24
2020	18
2019	18
2018	11
2017	12
2016	9
2015	10
2014	9
2013	3
2012	8
2011	3
2010	2
2009	0
2008	2
2007	0
2006	0
2005	1
2004	0
2003	0
2002	0
2001	1

The bibliometric trend based on the number of documents published per year reveals a growing academic interest in themes related to the role of academia, the Quadruple Helix model, and their influence on performance or business. From 2001 to 2010, the publication output was minimal, with only sporadic contributions, most years recording one or zero documents. This indicates that scholarly exploration of the Quadruple Helix framework or academia's catalytic role in innovation and performance was still in its early stages. However, starting from 2011,

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the research trajectory began to show a gradual increase, with consistent output each year, signalling the emergence of the topic in academic discourse.

The growth becomes more prominent from 2020 onwards, with a significant surge in 2024 (43 documents) and continuing strongly into 2025 (18 documents as of the current data point in June). This spike suggests heightened scholarly attention, possibly influenced by global trends in sustainable development, food security, and stakeholder collaboration in response to post-pandemic supply chain disruptions. The 2023 output (31 documents) also marks a peak, reinforcing the relevance of this research domain. Such an upward trend reflects increasing recognition of academia's role in multi-actor innovation systems, especially within sectors like agriculture and livestock. This reinforces the timeliness and importance of investigating how academic institutions can act as catalysts in strengthening Malaysia's cattle supply chain through collaborative models like the Quadruple Helix.

Document by Subject Area.

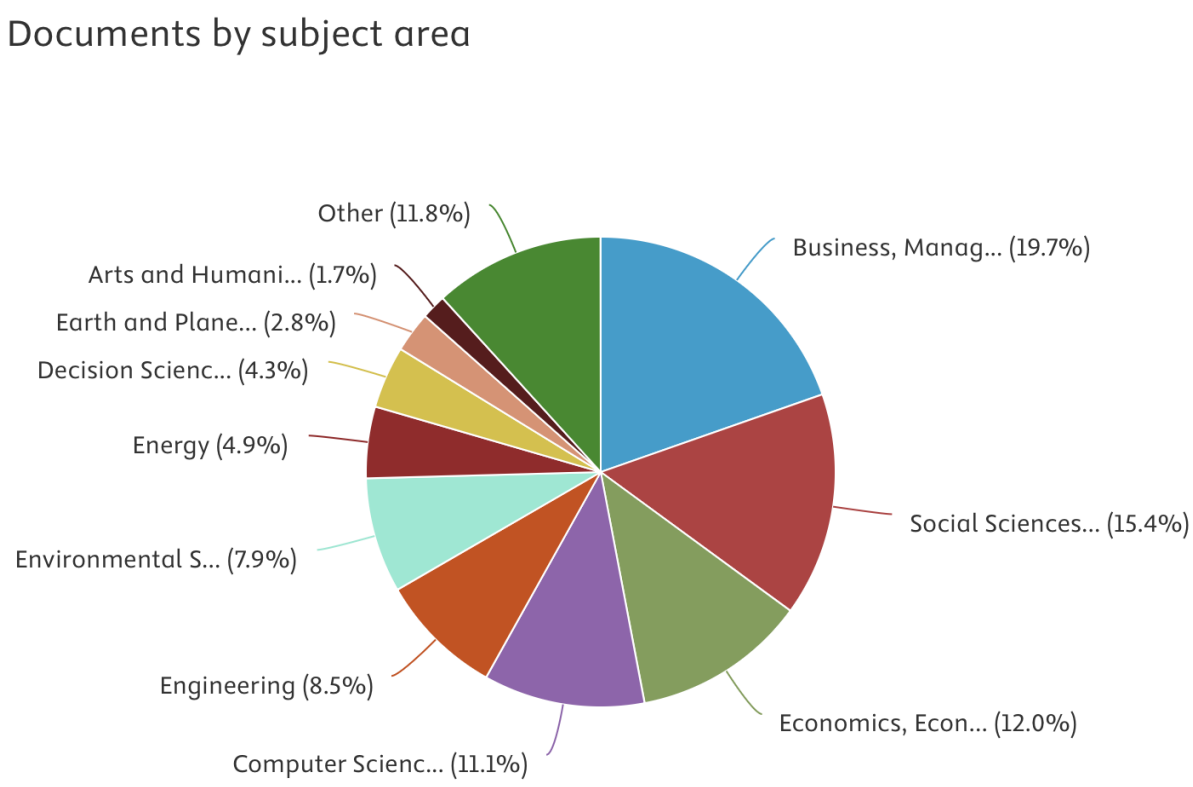

Figure 3: Document by Subject Area

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Table 3: Document by Subject Area

