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MULTISECTORAL INTERACTIONS IN THE PHILIPPINE INNOVATION SYSTEM: A QUALITATIVE META-ANALYSIS USING THE QUADRUPLE HELIX FRAMEWORK

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Acceptance Page

This Thesis of **RALY JAMES P. CUSTODIO** titled **"MULTISECTORAL INTERACTIONS IN THE PHILIPPINE INNOVATION SYSTEM: A QUALITATIVE META-ANALYSIS USING THE QUADRUPLE HELIX FRAMEWORK"** is hereby accepted by the Faculty of Management and Development Studies, U.P. Open University, in partial fulfilment of the requirements for the degree **Master of Research and Development Management**.

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Biographical Sketch

Dr. Raly James P. Custodio is Scientific Staff (Postdoctoral Researcher) in the Networking Aging Group, Department of Ergonomics, at the Leibniz Research Centre for Working Environment and Human Factors at TU Dortmund (IfADo), Germany. He holds a Ph.D. and M.Sc. in Pharmacy, specializing in Neuropharmacology, from Sahmyook University, South Korea, as well as an M.A. in Nursing (Clinical Supervision) and a B.Sc. in Nursing from the University of San Carlos and Colegio de Sta. Lourdes of Leyte Foundation, Inc., Philippines, respectively.

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Dedication

This thesis is dedicated to the researchers, scientists, academicians, innovators, practitioners, policymakers, and institutions whose commitment to evidence-based research continues to advance science, technology, and innovation in the Philippines. This also honors the collective contributions of government, universities, industry, communities, and citizens in strengthening knowledge creation, collaboration, and the Philippine innovation ecosystem. May this work contribute, however modestly, to a more connected, evidence-informed, resilient, and globally competitive Philippine innovation ecosystem.

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ABSTRACT

Innovation is widely recognized as a driver of socioeconomic development, yet multisectoral interactions within the Philippine innovation ecosystem remain insufficiently understood. This study employed a qualitative meta-analysis to examine interactions among government, universities, industry, and communities through the Quadruple Helix framework. Guided by PRISMA-ScR, 31 analytical cases from the pre-policy (2013–2018) and post-policy (2020–2025) periods were synthesized to examine changes following the 2019 Philippine Innovation Act and Innovative Startup Act. The findings indicate a shift from a program-driven, semi-operational system characterized by fragmented and localized collaboration toward a more system-driven and state-centric configuration with stronger institutional coordination, governance integration, and government–university collaboration. Government and universities remained the primary institutional anchors, while industry participation was uneven and community involvement remained weakly institutionalized. Overall, the Philippine innovation ecosystem has become more institutionally coordinated, but persistent relational fragmentation and uneven multisectoral participation continue to constrain deeper ecosystem integration.

Keywords: Quadruple Helix; innovation ecosystem; multisectoral interactions; qualitative meta-analysis; innovation governance; Philippines

CHAPTER 1

INTRODUCTION

Background of Study

Innovation as a Driver of Economic Development

Innovation has long been recognized as a key driver of economic development, with its foundations rooted in Joseph Schumpeter's concept of creative destruction. According to Schumpeter (1934), economic progress occurs through the continuous introduction of new combinations of knowledge, technologies, products, and production methods that replace outdated systems and stimulate structural transformation (Antonelli, 2015; Schumpeter, 1934). Since then, innovation has come to be viewed not simply as technological advancement but as a fundamental mechanism through which economies improve productivity, strengthen competitiveness, and achieve sustainable development.

This recognition has prompted many developing countries, particularly low- and middle-income economies, to place innovation at the center of their national development strategies. Innovation policies are increasingly being integrated into economic planning to strengthen domestic capabilities, enhance competitiveness, and support long-term socioeconomic growth (Casadella & Tahi, 2023; Fu & Shi, 2022; Lema et al., 2021). At the international level, organizations such as the United Nations Economic and Social Commission for Asia and the Pacific (UN-ESCAP), the Organisation for Economic Co-operation and Development (OECD), and the World Intellectual Property Organization (WIPO) have likewise promoted innovation as a central pillar of sustainable development and economic resilience (OECD, 2023; UN-ESCAP, 2016; WIPO, 2023a). These initiatives reflect a growing consensus that innovation contributes not only to economic performance but also to addressing

broader societal challenges and improving quality of life (Fagerberg & Hutschenreiter, 2020).

Although many developing countries have made significant progress in strengthening their innovation systems (Krishna, 2022; Lee et al., 2021), developed economies continue to outperform them through sustained investments in research and development (R&D), higher education, infrastructure, technological capabilities, and institutional capacity (WIPO, 2023b). These investments create environments that encourage knowledge creation, technological advancement, entrepreneurship, and innovation-led growth. Historically, development strategies for low- and middle-income countries emphasized the diffusion and adoption of innovations originating from advanced economies rather than the development of indigenous innovation capabilities (Lema et al., 2021). Increasingly, however, attention has shifted toward building domestic innovation systems that enable countries to generate, adapt, and commercialize their own knowledge.

Innovation is therefore no longer regarded as the exclusive domain of advanced economies. Developing countries possess considerable potential to create new products, services, technologies, and organizational practices that improve productivity, generate employment, and support inclusive economic growth (Cirera & Maloney, 2017; Mohamed et al., 2022). Realizing this potential, however, requires more than investments in science and technology alone. It also depends on strengthening institutions, developing human capital, fostering collaboration among diverse stakeholders, and creating policy environments that encourage knowledge exchange and innovation.

As innovation has become increasingly collaborative and knowledge-intensive, it is now understood as a systemic process rather than the product of individual

organizations acting independently. Innovation emerges through interactions among multiple actors that collectively generate, exchange, apply, and diffuse knowledge. This shift in perspective has led to growing interest in innovation ecosystems and collaborative innovation frameworks that explain how government, universities, industry, and, increasingly, communities work together to support innovation and national development. These perspectives provide a more comprehensive understanding of innovation as a multisectoral process and form the conceptual foundation for examining the Philippine innovation ecosystem in this study.

