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ACADEMICIAN AS A CATALYST IN MAINTAINING MALAYSIA'S CATTLE SUPPLY CHAIN INDUSTRY BASED ON THE QUADRUPLE HELIX MODEL.

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Abstract:

This study explores the pivotal role of academicians in strengthening Malaysia's cattle supply chain industry through the Quadruple Helix Model (QHM), which integrates academia, government, industry, and civil society. Despite policy efforts under initiatives such as the National Agro-Food Policy 2.0, the cattle sector faces structural weaknesses, low technological adoption, and limited youth involvement. Using a qualitative approach, data were collected through semi-structured interviews with key stakeholders, academic researchers, government officials, industry players, and NGOs, and were analysed thematically alongside case studies of successful academic-industry collaborations. Findings reveal that while academia contributes significantly through research, innovation, and capacity building, these contributions often fail to translate into practice due to weak institutional linkages and poor communication. Many stakeholders reported that academic outputs are not easily accessible or applicable in operational contexts, while government policies frequently lack alignment with research agendas. However, evidence from successful case studies shows that cattle productivity, disease management, and sustainable practices improve notably when academia is actively engaged through technology trials, training, and collaborative projects. Although increasingly influential in shaping market preferences and sustainability norms, civil society remains underrepresented in formal decision-making. This underutilization of civil input and fragmented

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stakeholder collaboration limits the full realization of the QHM's potential. The study concludes that strengthening communication, aligning policies with research, and integrating civil society into innovation processes are essential to leveraging academia's catalytic role. A robust Quadruple Helix framework promises to enhance innovation diffusion, promote sustainable practices, and improve the resilience of Malaysia's cattle supply chain, ultimately contributing to national food security goals.

Keywords:

Supply Chain Management, Academician, Cattle Industry

Introduction

Food security has become a pressing global concern, intensified by rapid population growth, shifting dietary patterns, and the escalating demand for agricultural commodities. The global population is projected to reach 9.8 billion by 2050 (United Nations Department of Economic and Social Affairs, 2017), necessitating an estimated 60% increase in food production from current levels (World Economic Forum, 2016). In response, the United Nations Sustainable Development Goals (SDGs) place food security and sustainable agriculture at the centre of global development, particularly through SDG 2, which aims to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture by 2030 (Food and Agriculture Organization, 2020).

Agriculture plays a fundamental role in ensuring the availability, accessibility, and affordability of food. A resilient food system must consistently supply affordable, safe, and nutritious food. Although Malaysia has made commendable strides, ranking 41st globally and 8th in the Asia-Pacific region in the 2022 Global Food Security Index (GFSI), the nation continues to face persistent challenges related to food self-sufficiency. Despite ongoing policy interventions, Malaysia remains dependent on food imports, raising concerns about its food system's sustainability and long-term resilience.

In response to these challenges, the Malaysian government has implemented a series of agricultural policy frameworks to strengthen domestic food production and reduce reliance on imports. These include the First, Second, and Third National Agricultural Policies (NAP I–III), the National Agro-Food Policy 1.0 (NAFP 1.0), and most recently, the National Agro-Food Policy 2021–2030 (NAFP 2.0), introduced by the Ministry of Agriculture and Food Industries (MAFI) in 2021. NAFP 2.0 emphasizes sustainable practices, technological advancement, and innovation as central pillars for enhancing food security and agro-food system resilience.

As shown in Table 1, Malaysia's population has steadily increased, with projections estimating approximately 43 million people by 2050 (CEIC Data, 2021). This demographic trend presents significant implications for future food demand and raises concerns about the adequacy of current policy responses in securing food availability over the long term.

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Table 1. Malaysia's Historical Population Growth Data

Malaysia – Historical population growth rate data		
Year	**Population growth rate**	**Growth rate (%)**
2023	33,308,525	1.09
2022	33,938,221	1.09
2021	33,573,874	1.13
2020	33,199,993	1.21
2019	32,804,020	1.25
2018	32,399,271	1.32
2017	31,975,806	1.43
2016	31,526,418	1.47
2015	31,068,833	1.51
2014	30,606,459	1.57
2013	30,134,807	1.60

Source: (United Nations, 2023)

The cattle industry is strategically important in supporting Malaysia's food security, rural development, and economic diversification goals. However, the sector faces several persistent constraints, including fragmented supply chains, rising production costs, disease management challenges, and the need for greater sustainability and resilience in farming practices.