Subject area	Documents	Percentage
Business, Management and Accounting	92	19.7
Social Sciences	72	15.4
Economics, Econometrics and Finance	56	12
Computer Science	52	11.1
Engineering	40	8.5
Environmental Science	37	7.9
Energy	23	4.9
Decision Sciences	20	4.9
Earth and Planetary Sciences	13	4.3
Arts and Humanities	8	2.8
Mathematics	8	1.7
Agricultural and Biological Sciences	7	11.8
Physics and Astronomy	7	
Chemistry	6	
Medicine	6	
Biochemistry, Genetics and Molecular Biology	5	
Chemical Engineering	5	
Materials Science	3	
Pharmacology, Toxicology and Pharmaceutics	3	
Multidisciplinary	2	
Immunology and Microbiology	1	
Nursing	1	
Psychology	1	

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The distribution of documents by subject area reveals that the research on academia as a catalyst in maintaining Malaysia's cattle supply chain through the Quadruple Helix model is heavily concentrated within the Business, Management, and accounting field, which accounts for the highest share at 19.7% (92 documents). This is closely followed by Social Sciences (15.4%) and Economics, Econometrics, and Finance (12%), indicating that most studies approach the topic from organizational, institutional, policy, and economic perspectives. These fields typically focus on stakeholder collaboration, innovation systems, performance outcomes, and governance—all of which align well with the Quadruple Helix framework. The presence of Decision Sciences (4.9%) and Engineering (8.5%) also suggests that decision-making models, systems optimization, and technological infrastructure are important aspects of this research trend.

Interestingly, Agricultural and Biological Sciences only account for 7 documents, despite the direct relevance of cattle supply chains to agriculture. This low representation (approximately 1.7%) suggests a research gap where the specific agricultural and livestock context is underexplored within the Quadruple Helix discourse. Furthermore, the presence of related fields such as Environmental Science (7.9%), Energy (4.9%), and Computer Science (11.1%) reflects a growing interdisciplinary interest, especially in areas such as sustainable agriculture, digital innovation, and climate-smart supply chains. These findings point to a need for more agriculture-specific studies integrating academic perspectives with practical livestock supply chain solutions in Malaysia. Therefore, your research can contribute meaningfully by bridging the gap between high-level innovation frameworks and on-the-ground realities in the cattle industry.

Document By Type.