The Innovation Ecosystem, Triple Helix, and Quadruple Helix Perspectives

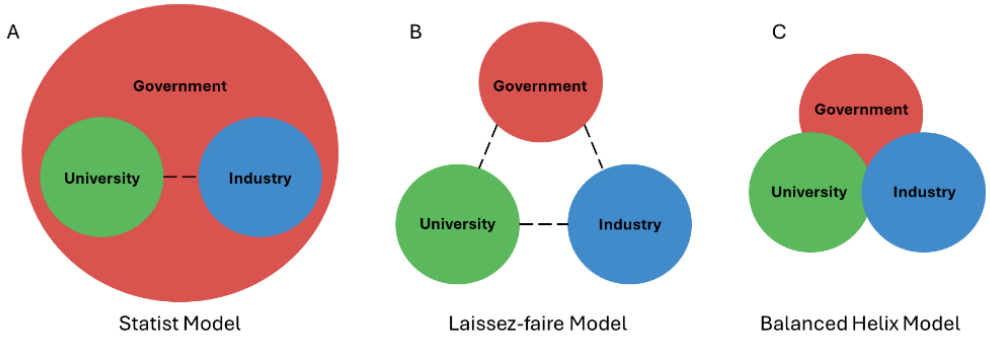
Contemporary innovation is increasingly understood as the product of interactions among multiple actors operating within interconnected institutional, economic, and social environments rather than the efforts of individual organizations acting independently (Granstrand & Holgersson, 2020; Zheng & Cai, 2022). This perspective is reflected in the concept of the innovation ecosystem, which views innovation as an evolving network of organizations, institutions, policies, and relationships that collectively facilitate the creation, diffusion, and application of knowledge. Governments, universities, industries, communities, and other stakeholders contribute complementary resources, expertise, and capabilities, making innovation a collaborative and adaptive process shaped by continuous interaction rather than isolated activities.

Among the frameworks developed to explain these interactions, the Triple Helix Innovation Model (THIM) remains one of the most influential. It conceptualizes innovation as the outcome of reciprocal relationships among government, universities, and industry, emphasizing that knowledge creation, research and development (R&D), technology transfer, commercialization, and supportive public policies are mutually

reinforcing processes (Etzkowitz & Leydesdorff, 1995, 2000; Leydesdorff & Zawdie, 2010). Within this framework, universities generate knowledge and develop human capital, industry transforms knowledge into commercially and socially valuable products and services, and government provides strategic direction through policies, regulation, funding, and institutional support (Fidanoski et al., 2022; Kelleher & Zecharia, 2021). Rather than operating independently, these institutional spheres increasingly assume complementary and, at times, overlapping functions that strengthen the innovation system as a whole.

The Triple Helix framework has been widely applied in both developed and developing economies to explain how institutional collaboration contributes to innovation and economic development (Afzal et al., 2018; OECD, 2013; Saad & Zawdie, 2008). However, interactions among the three institutional spheres do not occur in a uniform manner. Instead, they reflect differences in governance structures, institutional capacity, economic development, and historical context. To account for these variations, three broad configurations have been identified: the Statist, Laissez-faire, and Balanced models (Etzkowitz & Leydesdorff, 2000). These configurations are illustrated in Figure 1.1.

Figure 1.1 The Triple Helix Innovation Model (THIM).



Note: Adapted from Etzkowitz and Leydesdorff (2000): interactions among government, university, and industry in three distinct configurations. The figure depicts the following models: A) Statist Model – Government-driven collaboration; B) Laissez-faire Model – Minimal intervention with largely independent institutional spheres; and C) Balanced Helix Model – Relatively integrated and collaborative relationships among the three actors.

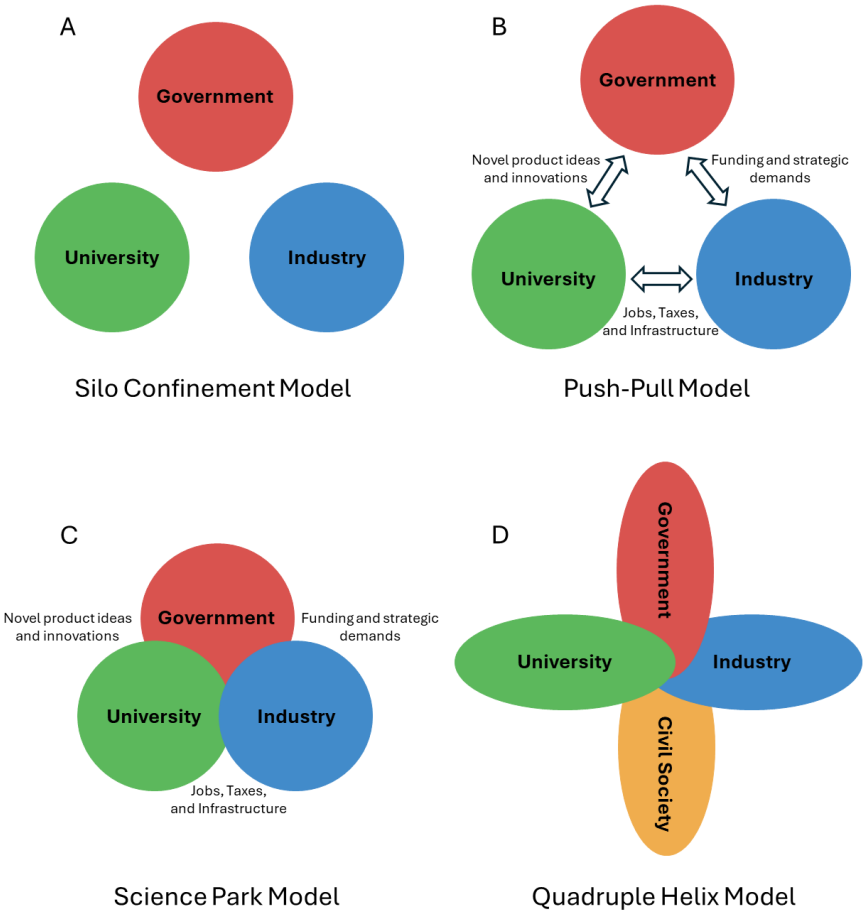
As shown in Figure 1.1, the Statist model places government at the center of innovation activities, exercising substantial influence over universities and industry. In contrast, the Laissez-faire model is characterized by greater institutional independence, with market forces and private-sector initiatives serving as the primary drivers of innovation while government intervention remains relatively limited. The Balanced model represents a more integrated arrangement in which government, universities, and industry collaborate while maintaining their institutional autonomy. Although the Balanced model is often regarded as the most desirable configuration because it promotes knowledge exchange and shared innovation, no single configuration is universally applicable. The dominant interaction pattern typically reflects a country's institutional capacity, governance structure, stage of development, and broader socioeconomic conditions (Cai, 2015; Ranga & Etzkowitz, 2015).

As innovation systems became increasingly complex and socially embedded, scholars recognized that innovation extends beyond interactions among government, universities, and industry alone. This broader perspective gave rise to the Quadruple Helix framework, which incorporates communities, civil society, users, and other

societal actors as a fourth institutional sphere (Carayannis & Campbell, 2012). The inclusion of community expands the understanding of innovation by recognizing that societal needs, local knowledge, public participation, and user engagement influence not only the adoption of innovations but also their creation and refinement. Communities therefore become active participants in identifying problems, co-producing solutions, validating innovations, and facilitating their diffusion. Innovation, in this sense, is viewed not only as an economic activity but also as a social process shaped by interactions between institutional and societal actors.