To address these multifaceted issues, a collaborative, cross-sectoral approach is essential. The Quadruple Helix Model (QHM), which integrates the contributions of government, industry, academia, and civil society, provides a comprehensive framework for fostering innovation and driving sustainable change within the cattle supply chain. Within this model, academia serves as a key catalyst, offering critical inputs through research and development, technology transfer, knowledge dissemination, and capacity-building initiatives. Academic institutions also support evidence-based policymaking, enhance operational efficiency, and facilitate the adoption of sustainable agricultural practices.

This article critically explores the role of academicians as enablers of transformation in Malaysia's cattle industry through the lens of the QHM. It aims to identify sectoral challenges, evaluate the effectiveness of national agro-food policies, and propose strategic interventions to enhance productivity, build resilience, and ensure the industry's long-term contribution to national food security.

Literature Review

The Quadruple Helix Model for the Cattle Industry

The Quadruple Helix Model (QHM) is a dynamic framework for innovation and collaboration that places citizens and end-users at the heart of developmental processes. This model is especially relevant in complex innovation ecosystems where inclusivity, co-creation, and responsiveness to societal needs are crucial. Traditional innovation models often exclude civil society, leading to solutions that, while technologically advanced, lack social alignment. QHM addresses this gap by emphasizing participatory innovation that is both inclusive and demand-driven.

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Evolving from the Triple Helix Model (THM), which focuses on collaboration among academia, industry, and government, the QHM incorporates civil society as a fourth, equally essential stakeholder. This progression aligns with broader societal shifts toward Society 5.0, a concept described by Carayannis and Campbell (2019) and further expanded by Carayannis and Morawska-Jancelewicz (2022). Society 5.0 represents a human-centered knowledge paradigm supported by advanced digital technologies such as AI, Big Data, robotics, and the Internet of Things (Carayannis et al., 2021; Fukuyama, 2018). In this paradigm, innovation must be technologically driven and reflect human values and social priorities, enabling citizens to actively contribute to and benefit from innovation processes.

In the context of Malaysia's cattle industry, the QHM offers a strategic lens through which inclusive innovation can be harnessed to support sustainable transformation. Aligning with Society 5.0 principles, integrating civil society alongside academia, government, and industry enables the sector to pursue goals of productivity, efficiency, resilience, equity, and relevance to national food security priorities.

Figure 1: Quadruple Helix Model

Source: (Carayannis & Campbell, 2019)

This collaborative model underscores the necessity of synergistic engagement to address systemic agricultural challenges. Academia contributes scientific research, technological innovation, and training; industry focuses on production efficiency and commercialization; government delivers policy direction, regulation, and infrastructure investment; and civil society, including farmers, consumers, and NGOs, brings grassroots insights, market feedback, and community mobilization. Their integration ensures that innovations are contextually appropriate and widely accepted.

Academic institutions play a central role by driving research, advancing sustainable farming technologies, and facilitating capacity-building initiatives. Their contributions are critical in addressing livestock health, climate variability, productivity gaps, and shifting consumer expectations. Meanwhile, industry actors execute research-based practices and offer feedback that helps refine academic and policy outputs. Their hands-on experience ensures that innovation is feasible and scalable across the value chain.

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Government bodies such as the Ministry of Agriculture and Food Industries (MAFI) provide the regulatory and financial frameworks to support innovation adoption. These agencies are key enablers for fostering multi-sector partnerships, ensuring alignment between policy goals and implementation. Civil society, comprising NGOs, community groups, and consumers, increasingly influences ethical and sustainability standards. Their advocacy shapes demand, enhances transparency, and promotes best practices in livestock management.