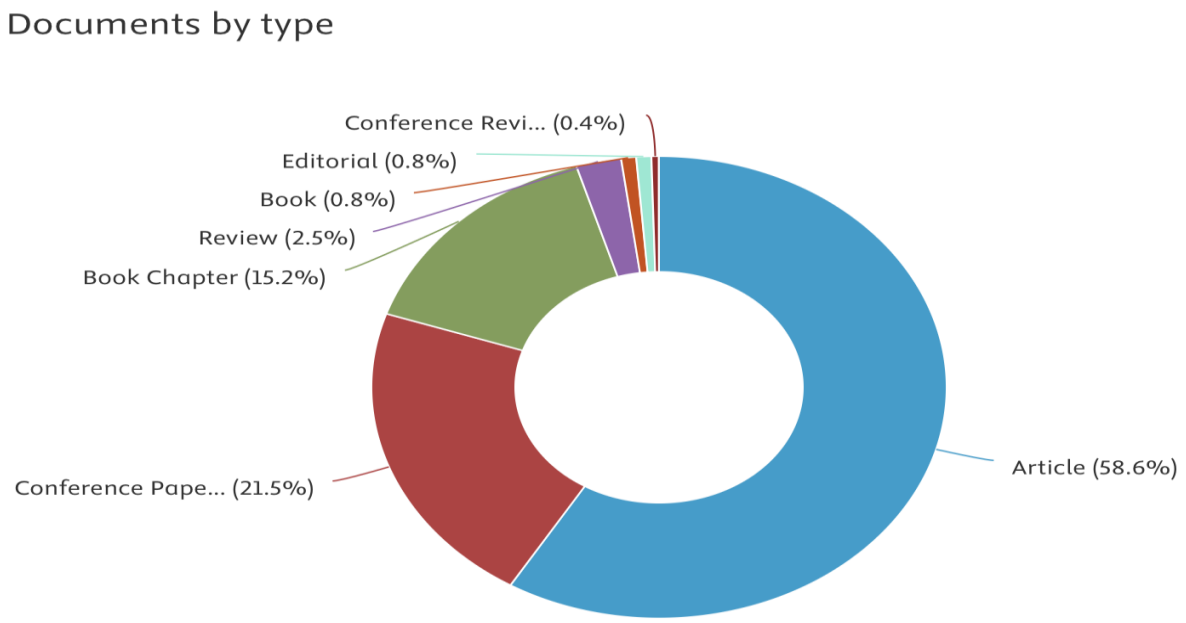

Figure 4: Document by Type

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Table 4: Document by Type

Document type	Documents	Percentage
Article	139	58.6
Conference Paper	51	21.5
Book Chapter	36	15.2
Review	6	2.5
Book	2	0.8
Editorial	2	0.8
Conference Review	1	0.4

The analysis of document types shows that most of the research related to academia as a catalyst within the Quadruple Helix model is published in the form of journal articles, accounting for 58.6% (139 documents) of the total. This indicates that peer-reviewed journals are the primary medium through which scholars disseminate theoretical insights, empirical findings, and case studies on this topic. Journal articles often undergo rigorous peer evaluation, which suggests a relatively high level of academic quality and credibility in the body of literature. Additionally, the presence of review articles (2.5%) further supports the maturity and consolidation of certain aspects of the research field, particularly in exploring conceptual frameworks like the Quadruple Helix and its application across industries.

Conference papers make up the second-largest category at 21.5% (51 documents), followed by book chapters (15.2%), highlighting the dynamic and evolving nature of this research area. The strong presence of conference proceedings suggests that this is still an emerging topic, with many ideas and innovations being tested, discussed, and refined in academic forums before being published in full journal formats. Book chapters also indicate growing scholarly contributions to edited volumes and thematic compilations, which are often interdisciplinary in nature. Meanwhile, the minimal presence of books, editorials, and conference reviews points to limited standalone comprehensive treatments or opinion-based contributions, suggesting potential for future in-depth publications focused on Malaysia's cattle supply chain and the integration of academic stakeholders through the Quadruple Helix model.

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The Most Cited Authors

Table 5: The Most Cited Authors

Authors	Title	Year	Source title	Cited by
Carayannis E.G.; Rakhmatullin R.(Carayannis & Rakhmatullin, 2014)	The Quadruple/Quintuple Innovation Helixes and Smart Specialisation Strategies for Sustainable and Inclusive Growth in Europe and Beyond	2014	Journal of the Knowledge Economy	310
Muraoka T.; Cui H.; Stupp S.I.(Muraoka et al., 2008)	Quadruple helix formation of a photoresponsive peptide amphiphile and its light-triggered dissociation into single fibers	2008	Journal of the American Chemical Society	184
Hasche N.; Höglund L.; Linton G.(Hasche et al., 2020)	Quadruple helix as a network of relationships: creating value within a Swedish regional innovation system	2020	Journal of Small Business and Entrepreneurship	93
Carayannis E.G.; Grigoroudis E.; Stamati D.; Valvi T.(Carayannis et al., 2021)	Social Business Model Innovation: A Quadruple/Quintuple Helix-Based Social Innovation Ecosystem	2021	IEEE Transactions on Engineering Management	88
Lindberg M.; Lindgren M.; Packendorff J. (Lindberg et al., 2014)	Quadruple Helix as a Way to Bridge the Gender Gap in Entrepreneurship: The Case of an Innovation System Project in the Baltic Sea Region	2014	Journal of the Knowledge Economy	76
Carayannis E.G.; Campbell D.F.J.(Carayannis & Campbell, 2011b)	Open Innovation Diplomacy and a 21st Century Fractal Research, Education and Innovation (FREIE) Ecosystem: Building on the Quadruple and Quintuple Helix Innovation Concepts and the "Mode 3" Knowledge Production System	2011	Journal of the Knowledge Economy	226