Alternative interpretations of innovation interactions have likewise been proposed to explain differences across countries with varying levels of economic development and institutional maturity. One such perspective identifies three broad interaction patterns: the Silo Confinement, Push–Pull, and Science Park models (Kimatu, 2016). The Silo Confinement model reflects weak collaboration and limited knowledge exchange among innovation actors. The Push–Pull model is characterized by stronger interaction through technology transfer, policy support, and reciprocal knowledge exchange among government, universities, and industry. The Science Park model represents a highly integrated innovation environment in which collaboration is facilitated through research parks, technology hubs, incubators, and other innovation infrastructures. This further argues that these interaction patterns gradually evolve toward the Quadruple Helix as community participation becomes increasingly important in innovation processes. These interaction models are presented in Figure 1.2.

Figure 1.2 Variations in innovation interaction models across different contexts.



Note: Adapted from Kimatu (2016): A) Silo Confinement Model – Limited interaction among actors; B) Push–Pull Model – Reciprocal engagement among government, university, and industry actors; C) Science Park Model – Collaborative innovation hubs integrating multiple stakeholders; and D) Quadruple Helix Model – Incorporation of civil society and community actors within innovation processes.

As illustrated in Figure 1.2, interaction patterns become progressively more collaborative as innovation systems mature. The transition from siloed relationships to integrated innovation environments demonstrates how stronger institutional linkages and broader stakeholder participation contribute to more dynamic and resilient innovation ecosystems. The addition of community as a fourth helix further recognizes that innovation is shaped not only by institutional collaboration but also by societal engagement, user participation, and locally generated knowledge.

Taken together, the innovation ecosystem, Triple Helix, and Quadruple Helix perspectives provide complementary lenses for understanding how innovation

systems operate. The innovation ecosystem offers a systems-level view of the relationships among institutional and societal actors, while the Triple Helix explains the fundamental interactions among government, universities, and industry that underpin knowledge generation and innovation. The Quadruple Helix extends this perspective by explicitly recognizing the contribution of communities and civil society to innovation processes. These perspectives collectively provide the conceptual basis for examining multisectoral interactions within the Philippine innovation ecosystem.

For the purposes of this study, the Triple Helix Innovation Model serves as the primary theoretical foundation because it provides the core concepts needed to explain institutional relationships among government, universities, and industry. The Quadruple Helix framework is adopted as the principal analytical lens to examine how community actors are represented within published studies and to interpret the emergence of broader multisectoral interactions across the Philippine innovation ecosystem. Together, these complementary perspectives support the analysis of actor interactions, the identification of innovation configurations, and the comparison of ecosystem dynamics between the pre-policy (2013–2018) and post-policy (2020–2025) periods following the Philippine innovation reforms of 2019. This combined perspective is particularly appropriate because the study seeks not only to examine institutional collaboration but also to understand how the Philippine innovation ecosystem is evolving toward a more inclusive and socially embedded model of innovation governance.

Innovation in the Philippine Context

The Philippines, a member of the Association of Southeast Asian Nations (ASEAN), has increasingly recognized innovation as a key driver of national development and economic competitiveness. This commitment is reflected in

landmark policy initiatives, particularly the Philippine Innovation Act (Republic Act No. 11293) and the Innovative Startup Act (Republic Act No. 11337), both enacted in 2019. These legislative measures seek to strengthen the country's innovation ecosystem by promoting innovation-driven entrepreneurship, expanding support for research and technology development, improving access to financing, and enhancing coordination among institutions involved in science, technology, and innovation (STI) (Ilas-Panganiban & Mitra-Ventanilla, 2020). The establishment of the National Innovation Council further institutionalized a whole-of-government approach to innovation governance by providing a mechanism for coordinating innovation policies and programs across sectors.

Despite these developments, the Philippine innovation ecosystem continues to face longstanding structural and institutional challenges. These include relatively low investment in research and development, infrastructure constraints, uneven research capacity across institutions, limited commercialization of research outputs, and varying levels of participation among innovation actors (Teves et al., 2023). Although government, universities, and industry remain the principal actors within the country's innovation system, there is growing recognition that communities, civil society organizations, users, and other societal stakeholders also contribute to innovation through knowledge sharing, co-creation, validation, and adoption. Understanding how these institutional and societal actors interact has therefore become increasingly important for explaining how innovation systems evolve within the Philippine context.

The enactment of the Philippine Innovation Act and the Innovative Startup Act also provides an important reference point for examining changes in the country's innovation ecosystem. These reforms were intended to strengthen institutional coordination, improve collaboration among innovation actors, and create an enabling

environment for innovation. Consequently, they provide a useful basis for comparing how multisectoral interactions were represented in published studies before and after the 2019 reforms. Rather than assuming that policy enactment automatically transformed the innovation system, the study examines whether published evidence reflects changes in actor participation, interaction patterns, and innovation configurations across the two policy periods.

Against this backdrop, the present study investigates how multisectoral interactions within the Philippine innovation ecosystem are represented and interpreted in published literature using the Quadruple Helix framework. Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR), relevant publications were systematically identified, screened, and synthesized, with each publication treated as an analytical case. The analysis focuses on how interactions among government, universities, industry, and community actors are documented and interpreted rather than on measuring actual interactions directly. Each case is examined to identify the actors involved, characterize their interaction patterns, classify the innovation configuration that best represents the case, and synthesize the enabling factors, barriers, structural gaps, and relational challenges reported by the original authors. These interpretations are derived from explicit evidence presented in the reviewed studies and are examined through the structural, functional, and relational dimensions of the Triple Helix and Quadruple Helix frameworks.

The analysis further compares documented interaction models and innovation configurations between the pre-policy period (2013–2018) and the post-policy period (2020–2025) to explore how multisectoral relationships are represented following the 2019 innovation reforms. Rather than evaluating policy effectiveness or attributing

observed patterns directly to legislative changes, the comparison is intended to identify recurring trends, emerging configurations, and shifts in the representation of actor interactions across the published literature.

By synthesizing evidence from multiple studies, this research generates conceptual and analytical insights into the structure, dynamics, and governance of the Philippine innovation ecosystem. The findings contribute to a deeper understanding of how government, universities, industry, and community actors are represented within published research, how different innovation configurations emerge across contexts, and how these interactions appear to evolve over time. Given the qualitative nature of the study and the unequal distribution of analytical cases across policy periods, the findings should be interpreted as indicative rather than conclusive. Nevertheless, they provide a contextually grounded foundation for future empirical research and informed discussions on innovation ecosystems, Quadruple Helix interactions, and innovation governance in the Philippines.