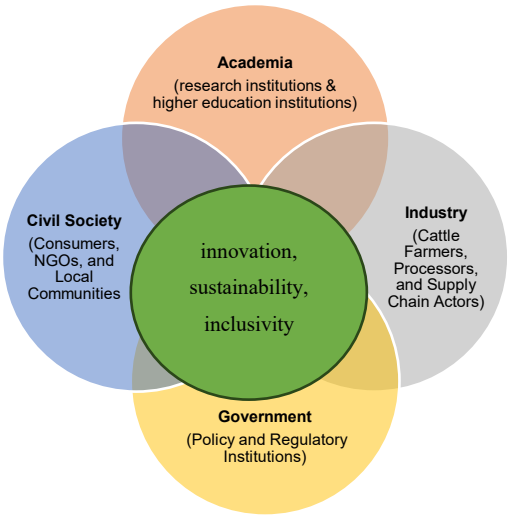

Figure 2: Quadruple helix innovation model

Source: (own illustration)

Collectively, these four helices establish a robust ecosystem for innovation, sustainability, and social relevance within the cattle industry. This model supports sectoral resilience and ensures long-term contributions to national food security and rural economic growth. Krishnan et al. (2025) emphasize that Malaysia's vision of becoming a high-income, developed nation is closely tied to the effective implementation of the Quadruple Helix Innovation Model (QHIM), which depends on the active collaboration of academia, government, industry, and civil society.

Sin et al. (2024) note that while there is growing interest among youth in the cattle sector, their participation is constrained by limited access to practical training and technical knowledge. Academics can play a transformative role by mentoring young entrepreneurs, offering structured training programs, and providing resources that reduce early-stage business risks. This form of engagement is essential for ensuring generational renewal and sustainability in the livestock industry.

Moreover, the QHM promotes continuous product, process, and service improvement by fostering ongoing stakeholder collaboration. Businesses, academic institutions, and governments benefit from access to real-time data, evolving market trends, and on-the-ground insights from civil society. This collaborative innovation leads to adaptive and high-impact solutions (Carayannis & Grigoroudis, 2016; Kolehmainen et al., 2016).

Despite its conceptual strengths, operationalizing the QHM in agriculture remains challenging. Schütz et al. (2019) and Carayannis & Morawska-Jancelewicz (2022) point out that civil society engagement is often tokenistic rather than systemic. In Malaysia, academic research

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frequently struggles to reach end-users due to bureaucratic barriers and a lack of trust among farmers.

However, international models such as India's National Dairy Development Board (NDDB). NDDB of India is a key organization focused on supporting and promoting dairy development in the country, particularly through producer-owned and controlled cooperatives. Brazil's The Brazilian Agricultural Research Corporation (EMBRAPA). EMBRAPA is an innovation-driven company that focuses on the generation of knowledge and technology for Brazilian agriculture. Australia's Cooperative Research Centres (CRCs) demonstrate that sustained, well-structured academic-industry-government partnerships can yield scalable and socially embedded innovations. These models highlight the importance of long-term institutional support, participatory governance, and co-creation components that require greater emphasis in Malaysia's agricultural strategy.

The Overview Of Malaysia's Challenges And Opportunities In The Agricultural Economic Sector

The agricultural sector in Malaysia continues to encounter persistent structural and systemic challenges, as identified in previous studies. These include low levels of technological adoption, environmental degradation, and the accelerating pace of urbanization, all of which impede national agricultural development and competitiveness (Dung & Heip, 2017). Globally and domestically, the sector has shown relatively sluggish growth in its contribution to gross domestic product (GDP). Within the ASEAN region, Malaysia ranks eighth out of ten countries, lagging agricultural-intensive nations such as Myanmar, Cambodia, Laos, and Vietnam, where the sector remains a cornerstone of rural livelihoods (Wee & Lim, 2022).
According to the Department of Statistics Malaysia (2023), Malaysia's GDP reached RM1,510.9 billion in 2022, reflecting an overall growth of 8.7% compared to RM1,390.6 billion in 2021. However, the agriculture sector recorded a marginal increase of just 0.1% during the same period, following a contraction of 0.1% in 2021. Within this sector, oil palm remained the dominant contributor to value-added output at RM36.1 billion (36.5%), followed by other agricultural activities at RM28.1 billion (28.3%) and the livestock subsector at RM16.5 billion (16.7%). Despite these figures, the livestock subsector experienced a 2.4% decline in beef production, underscoring productivity concerns.