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Galvao A.; Mascarenhas C.; Marques C.; Ferreira J.; Ratten V. (Galvao et al., 2019)	Triple helix and its evolution: a systematic literature review	2019	Journal of Science and Technology Policy Management	136
Compagnucci L.; Spigarelli F.; Coelho J.; Duarte C.(Compagnucci et al., 2021)	Living Labs and user engagement for innovation and sustainability	2021	Journal of Cleaner Production	90
Colapinto C.; Porlezza C.(Colapinto & Porlezza, 2012)	Innovation in Creative Industries: From the Quadruple Helix Model to the Systems Theory	2012	Journal of the Knowledge Economy	89

The bibliometric data highlights that Elias G. Carayannis is the most influential and frequently cited author in the field related to the Quadruple Helix model, contributing multiple high-impact publications (Carayannis & Rakhmatullin, 2014). His 2014 article “The Quadruple/Quintuple Innovation Helixes and Smart Specialization Strategies for Sustainable and Inclusive Growth in Europe and Beyond” has received 310 citations, underscoring its foundational role in defining and expanding the Quadruple Helix concept(Carayannis & Rakhmatullin, 2014). Additionally, his 2011 paper on “Open Innovation Diplomacy” garnered 226 citations(Carayannis & Campbell, 2011a), and his 2021 collaborative work on social business model innovation has also made a significant impact with 88 citations (Carayannis et al., 2021). These works collectively reflect his leadership in theorizing how academia, government, industry, and civil society can co-create innovation ecosystems for sustainability, inclusivity, and knowledge-driven growth principles highly relevant to reforming Malaysia’s cattle supply chain.

Other highly cited contributions include those from Muraoka et al. (2008) with 184 citations(Muraoka et al., 2008), though this work focuses more on biochemical applications of the term "quadruple helix" rather than socio-economic innovation frameworks. Lindberg, Lindgren, and Packendorff (2014) and Hasche et al. (2020) have also contributed significantly with 76 (Lindberg et al., 2014)and 93 (Hasche et al., 2020)citations, respectively, especially in exploring the Quadruple Helix in regional innovation and entrepreneurship contexts. Galvao et al. (2019), with 136 citations, provide a comprehensive literature review on the evolution from Triple to Quadruple Helix models(Galvao et al., 2019), serving as a vital reference for scholars mapping the theoretical expansion of innovation systems. These high-impact works form the intellectual backbone of your research domain and offer valuable frameworks to adapt and apply within the Malaysian cattle supply chain, particularly in strengthening the academic sector’s catalytic role through collaborative innovation.

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Top 10 Countries Based On Publication