Research Questions

To address the problem and achieve the objectives of this study, the following research questions (RQ) were formulated:

Main Research Question: How are multisectoral interactions represented and interpreted in published studies on the Philippine innovation ecosystem using the Quadruple Helix framework?

Sub-research Question 1: Who are the key actors, and what interaction patterns characterize their relationships across the analyzed cases?

Sub-research Question 2: What interaction models or innovation configurations best characterize the multisectoral interactions identified across the analyzed cases?

Sub-research Question 3: How do interaction models and innovation configurations differ between the pre-policy period (2013–2018) and the post-policy period (2020–2025) following the enactment of the Philippine Innovation Act and the Innovative Startup Act in 2019?

Objectives of the study

The main objective of this study was to critically examine and synthesize multisectoral interactions documented in published studies on the Philippine innovation ecosystem using the Quadruple Helix framework. Specifically, the study aimed to identify the key actors and their interactions, classify the interaction models or innovation configurations represented across analytical cases, compare these configurations between the pre-policy and post-policy periods, and derive conceptual insights into the governance of the Philippine innovation ecosystem.

Specifically, the study aimed to:

1. Identify the key actors involved in the Philippine innovation ecosystem and examine how their interactions are represented across the analyzed cases.
2. Characterize the interaction patterns and interrelationships among government, universities, industry, and community actors.
3. Identify and classify the interaction models or innovation configurations represented across the analyzed cases using the Quadruple Helix framework.
4. Compare the interaction models and innovation configurations observed during the pre-policy period (2013–2018) and the post-policy period (2020–2025) following the enactment of the Philippine Innovation Act and the Innovative Startup Act in 2019.

5. Generate conceptual insights into the structure, dynamics, and governance of the Philippine innovation ecosystem based on the identified interaction models and innovation configurations.

Significance of Study

This study contributes to the understanding of the Philippine innovation ecosystem by providing a systematic qualitative meta-analysis of multisectoral interactions documented in published studies. Using the Quadruple Helix framework as its principal analytical lens, the study synthesizes evidence from diverse innovation contexts to identify the key actors involved, characterize their interactions, determine the interaction models and innovation configurations represented across analytical cases, and compare these configurations between the pre-policy and post-policy periods following the Philippine innovation reforms of 2019.

The findings are relevant to several stakeholder groups. For policymakers, the study offers a broader understanding of the interaction patterns, opportunities, and challenges associated with multisectoral collaboration within the Philippine innovation ecosystem. Although the study does not evaluate the effectiveness of specific policies or establish causal policy outcomes, it provides conceptual and analytical insights that may support future discussions on science, technology, and innovation (STI) governance, institutional coordination, and ecosystem development. For universities and research institutions, the findings contribute to a better understanding of their roles as knowledge producers, innovation intermediaries, and collaborative partners within the innovation ecosystem. By examining how academic institutions are represented across different innovation contexts, the study identifies opportunities to strengthen research collaboration, knowledge exchange, technology transfer, and community engagement. For industry, the study provides insights into how firms

participate in multisectoral innovation activities and how their relationships with government, universities, and community actors are represented in the literature. The findings highlight the different forms of collaboration that support innovation, technology commercialization, and broader ecosystem development while identifying areas where industry participation remains limited. The study is likewise relevant to community organizations, civil society groups, innovation intermediaries, and other societal stakeholders. By explicitly examining the role of community actors within innovation processes, the study contributes to a growing understanding of how public participation, local knowledge, user engagement, and collaborative problem-solving are represented within the Philippine innovation ecosystem and how these interactions reflect emerging Quadruple Helix configurations.

Beyond its practical contributions, the study advances the theoretical literature on innovation ecosystems, the Triple Helix Innovation Model, and the Quadruple Helix framework. By identifying and comparing interaction models and innovation configurations across analytical cases, the study provides a contextually grounded interpretation of how multisectoral interactions are organized within the Philippine innovation ecosystem. It also contributes to ongoing discussions on the emergence of community participation, the changing relationships among institutional actors, and the evolving structure of innovation governance in developing-country contexts. Methodologically, the study demonstrates the value of qualitative meta-analysis as an approach for synthesizing evidence from diverse innovation settings. Treating each publication as an analytical case makes it possible to identify recurring interaction patterns, innovation configurations, structural gaps, and relational challenges while acknowledging the limitations inherent in published literature, including publication

bias, visibility bias, uneven case representation, and contextual variation across sectors and policy periods.

Ultimately, this study provides a more comprehensive and contextually grounded understanding of multisectoral interactions within the Philippine innovation ecosystem. By identifying recurring interaction patterns, classifying innovation configurations, and generating conceptual and analytical insights into innovation governance, the study contributes to the continuing development of innovation ecosystem research and provides a foundation for future empirical investigations of Quadruple Helix interactions and broader innovation processes in the Philippines and other developing-country contexts.

Scope and Limitation of the Study

This study employed a qualitative meta-analysis to examine multisectoral interactions within the Philippine innovation ecosystem using the Quadruple Helix framework as its principal analytical lens. Published literature served as the primary source of evidence. Rather than measuring actual interactions among innovation actors, the study examined how interactions among government, universities, industry, and community actors are represented, interpreted, and discussed in published research. Each selected publication was treated as an analytical case, allowing for the systematic identification and comparison of key actors, interaction patterns, interaction models, innovation configurations, governance arrangements, and institutional relationships across different innovation contexts.

The review was limited to studies that:

- Focused on the Philippine innovation ecosystem;

- Were original research articles written in English and available in full-text format; and
- Included at least one author affiliated with a Philippine institution to ensure contextual relevance and familiarity with the local innovation environment.

Each analytical case was classified according to the interaction model or innovation configuration that best characterizes the documented relationships among actors. This classification was based on the composition of actors, the nature of their interactions, governance arrangements, and the degree of integration among government, universities, industry, and community actors as reported in the reviewed studies. These criteria provided a common analytical basis for comparing cases while recognizing that innovation systems operate within diverse institutional and sectoral contexts.

The study did not involve primary data collection through interviews, surveys, observations, or other field-based methods. Consequently, the findings reflect how multisectoral interactions were represented in published literature and may not fully capture the breadth and complexity of innovation activities occurring in practice. The analysis therefore acknowledges the potential influence of publication bias, visibility bias, and endogeneity, recognizing that the absence of documented interactions should not be interpreted as evidence that collaboration did not occur. Moreover, the identification of structural gaps, functional barriers, and relational challenges was based on findings explicitly reported by the original study authors. These were interpreted using the structural, functional, and relational dimensions of the Triple Helix and Quadruple Helix frameworks to facilitate consistent comparison across analytical cases. Accordingly, these classifications should be understood as analytical

interpretations derived from the published evidence rather than definitive assessments of innovation performance or institutional effectiveness.