The global agricultural landscape is rapidly evolving due to technological advancements and globalization. These transformations have created more efficient, sustainable, and digitally enhanced farming systems. Innovations in smart agriculture, biotechnology, and precision farming offer viable solutions to enduring issues such as food insecurity, aging farming populations, and high unemployment rates, challenges Malaysia faces (Shariff et al., 2024, 2025).

In Malaysia, the agriculture sector is particularly affected by labor shortages, mainly due to the aging farming population and the limited participation of youth. This disengagement is often attributed to negative perceptions of agriculture as a labour-intensive, low-income, and low-innovation sector. Further aggravating the situation are the deficiencies in technical expertise and the underutilization of modern technologies, which continue to hamper productivity and long-term resilience (Azri et al., 2025). Nevertheless, growing awareness of the benefits of agricultural modernization presents new opportunities to rejuvenate the sector and enhance food security.

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Food security has become an increasingly influential factor in shaping global agricultural practices. Milovanovic (2014) notes that global farming is now significantly driven by food access and supply concerns. Global food production is projected to increase by 56% by 2050 to support an estimated population of 10 billion (Ranganathan et al., 2018). This demand is intensified by urbanization, demographic growth, and rising income levels (Food and Agriculture Organization, 2020). Frona et al. (2019) state that addressing this challenge is essential for sustainable agricultural development.

However, population growth also creates opportunities for innovation and sectoral expansion. Modernizing agriculture through technology adoption mitigates food security risks and stimulates employment and rural economic development (IMF, 2019). In many advanced economies, agriculture has evolved from traditional, labor-dependent operations into high-tech, knowledge-intensive industries, offering a model for Malaysia to emulate.

To enrich this discussion, references to Malaysia's recently launched "National Agrofood Policy 2.0 Mid-Term Review (2024)" could be included. This policy document emphasizes strategic shifts toward sustainable practices, climate resilience, and agri-digital innovation. The "Youth in AgriTech 2025" initiative and the "Smart Farming Integration Programme" also offer updated frameworks for addressing labor challenges and fostering youth-led agricultural transformation. These developments further underscore the urgency and potential of aligning national policy and academic research with emerging agricultural paradigms.

Cattle Performance in Malaysia

Cattle farming in Malaysia faces numerous structural and operational challenges, particularly when compared to the more developed poultry and swine sectors. Growth in the cattle industry has been hindered by limited access to high-quality feed, slow herd population increases, and insufficient production levels to meet national beef consumption demands. Compounding these limitations is the lack of comprehensive and centralized data on breeder preferences, which obstructs targeted improvements aligned with Malaysia’s food security objectives.

The cattle farming landscape is predominantly characterized by small-scale operations, with most herds comprising fewer than 50 animals. Medium- and large-scale commercial farms, defined as having more than 50 heads, remain relatively scarce. Traditional systems such as integrated farming and backyard grazing continue to dominate. These practices are particularly entrenched among smallholder paddy farmers in northern states like Kedah and Kelantan, where cattle rearing is commonly undertaken after the paddy harvest (Jalaludin & Halim, 2014). Integration with oil palm plantations is currently the most widely adopted model, offering benefits such as additional income, reduced weed control costs, and enhanced soil fertility (Ibragimov et al., 2016; Zayadi, 2021).

At the national level, the livestock sector remains an essential contributor to Malaysia's agricultural economy. In 2020, the livestock subsector registered a food production index of 107.4, accounting for approximately 8.21% of agricultural output. By 2021, the livestock industry contributed RM16.52 billion to Malaysia’s GDP, a slight increase from RM16 billion in the previous year (Statista, 2024). Within this subsector, cattle production grew modestly from 35,934.09 metric tons in 2021 to 36,800.57 metric tons in 2022. Similarly, the national cattle population increased from 717,431 to 733,655 heads during the same period. At the state level, Pahang held the highest cattle population with 149,062 heads, while Perlis reported the lowest at 5,973 heads (Perangkaan Ternakan, 2023).