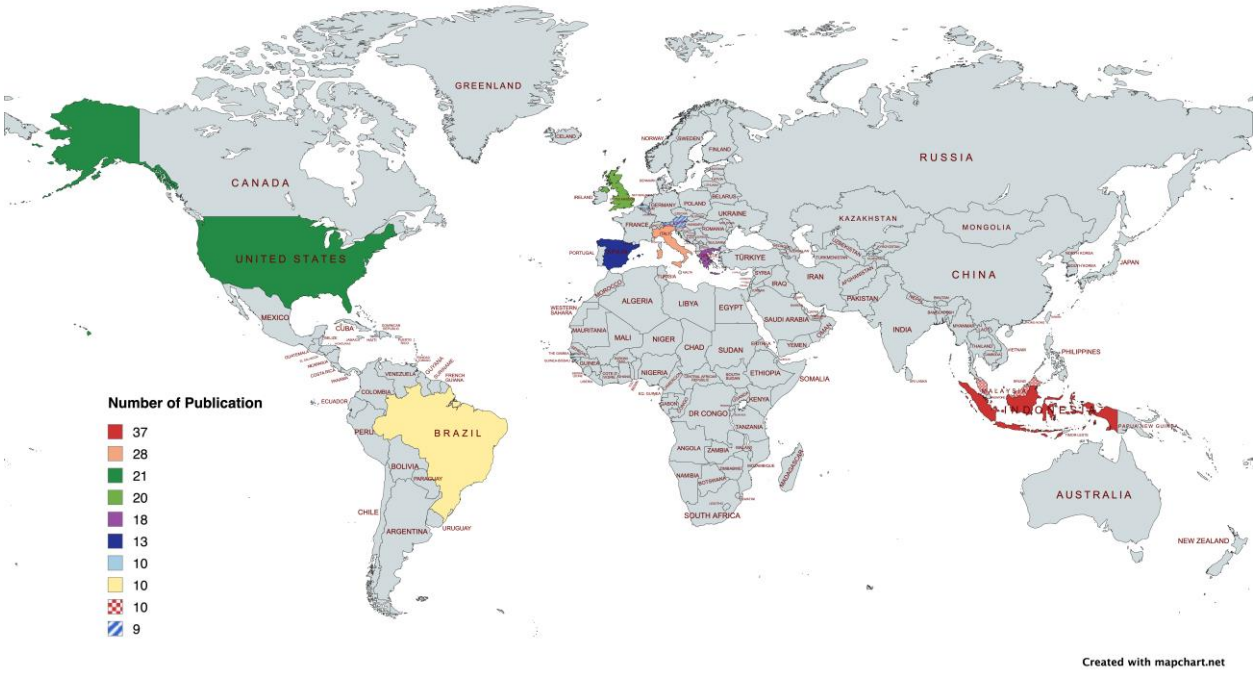

Figure 5: Top 10 Countries Based On Publication

Table 6: Top 10 Countries Based On Publication

Country/Territory	Documents	Percentage
Indonesia	37	11.08
Italy	28	8.38
United States	21	6.29
United Kingdom	20	5.99
Greece	18	5.39
Spain	13	3.89
Belgium	10	2.99
Brazil	10	5.99
Malaysia	10	2.99
Austria	9	2.69

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The bibliometric data on the top 10 countries contributing to research on the Quadruple Helix model and academia's role in performance and innovation reveals that Indonesia leads with 37 documents (11.08%), followed by Italy (8.38%), the United States (6.29%), and the United Kingdom (5.99%). These countries have shown a strong academic interest in collaborative innovation models, likely due to their policy focus on sustainable development, public-private partnerships, and regional innovation systems. The presence of Greece (5.39%), home to one of the leading Quadruple Helix theorists, Elias G. Carayannis, underscores its foundational role in shaping the theoretical landscape. These nations typically explore the Quadruple Helix model in diverse sectors, ranging from technology and business to social entrepreneurship and regional development.

Notably, Malaysia accounts for only 10 documents (2.99%), indicating that while the concept has begun to gain traction locally, it remains relatively underrepresented in academic discourse specific to Malaysia's cattle supply chain industry. This reflects a significant research gap and a timely opportunity for scholars to explore how the integration of academia, industry, government, and civil society can enhance livestock supply chain performance, food security, and rural development. The relatively low Malaysian output also highlights the need for more locally grounded research and policy-oriented case studies that demonstrate the practical application of the Quadruple Helix model in the agricultural context. By focusing on this niche, your study could not only fill a national research void but also contribute to the global body of knowledge with a unique case from Southeast Asia.

Popular Keywords Related To This Study.