To examine possible differences in documented multisectoral interactions, the analytical cases were grouped into two periods: the pre-policy period (2013–2018) and the post-policy period (2020–2025), using the enactment of the Philippine Innovation Act and the Innovative Startup Act in 2019 as the temporal reference point. This comparison was intended to identify differences in the representation of interaction patterns, interaction models, and innovation configurations reported in the literature. However, variations in the number, composition, disciplinary focus, and sectoral distribution of analytical cases across the two periods limit direct comparability. Consequently, the study did not seek to determine policy effectiveness or establish causal relationships between the 2019 reforms and observed interaction patterns. Given its qualitative and interpretive design, the study was intended to generate conceptual and analytical insights rather than statistical generalizations or formal evaluations of innovation policy. The findings should therefore be interpreted as indicative of recurring patterns, emerging innovation configurations, and evolving forms of multisectoral interaction documented in published studies.

Despite these limitations, the study provides a systematic and contextually grounded synthesis of the Philippine innovation ecosystem by identifying key actors, characterizing their interactions, and comparing interaction models and innovation configurations across pre-policy and post-policy periods. The findings deepen understanding of innovation governance, multisectoral collaboration, and emerging Quadruple Helix dynamics while providing a foundation for future empirical studies using primary data and complementary methods.

CHAPTER II

THEORETICAL BACKGROUND

Review of Related Literature

Innovation and Economic Development

Innovation has long been recognized as a fundamental driver of economic development, influencing productivity, competitiveness, and social well-being (Antonelli, 2015; Schumpeter, 1934). Since Schumpeter introduced the concept of creative destruction, innovation has been understood as a process through which new technologies, products, services, and organizational practices replace existing ones, transforming industries and creating new opportunities for economic growth (Schumpeter, 1934). As economies have become increasingly knowledge-based, innovation has evolved from being viewed primarily as the outcome of scientific and technological advancement to being recognized as a strategic resource for long-term economic and societal development.

Current scholarship suggests that the relationship between innovation and economic development extends well beyond technological progress alone. Institutional arrangements, governance structures, social conditions, and collaborative networks all shape how knowledge is generated, exchanged, and translated into economic and societal value (Fagerberg et al., 2010). Rather than occurring within isolated organizations, innovation emerges through interactions among multiple actors that contribute complementary knowledge, resources, and capabilities. Consequently, innovation is increasingly viewed as a systemic process whose effectiveness depends on the quality of relationships among institutions and the broader environments in which they operate.

This systems-oriented perspective has contributed to the emergence of the innovation ecosystem as a useful framework for understanding contemporary innovation processes. Innovation ecosystems differ from natural ecosystems because they are intentionally formed through institutional arrangements, governance mechanisms, and policy interventions that facilitate collaboration among diverse stakeholders (Oh et al., 2016). Their success depends not only on the capabilities of individual organizations but also on the extent to which governments, universities, industries, and other actors coordinate their activities, exchange knowledge, and mobilize resources toward common innovation objectives. Innovation, therefore, is increasingly understood as a collective endeavor sustained through continuous interaction rather than the isolated efforts of individual institutions.

The broader social and cultural environment likewise shapes the capacity of innovation systems to generate and diffuse knowledge. Collaborative values, trust, openness to new ideas, and shared responsibility create conditions that encourage knowledge exchange, organizational learning, and long-term cooperation. Conversely, fragmented institutional environments, rigid hierarchies, and weak social cohesion may constrain collaboration and reduce opportunities for innovation (Kostis, 2021). These observations suggest that strengthening innovation systems requires more than investments in science and technology; it also requires institutional and cultural environments that encourage cooperation, learning, and the effective exchange of knowledge.

Experiences from emerging and newly industrialized economies further demonstrate that innovation is not the exclusive domain of advanced countries. The sustained economic development achieved by countries such as South Korea, Taiwan, and Singapore illustrates the importance of investing in technological capability,

human capital, institutional learning, and long-term collaboration among public and private actors (Fagerberg et al., 2010). Their experiences indicate that successful innovation systems depend not only on acquiring technologies from abroad but also on developing the capacity to absorb, adapt, improve, and generate knowledge within domestic institutions. These countries demonstrate how deliberate investments in innovation capabilities can strengthen national competitiveness and support sustained economic transformation.

Empirical evidence likewise points to a close relationship between innovation and economic performance. Cross-country analyses indicate that innovation contributes to economic growth. In contrast, economic development can, in turn, create conditions that either facilitate or constrain future innovation depending on the quality of institutional arrangements (Duyen & Tinh, 2024). Stable governance systems, effective public institutions, and strategic investments in research and development tend to encourage innovation by providing direction and reducing uncertainty. At the same time, excessive bureaucratic rigidity, institutional fragmentation, and regulatory complexity may discourage experimentation, limit organizational flexibility, and weaken entrepreneurial activity. These findings underscore the importance of governance arrangements that balance coordination with adaptability.

Collectively, the literature demonstrates that the interaction of technological capabilities, institutional arrangements, governance structures, and broader social conditions shapes innovation-driven development. Innovation should therefore be viewed not merely as the result of scientific discovery or technological advancement but as a socio-institutional process involving multiple actors whose interactions influence the creation, diffusion, and application of knowledge. This perspective shifts

attention from individual organizations to the broader systems of relationships that enable innovation to occur.

For developing economies such as the Philippines, these insights highlight the importance of understanding how innovation actors interact within an evolving innovation ecosystem. They also provide a strong rationale for examining innovation through frameworks that emphasize collaboration rather than focusing exclusively on technological outputs or the performance of individual institutions. The Triple Helix and Quadruple Helix perspectives are particularly relevant because they explain how government, universities, industry, and, increasingly, community actors contribute to innovation through different forms of institutional interaction. These perspectives provide the theoretical foundation for the present study, which examines how multisectoral interactions are represented in the Philippine innovation ecosystem, identifies the interaction models and innovation configurations reflected in published studies, and explores how these configurations evolved following the Philippine innovation reforms enacted in 2019.

The Innovation Ecosystem

The innovation ecosystem has become one of the most widely used perspectives for understanding how innovation is created, developed, and sustained through the interaction of multiple actors operating within interconnected institutional environments (Adner & Kapoor, 2010; de Vasconcelos Gomes et al., 2018). Unlike traditional linear models, which portray innovation as a sequence progressing from scientific discovery to commercialization, the innovation ecosystem perspective recognizes innovation as a dynamic process shaped by continuous interaction, knowledge exchange, and resource sharing among diverse organizations and stakeholders. Innovation, therefore, is viewed not as the outcome of isolated

institutions but as the product of relationships that evolve within broader economic, institutional, and societal contexts.