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When benchmarked against the poultry and swine industries, the cattle sector lags in productivity, commercialization, and technological adoption. The poultry industry, for instance, is highly commercialized and benefits from superior feed conversion rates, advanced breeding practices, and robust investments in biosecurity and disease management. Likewise, the swine industry is supported by structured breeding programs and dedicated government assistance (Wee & Lim, 2022; Shariff et al., 2025). In contrast, the cattle industry remains fragmented and heavily reliant on smallholder farmers, particularly in regions like Perlis and Kelantan, which lack sufficient institutional and infrastructural support. States like Pahang and Selangor demonstrate comparatively stronger frameworks due to better access to academic, financial, and extension services (Perangkaan Ternakan, 2023).

Recent data from the Department of Veterinary Services (DVS) and the National Food Security Action Plan 2025 could be incorporated to strengthen this section. These sources provide updated targets for local beef self-sufficiency, cattle breed improvement initiatives, and incentives for integrated cattle-oil palm systems. Additionally, Malaysia's Smart Livestock Farming 2025 roadmap outlines plans to incorporate digital tools and precision livestock management into mainstream cattle production, further highlighting opportunities for modernization and academic involvement in data-driven interventions.

Role of Academicians in Improving the Cattle Supply Chain Industry in Malaysia

As a developing country, Malaysia places a high priority on fostering economic growth through innovation. Recognizing the essential role of innovation in achieving national development goals, the government has implemented strategic leadership and policy initiatives to transition the country toward an innovation-led economy. A key component of this transformation is the Ministry of Education's (MOE) proactive involvement, particularly through the Malaysia Education Blueprint (2015–2025) for Higher Education. This strategic framework positions higher education institutions as central agents in driving innovation, talent development, and economic competitiveness.

The Quadruple Helix (QH) model evolves from the earlier Triple Helix (TH) framework by expanding the core relationship among academia, industry, and government to include civil society as a fourth pillar. This inclusion reflects a growing recognition of the importance of community involvement and end-user perspectives in shaping socially responsive innovation outcomes (García-González & Ramírez-Montoya, 2019). The QH model addresses a key limitation of the TH model by acknowledging that innovation is driven by institutional actors, co-created with the public, and informed by societal needs and values (Schütz et al., 2019).

The shift from the TH to the QH model presents notable challenges for universities, including the need for structural adjustments and strategic realignments. This transformation requires redefining the academic role within a broader, more dynamic innovation ecosystem (Sharif et al., 2024). Universities are well-positioned to contribute to the QH framework through expert knowledge generation, technical advancement, capacity-building, and policy engagement. Their contributions also include facilitating access to research funding and translating scientific outputs into practical innovations that respond to market and societal demands.

In Malaysia’s cattle industry, academicians are vital in supporting sectoral transformation. Their research supports the development of improved cattle breeding practices, feed efficiency strategies, and sustainable farming systems that minimize environmental degradation. Furthermore, academics serve as intermediaries for technology transfer and lead training

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initiatives targeting farmers, industry stakeholders, and policymakers. These activities strengthen collaboration between the public and private sectors while enhancing the effectiveness of civil society participation. Through their contributions, academia supports increased productivity, greater resilience, and improved sustainability in the cattle supply chain, all of which are critical to advancing national food security and rural economic development. These efforts align closely with the Quadruple Helix Model and demonstrate the increasing institutional support for research-based livestock transformation.

Methodology

This study adopts a qualitative research design to investigate the role of academia in strengthening Malaysia's cattle supply chain, guided by the Quadruple Helix (QH) innovation framework. The primary aim is to explore how academic institutions contribute to technological advancement, stakeholder collaboration, and sustainable practices within the livestock sector. Data were collected through semi-structured interviews and case studies, enabling a comprehensive understanding of cross-sector dynamics.

A total of 18 semi-structured interviews were conducted using purposive sampling to ensure the inclusion of relevant stakeholders. The sample comprised six academic researchers, four government officials from the Ministry of Agriculture and Food Industries (MAFI) and the Department of Veterinary Services (DVS), four cattle farmers (both small- and medium-scale), two NGO representatives, and two industry players from the feed and veterinary service sectors. Respondents were selected from Perlis, Kedah, and Pulau Pinang, representing a balanced geographic and institutional spread. Gender distribution included 11 males and seven female participants; all actively engaged in cattle-related programs aligned with the Quadruple Helix model.