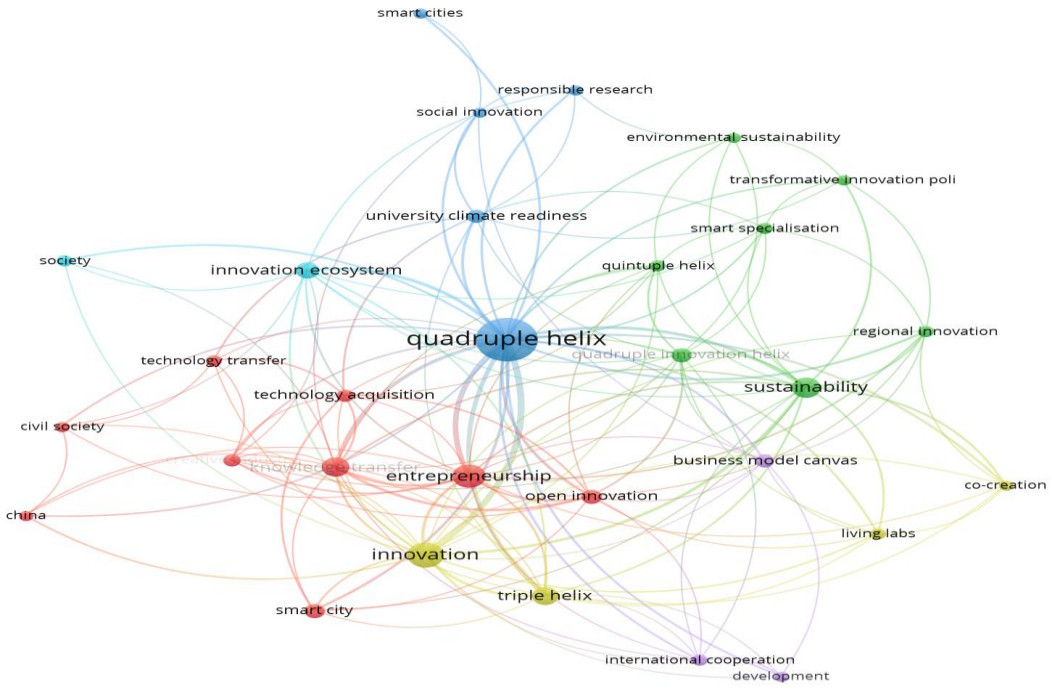

Figure 6: Popular Keywords Related To This Study.

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The keyword co-occurrence network visualization you provided offers a valuable overview of the thematic structure and conceptual relationships within the literature on the Quadruple Helix model. The centrality of the term “quadruple helix” (highlighted in bold blue at the core) demonstrates its foundational role in this research domain, with strong links to a variety of other key themes such as sustainability, entrepreneurship, innovation, social innovation, and open innovation. These interconnected nodes indicate that the Quadruple Helix is commonly explored in the context of multi-actor innovation ecosystems, where academia collaborates with government, industry, and civil society to drive inclusive and sustainable development. Notably, terms like "university", "technology transfer", and "innovation ecosystem" emphasize academia’s role in knowledge generation and application, reinforcing your focus on academia as a catalyst.

The clustering of related terms into color-coded communities further reveals thematic subdomains. For example, the green cluster connects sustainability, regional innovation, transformative innovation policy, and smart specialization, indicating a strong policy and development focus. Meanwhile, the red cluster ties entrepreneurship, technology acquisition, civil society, and innovation, emphasizing practical, economic, and societal applications. The light blue and purple clusters touch on broader contexts such as smart cities, international cooperation, and climate readiness. The relatively even distribution of topics suggests a multidisciplinary field that encompasses business, technology, policy, and societal well-being. This network supports your research direction by showing clear evidence of academia’s active engagement in systems-level innovation relevant to Malaysia’s cattle supply chain through the Quadruple Helix model. However, the absence of agriculture- or livestock-specific keywords also highlights a gap that your research can address.

Co-Authorship Based On Countries’ Celebration.