The concept originated from the business ecosystem literature, where attention was initially directed toward networks of organizations that collectively create and capture value around a focal firm or technological platform (Moore, 1993). As the concept matured, its scope expanded beyond firm-centered relationships to encompass the broader processes through which governments, universities, industries, research institutions, communities, users, and other stakeholders contribute to innovation. This broader perspective recognizes that different actors possess complementary resources, capabilities, and knowledge that become more valuable when mobilized through collaborative arrangements rather than through independent action (Adner & Kapoor, 2010; de Vasconcelos Gomes et al., 2018).

Despite its widespread application, the innovation ecosystem has been interpreted in different ways across the literature. A commonly accepted synthesis describes it as an evolving set of actors, activities, artifacts, institutions, and relationships that collectively influence the generation, diffusion, and application of innovation (Granstrand & Holgersson, 2020). This definition extends the concept beyond organizational networks by recognizing that technologies, infrastructure, regulatory systems, and institutional arrangements also shape innovation processes. It likewise acknowledges that ecosystem relationships are rarely purely collaborative or purely competitive. Instead, organizations often cooperate in some activities while competing in others, creating a dynamic balance that influences innovation performance.

Another important characteristic of innovation ecosystems is their capacity to evolve. Ecosystems continually change as new actors emerge, existing relationships

strengthen or weaken, technologies advance, and institutional conditions shift. Rather than remaining static, ecosystems develop through successive stages described as emergence, expansion, leadership, and renewal, with each stage characterized by different patterns of interaction, resource mobilization, and value creation (Dias Sant´ Ana et al., 2020). These evolutionary processes may occur at organizational, regional, national, or international levels, demonstrating that innovation ecosystems operate across multiple scales and adapt to changing economic and technological environments.

The structure of an innovation ecosystem also varies according to the way actors are organized and coordinated. In some settings, interactions revolve around a central organization, platform, or institution that facilitates collaboration among participating actors. In others, coordination is distributed across multiple organizations without a single dominant actor. Regardless of the governance structure, ecosystem performance depends largely on the capacity of participating organizations to exchange knowledge, coordinate complementary activities, mobilize resources, and build relationships that support collective innovation (Dias Sant´ Ana et al., 2020; Walrave et al., 2018).

Governance therefore occupies a central position within innovation ecosystems. Because innovation involves organizations with different objectives, capabilities, and institutional responsibilities, mechanisms are needed to coordinate activities, align incentives, and manage interdependencies. Effective ecosystem governance involves establishing institutional arrangements that encourage collaboration while allowing sufficient flexibility for experimentation and adaptation. At the same time, ecosystem actors must respond to broader external influences, including regulatory changes, technological developments, market conditions, and evolving societal expectations

(Granstrand & Holgersson, 2020; Walrave et al., 2018). The capacity to adapt to these changing conditions is often a defining characteristic of resilient innovation ecosystems.

More recent scholarship has also broadened the scope of innovation ecosystems by recognizing the contributions of actors beyond government, universities, and industry. Communities, civil society organizations, users, innovation intermediaries, and other societal stakeholders increasingly participate in identifying local needs, contributing contextual knowledge, co-producing innovations, and supporting the diffusion and adoption of new technologies (Kimatu, 2016). Their participation highlights that innovation is not solely an economic or technological activity but also a social process shaped by public engagement, local contexts, and collaborative learning. This broader understanding closely aligns with the emergence of the Quadruple Helix perspective, which recognizes community participation as an integral component of contemporary innovation systems.

Overall, the innovation ecosystem perspective provides a comprehensive framework for understanding innovation as the outcome of interactions among interconnected institutional and societal actors. By emphasizing collaboration, governance, knowledge exchange, and the co-creation of value, it offers an appropriate systems perspective for examining multisectoral interactions within the Philippine innovation ecosystem. More importantly, it provides the broader theoretical context within which the Triple Helix explains institutional collaboration among government, universities, and industry, while the Quadruple Helix extends this perspective by incorporating the increasingly important role of communities and civil society. Together, these perspectives provide the conceptual foundation for examining

the interaction models, innovation configurations, and governance patterns explored in this study.

Triple and Quadruple Helix Frameworks

The Triple Helix has become one of the most widely adopted frameworks for explaining how innovation emerges through interactions among universities, industry, and government. Rather than portraying innovation as a linear process in which scientific discoveries progress directly toward commercialization, the framework views innovation as a collaborative and iterative process in which knowledge is continuously created, exchanged, transformed, and applied through sustained interaction among institutional actors (Etzkowitz & Leydesdorff, 1995). Innovation is therefore understood as the outcome of relationships that enable organizations to combine complementary knowledge, resources, and capabilities rather than as the product of isolated institutional efforts.

Within this framework, universities, industry, and government perform distinct yet complementary functions. Universities contribute scientific knowledge, research capability, and human capital development. Industry transforms knowledge into products, services, and commercial applications, while government establishes the policy environment, regulatory mechanisms, and institutional support necessary for innovation to flourish. As innovation systems evolve, these institutional boundaries become increasingly permeable, allowing universities to engage in entrepreneurial activities, industries to participate more actively in research and development, and governments to assume broader roles in facilitating collaboration, coordinating innovation policies, and strengthening institutional linkages (Etzkowitz & Leydesdorff, 2000). This functional overlap encourages the formation of hybrid organizations,

innovation intermediaries, research partnerships, and other collaborative arrangements that strengthen the innovation ecosystem.

The literature likewise recognizes that relationships among the three institutional spheres vary according to national context. Three broad configurations have been identified: the Statist, Laissez-faire, and Balanced Triple Helix models (Etzkowitz & Leydesdorff, 2000). In the Statist configuration, government assumes the dominant coordinating role and exerts substantial influence over universities and industry. Such arrangements may facilitate strategic planning, policy coherence, and resource mobilization, particularly in developing countries where public institutions remain the primary drivers of innovation. However, excessive state dominance may also reduce institutional autonomy and constrain bottom-up innovation initiatives.

The Laissez-faire configuration represents the opposite arrangement, where universities, industry, and government operate largely as independent institutional spheres and interact mainly through market-based mechanisms and formal contractual relationships. Although this configuration may promote organizational autonomy and competition, weaker coordination can limit knowledge integration and reduce opportunities for collaborative innovation. Between these two extremes lies the Balanced Triple Helix, where the three institutional spheres retain their respective roles while participating in sustained collaboration through research partnerships, innovation networks, technology transfer activities, and hybrid organizations. This configuration is generally associated with stronger knowledge exchange, greater institutional adaptability, and more integrated innovation systems. Nevertheless, the literature cautions against viewing the Balanced model as universally optimal. The most appropriate configuration depends largely on a country's institutional maturity, governance structure, political environment, economic conditions, and innovation

capacity (Cai, 2015; Ranga & Etzkowitz, 2015). Consequently, state-centric arrangements may represent transitional stages in developing innovation systems rather than evidence of institutional weakness.