Interview transcripts were analysed thematically following Braun and Clarke's (2006) six-phase framework. Data coding was performed using NVivo 14 software. Initial codes were generated inductively, and thematic patterns were refined through multiple coding cycles. Two additional researchers established Inter-coder reliability through independent reviews to enhance analytical rigor. This process ensured validity, reduced subjectivity, and aligned the emerging themes with the research objectives.

In addition to the interview data, the study integrates in-depth case studies of successful academic-industry-government collaborations. These include initiatives such as university-led breed enhancement trials and community training programs that have demonstrated measurable improvements in cattle productivity, disease management, and environmental sustainability.

The research was conducted over three months, allowing adequate stakeholder engagement, data processing, and synthesis time. Ethical standards were strictly maintained throughout, including informed consent procedures, participant anonymity, and transparency in data usage. These protocols safeguard the study's credibility, trustworthiness, and ethical compliance.

To further strengthen methodological relevance, the study may incorporate innovations such as participatory digital platforms that enhance stakeholder coordination in livestock sectors. For example, adopting real-time data-sharing systems and mobile applications in Smart Agro 5.0 initiatives could be integrated into future research protocols to support enhanced academic

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outreach and decision-making. Including these tools would modernize data collection and analysis and align the research framework with national agricultural digitalisation strategies.

Discussion And Findings

The qualitative findings reveal that academia is crucial yet underutilized in Malaysia's cattle supply chain. Stakeholder interviews highlighted a shared understanding of the capacity of academic institutions to drive technological innovation, foster stakeholder collaboration, disseminate knowledge, and promote sustainable agricultural practices. Despite these strengths, their contributions remain largely unrealized due to weak institutional linkages and persistent communication gaps among the Quadruple Helix actors, such as academia, industry, government, and civil society. Several farmers and industry representatives pointed out that academic research outputs are often inaccessible or presented in formats that are difficult to apply in real-world settings, thereby hampering effective knowledge transfer from research to practice.

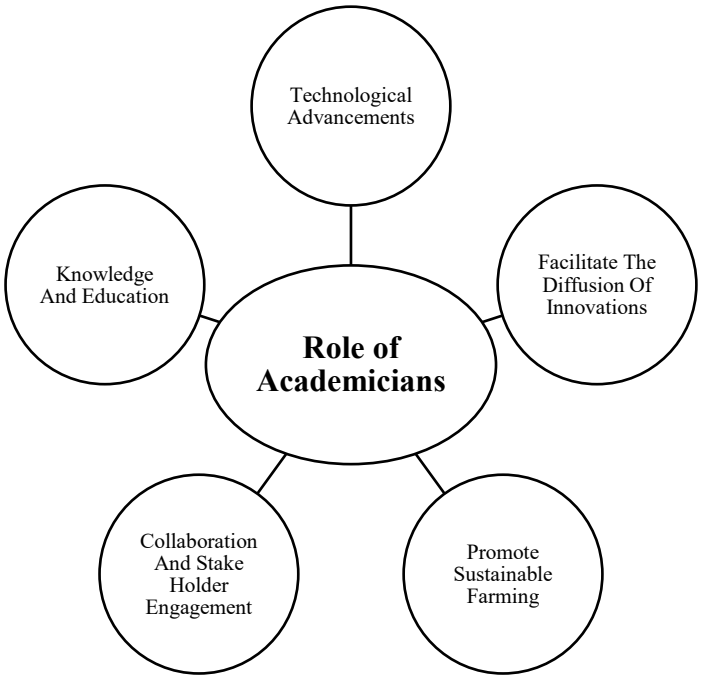

Figure 3: Role of Academician

Source: (own illustration)

While generally supportive, government policy is often misaligned with academic institutions' research priorities. For example, although the National Agro-Food Policy 2.0 (NAFP 2.0) promotes sustainable agriculture, it lacks concrete mechanisms for integrating academic contributions or establishing public-private-university partnerships. This disconnect restricts the potential scale and impact of research-based innovations. In contrast, case studies show that when academia is actively involved in field-level initiatives such as extension services, training programs, and technology trials, there are marked improvements in cattle productivity and disease management. These collaborations are most successful when complemented by government support and NGO facilitation.