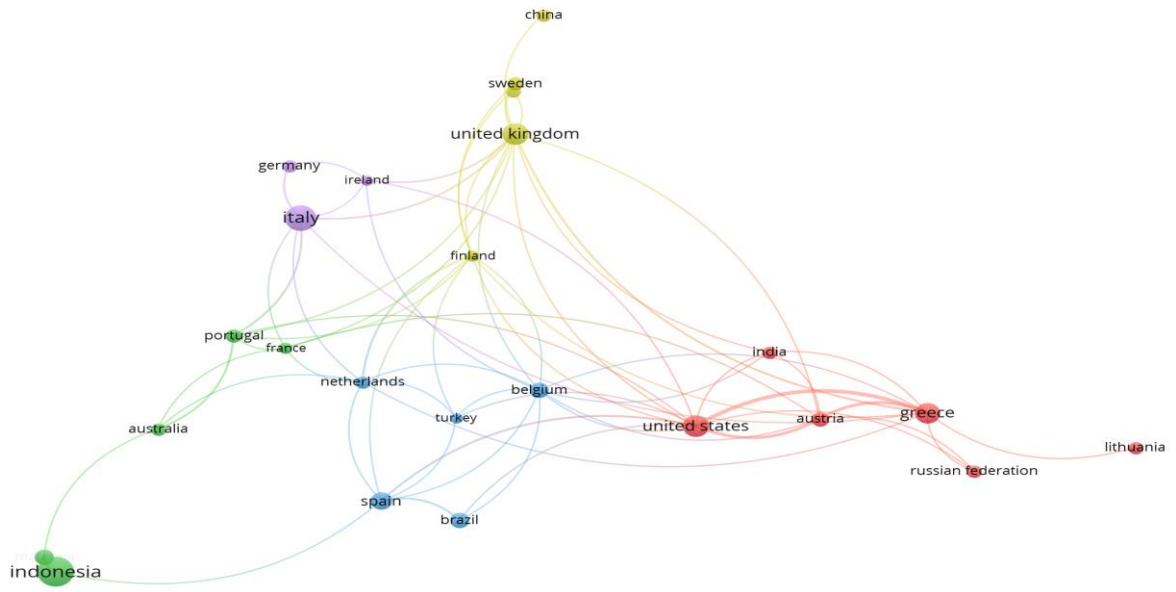

Figure 7: Co-Authorship Based On Countries’ Celebration.

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The visualized co-authorship network by country illustrates the international collaboration landscape within the research domain of the Quadruple Helix model and academia's role in innovation. The United Kingdom emerges as a central hub, forming strong collaborative links with countries such as Sweden, China, Finland, Ireland, and Germany, highlighting its leadership in cross-national research initiatives. Other prominent clusters include Italy, Greece, and the United States, which appear as significant players with dense linkages, indicating their consistent scholarly output and participation in global research networks. These countries are not only prolific in publication but also actively engage in international knowledge-sharing, often shaping innovation policies and theoretical frameworks applied globally.

Of particular interest is Indonesia, which, while geographically and thematically distant from the European core, forms its own cluster and shows collaborative ties with Malaysia and Australia, reflecting regional academic alliances in Southeast Asia. Malaysia's inclusion in this network, though with fewer direct connections, suggests emerging participation in the global discourse on the Quadruple Helix, with room to expand collaborative research. This visualization supports the bibliometric data showing lower publication volumes from Malaysia and points to a potential opportunity: by strengthening international partnerships, especially with active countries like the UK, Greece, or Indonesia, Malaysian scholars can enhance visibility and contribute more substantially to the application of Quadruple Helix principles in sectors like cattle supply chain management. Your research can play a bridging role in connecting local agricultural innovation efforts with global academic ecosystems.

Conclusion

This bibliometric analysis aimed to explore the role of academicians as catalysts in maintaining Malaysia's cattle supply chain industry through the Quadruple Helix model. The study sought to answer key research questions, including publication trends, influential subject areas, highly cited articles, leading countries in research output, popular keywords, and international collaboration patterns.

The analysis revealed a growing interest in the Quadruple Helix framework, with a notable increase in publications from 2020 onwards, peaking in 2024. Business, Management, and Accounting emerged as the dominant subject area, while Agricultural and Biological Sciences were underrepresented, indicating a research gap in applying the model to livestock supply chains. The most cited works were led by scholars such as Carayannis, whose contributions laid the foundation for Quadruple Helix theory. Indonesia, Italy, and the United States were the top contributors, while Malaysia's research output remained limited. Keyword analysis highlighted themes like sustainability, innovation, and entrepreneurship, though agriculture-specific terms were scarce. Co-authorship networks demonstrated strong collaborations among European nations, with Malaysia showing potential for deeper international engagement.

This study contributes to the field by mapping the current research landscape and identifying gaps, particularly in the application of the Quadruple Helix model to Malaysia's cattle supply chain. The findings underscore the need for greater interdisciplinary research, stronger academia-industry-government-civil society partnerships, and localized studies to address logistical and sustainability challenges in the livestock sector.

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Limitations include the reliance on Scopus data, which may exclude relevant non-indexed publications, and the broad search query, which captured diverse themes beyond agriculture. Future research could focus on targeted studies integrating Quadruple Helix principles with livestock supply chain dynamics, as well as comparative analyses across regions.

In summary, this bibliometric analysis highlights the evolving discourse on collaborative innovation models and emphasizes the untapped potential of academicians in transforming Malaysia's cattle supply chain. By bridging theoretical frameworks with practical applications, this research paves the way for more inclusive and sustainable agricultural systems. Further exploration in this area promises to enhance food security, economic resilience, and stakeholder synergy in the livestock industry.

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