Beyond these structural configurations, the Triple Helix has also been interpreted as an evolutionary framework in which innovation systems continuously adapt to technological change, policy reforms, and shifting economic priorities through communication, institutional learning, and reciprocal feedback among participating actors (Leydesdorff & Zawdie, 2010). Innovation capacity therefore depends not only on the presence of government, universities, and industry but also on the quality of the relationships that connect them. Continuous interaction enables institutions to respond collectively to emerging opportunities while strengthening the long-term resilience of the broader innovation ecosystem.

Differences in institutional capacity also produce distinct patterns of interaction across countries. Comparative studies have described developmental trajectories ranging from Silo Confinement, where interactions remain fragmented and weakly institutionalized, to Push–Pull arrangements characterized by stronger reciprocal engagement, and ultimately to Science Park models that integrate universities, industry, and government through dedicated innovation infrastructures (Kimatu, 2016). These interaction models demonstrate that innovation systems evolve as governance mechanisms mature, institutional capacities strengthen, and collaborative relationships become more deeply embedded. They also illustrate that innovation configurations should be interpreted within their historical, political, and socioeconomic contexts rather than against a single universal standard.

As innovation systems have become increasingly complex, scholars have recognized that innovation extends beyond the traditional relationships among

government, universities, and industry. Communities, civil society organizations, users, innovation intermediaries, and other societal actors now contribute to identifying societal needs, co-producing knowledge, validating technologies, facilitating adoption, and shaping innovation priorities. This broader understanding gave rise to the Quadruple Helix, which extends the original framework by incorporating civil society as a fourth institutional sphere (Carayannis & Campbell, 2012). Rather than replacing the Triple Helix, the Quadruple Helix broadens its scope by recognizing that innovation is simultaneously an institutional, economic, and social process. The inclusion of community actors reflects growing recognition that sustainable innovation depends not only on scientific excellence and economic competitiveness but also on public participation, contextual knowledge, user engagement, and societal relevance.

Viewed together, the Triple Helix and Quadruple Helix provide complementary perspectives for understanding innovation systems. The Triple Helix offers a robust theoretical explanation of how institutional relationships among government, universities, and industry shape innovation processes, governance arrangements, and knowledge exchange. The Quadruple Helix extends this perspective by incorporating community actors and emphasizing the social dimensions of innovation. This expanded perspective is particularly relevant for developing countries, where innovation increasingly depends on multisectoral collaboration that extends beyond formal institutions.

Accordingly, this study adopts the Triple Helix as its principal theoretical foundation because it provides a well-established basis for explaining institutional relationships, governance structures, and interaction patterns within innovation systems. At the same time, the Quadruple Helix serves as the primary analytical framework for interpreting the emerging participation of community actors and

examining how multisectoral interactions, innovation configurations, and governance arrangements are represented across the analytical cases before and after the Philippine innovation reforms of 2019.

Innovation Ecosystems and Helix Frameworks in Developing Countries

The application of innovation ecosystem and Helix-based frameworks in developing countries differs considerably from that observed in more advanced economies. Although collaboration among government, universities, industry, and, increasingly, community actors is widely recognized as essential for innovation, many developing countries continue to face institutional, economic, and governance challenges that constrain effective interaction. Weak research capacity, fragmented institutional arrangements, limited private-sector investment in research and development (R&D), and inconsistent policy implementation often restrict the formation of mature innovation ecosystems.

One recurring observation in the literature is that innovation systems in developing countries are characterized by relatively weak institutional linkages. Universities frequently remain focused on teaching rather than research commercialization, industries often have limited absorptive capacity to utilize scientific knowledge, and governments primarily perform regulatory functions instead of actively facilitating collaborative innovation (Saad & Zawdie, 2008). Under these conditions, innovation tends to occur through isolated initiatives rather than through sustained multisectoral collaboration. Strengthening innovation systems therefore requires more than increasing research investment; it also involves building institutional capacity, fostering trust among actors, encouraging entrepreneurial universities, and creating governance mechanisms that support continuous interaction and collective learning (Saad & Zawdie, 2008).

Experiences from Southeast Asia illustrate both the opportunities and the challenges associated with strengthening innovation systems in developing economies. In Indonesia, efforts to integrate universities with industry and government have produced encouraging initiatives, including technology business incubators, regional innovation clusters, and university-based commercialization programs. Nevertheless, collaboration remains uneven because of weak institutional coordination, inconsistent policy implementation, and limited financial support for research and technology commercialization (Ranga & Etzkowitz, 2013). These experiences suggest that innovation policies cannot simply replicate models from developed economies but must instead be adapted to local institutional conditions, governance structures, and regional development priorities.

Malaysia presents a different trajectory in which stronger government coordination has facilitated closer collaboration among universities, industry, and public institutions. National funding programs, dedicated research management structures, and commercialization initiatives have contributed to a more organized innovation system and strengthened institutional partnerships (Afzal et al., 2018). Despite these advances, challenges remain, particularly in increasing private-sector investment in research, improving technology commercialization, and enhancing policy implementation. These observations indicate that government leadership can accelerate innovation system development. However, continued participation from universities, industry, and other stakeholders remains necessary to achieve a more balanced and sustainable innovation ecosystem.

Viewed collectively, these studies demonstrate that the development of innovation ecosystems in developing countries depends on far more than the presence of the traditional Triple Helix actors. Institutional capacity, governance quality,

policy coherence, financial support, and the ability of organizations to collaborate over time all influence how innovation systems evolve. Countries with stronger institutional coordination generally exhibit more integrated innovation systems, whereas fragmented governance arrangements often result in weaker collaboration and slower knowledge transfer.

More recent developments further suggest that innovation in developing countries increasingly extends beyond interactions among government, universities, and industry alone (Carayannis & Campbell, 2012). Communities, civil society organizations, innovation intermediaries, and users are becoming more visible participants in innovation processes by contributing local knowledge, validating technologies, identifying societal needs, and supporting the diffusion and adoption of innovations. These developments reflect the gradual transition from traditional Triple Helix arrangements toward broader innovation ecosystem perspectives and emerging Quadruple Helix configurations. Rather than replacing the Triple Helix, the Quadruple Helix extends it by recognizing that sustainable innovation also depends on meaningful engagement with society and the communities that innovation ultimately intends to serve.