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Civil society has a growing influence over market preferences, especially concerning animal welfare and sustainable sourcing. NGOs and local communities provide valuable feedback that can shape academic research and inform product development. However, their role in formal decision-making and innovation processes remains limited. This underrepresentation hinders the full implementation of the Quadruple Helix Model, which relies on the active participation of all four helices.

In summary, the effectiveness of the Quadruple Helix framework in Malaysia's cattle industry is constrained by fragmented coordination, policy misalignment, and inadequate knowledge-sharing platforms. To overcome these challenges, it is essential to establish structured communication channels, develop shared innovation hubs, and promote joint capacity-building programs among all stakeholders. Doing so would enhance the sector's resilience and performance, contributing significantly to national food security.

Latest insights could further enrich this discussion. For instance, MAFI's 2024 mid-term review of NAFP 2.0 emphasizes a shift toward climate-smart agriculture and digital farming systems. These priorities align with university-led innovations in cattle health monitoring and precision feeding. Additionally, the Smart Agro 5.0 initiative in Johor and Selangor demonstrates how IoT-based livestock tracking is beginning to reshape herd management practices. Internationally, programs like Australia's Livestock Data Interoperability and India's e-GOPALA app offer replicable models for integrating academic knowledge into national livestock strategies. Including these developments will position academia as a central driver of policy-relevant, scalable solutions for Malaysia's cattle industry.

Conclusion

This study affirms academia's critical yet underutilized role in enhancing Malaysia's cattle supply chain through research-driven innovation, sustainable practices, and cross-sector collaboration within the Quadruple Helix Model. Despite widespread recognition of this potential, academic engagement remains fragmented due to weak institutional linkages, insufficient knowledge transfer mechanisms, and a disconnect between research outputs and policy implementation.

Addressing these challenges requires systemic efforts to strengthen communication across the four helices of academia, government, industry, and civil society. More precise alignment between academic research and national policy frameworks, particularly the National Agro-Food Policy 2.0 (NAFP 2.0), is essential. Academic institutions should proactively contribute to policy pillars such as sustainable livestock practices, youth agropreneurship, and food security resilience. For instance, partnerships between universities and the Ministry of Agriculture and Food Industries (MAFI) can facilitate integrated training hubs, real-time livestock health surveillance, and certification schemes for sustainable beef production.

Latest advancements also warrant attention. The 2024 Mid-Term Review of NAFP 2.0 underscores digital agriculture and climate-resilient livestock systems as policy priorities, aligning closely with university-led innovation efforts. The 2025 Agropreneur Muda Report reveals emerging opportunities and barriers in youth-led cattle enterprises. Smart Agro 5.0 initiatives in Johor and Selangor demonstrate the practical integration of IoT and AI for herd management. Furthermore, international benchmarks such as Australia's Livestock Data Interoperability Program and India's e-GOPALA platform exemplify successful academia-supported, data-driven livestock innovations that Malaysia could adapt to local conditions.

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Empirical case studies in this research demonstrate the tangible benefits of academic involvement in field-level interventions. When engaged in extension services and pilot initiatives, universities helped reduce calf mortality and improve breed productivity, reflecting the importance of practical, on-ground collaboration. Establishing innovation nodes within agroparks or veterinary institutions could be permanent platforms for academia-government-industry engagement, ensuring that research is translated into action.

Nevertheless, this study is not without limitations. Its qualitative findings may not be widely generalizable across Malaysia's diverse cattle farming landscape. Reliance on semi-structured interviews and case-based insights could introduce respondent bias, and the selection of participants may not reflect the full spectrum of regional and sectoral experiences. Moreover, focusing on the Quadruple Helix Model may exclude other influential variables shaping the industry.

Future research should adopt a mixed-method or quantitative approach to evaluate the measurable impacts of academic interventions on cattle productivity, disease management, and sustainability. Comparative studies between cattle and other livestock sectors, such as poultry or swine, could uncover adaptable best practices and policy-integration strategies for broader livestock development.

Embedding these trends into future academic-industry collaborations will further elevate the role of academia in transforming the national cattle industry.

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