These perspectives are particularly relevant to the Philippine context. Like many developing countries, the Philippines continues to strengthen its innovation ecosystem while addressing institutional fragmentation, uneven industry participation, and evolving mechanisms for community engagement. Examining how these interactions are represented across published studies therefore provides an opportunity to understand better the country's emerging innovation configurations and the extent to which its innovation ecosystem exhibits characteristics associated with both the Triple Helix and the Quadruple Helix frameworks.

The Philippine Innovation Ecosystem

The Philippine innovation ecosystem has undergone substantial institutional development over the past decade through reforms intended to strengthen collaboration among government, universities, industry, and, increasingly, community actors. Two landmark legislations enacted in 2019, the Philippine Innovation Act (Republic Act No. 11293) and the Innovative Startup Act (Republic Act No. 11337), represent important milestones in the country's efforts to institutionalize innovation as a national development strategy. Together, these laws provide the policy, governance, and financial mechanisms needed to strengthen research and development (R&D), technology transfer, entrepreneurship, startup development, and multisectoral collaboration within the national innovation ecosystem.

The Philippine Innovation Act establishes the country's overarching innovation policy by creating governance structures that promote coordination across institutions responsible for science, technology, education, and economic development. Through the creation of the National Innovation Council and the Innovation Fund, the Act seeks to strengthen institutional coordination, improve policy coherence, expand research capacity, and encourage the translation of scientific knowledge into innovations that contribute to national competitiveness and inclusive development. Complementing this legislation, the Innovative Startup Act focuses on developing innovation-driven enterprises by providing financial assistance, incubation support, mentoring programs, regulatory incentives, and improved access to domestic and international markets. The Act likewise promotes collaboration among the Department of Science and Technology (DOST), Department of Trade and Industry (DTI), Department of Information and Communications Technology (DICT), universities, private investors,

and startup communities, thereby broadening participation within the national innovation ecosystem.

Collectively, these legislative reforms illustrate a transition from isolated innovation initiatives toward a more coordinated innovation ecosystem. Although interactions among government, universities, and industry remain central, the institutional arrangements created under both Acts also recognize the growing contribution of startups, innovation intermediaries, investors, and entrepreneurial communities. This broader orientation reflects characteristics increasingly associated with the Quadruple Helix, where innovation is influenced not only by formal institutions but also by societal participation and collaborative networks.

Evidence from the Philippine startup ecosystem demonstrates how these policy reforms have shaped innovation practice. The development of startup communities began largely through private-sector initiatives during the early 2000s before becoming increasingly supported by government programs and national innovation policies (Teves et al., 2023). The introduction of the Philippine Innovation Act and the Innovative Startup Act accelerated this process by providing institutional support for startup development, contributing to the rapid growth of the country's startup ecosystem. Expansion has been particularly evident in fintech, digital services, media, e-commerce, education technology, health technology, and agricultural technology, reflecting increasing diversification of innovation activities beyond traditional technology sectors (Teves et al., 2023).

Government continues to play a prominent role in this evolving ecosystem through funding programs, policy coordination, and institutional support. The National Innovation Council, Innovation Fund, and various startup support mechanisms administered by DOST, DTI, and DICT have strengthened the country's innovation

infrastructure. Venture capital firms, incubators, accelerators, universities, and research institutions complement these initiatives by providing financial resources, mentoring, technical expertise, and commercialization support. Nevertheless, important challenges remain, including limited access to advanced-stage financing, uneven regional development, and the relatively small number of mature accelerator programs capable of supporting high-growth startups (Teves et al., 2023).

Human capital also remains a critical component of ecosystem development. Although the Philippines has expanded its pool of researchers and continues to strengthen science, technology, engineering, and mathematics (STEM) education, research capacity remains comparatively lower than that of several neighboring ASEAN countries. Programs such as the Balik Scientist Program seek to address these limitations by encouraging Filipino researchers abroad to contribute to domestic research and innovation. Continued investment in research training, entrepreneurship education, and talent development remains essential for strengthening the country's innovation capacity.

Recent assessments likewise indicate that the Philippine innovation ecosystem has demonstrated measurable progress while continuing to face important structural constraints (Custodio, 2025). National research productivity has increased across several scientific disciplines, supported by institutions such as DOST and leading universities. The country's improvement in the Global Innovation Index also suggests gradual strengthening of its innovation system. However, persistent weaknesses remain, including relatively low gross expenditure on research and development (GERD), limited private-sector investment, weak university–industry collaboration, fragmented institutional coordination, and continuing shortages of highly skilled researchers. These observations suggest that policy reforms have strengthened the

institutional foundations of innovation but have not yet fully addressed long-standing structural constraints within the national innovation ecosystem.

Technology Business Incubators (TBIs) have emerged as important intermediaries within this evolving ecosystem. Rather than functioning solely as university support units, TBIs increasingly connect government programs, academic research, entrepreneurs, investors, and industry partners through incubation services, mentoring, technology commercialization, and startup development (España & Rosario, 2025; España, 2025). Their contribution extends beyond startup support by strengthening knowledge exchange, facilitating collaboration across sectors, and improving the translation of research into practical innovations. The concept of adaptive resilience further explains how TBIs sustain these functions by continuously adapting their organizational structures, support mechanisms, and financing strategies to changing ecosystem conditions (España & Rosario, 2025). These findings illustrate that innovation intermediaries have become increasingly important in strengthening relationships among institutional and societal actors within the Philippine innovation ecosystem.

Viewed collectively, the literature suggests that the Philippine innovation ecosystem continues to evolve toward a more coordinated yet predominantly state-centric system. Government remains the principal actor driving policy direction, institutional coordination, and resource allocation, while universities provide research capacity and human capital, and industry contributes commercialization and technological application. At the same time, startup communities, innovation intermediaries, investors, civil society organizations, and other community actors are becoming more visible participants within innovation processes. These developments indicate emerging characteristics of the Quadruple Helix, although community

participation remains uneven and less institutionalized than the traditional relationships among government, universities, and industry.

These observations provide an important context for the present study. Rather than assuming that the Philippine innovation ecosystem conforms to a particular Helix configuration, this research examines how interactions among government, universities, industry, and community actors are represented across published studies. By comparing analytical cases before and after the 2019 innovation reforms, the study explores how interaction patterns, innovation configurations, and governance arrangements have evolved within the Philippine innovation ecosystem and whether emerging Quadruple Helix characteristics are evident in the published literature.

Synthesis and Research Gap

Literature consistently identifies innovation as a key driver of economic and social development, while also demonstrating that innovation does not emerge from technological advancement alone. Rather, it develops through interactions among institutions, organizations, and societal actors operating within broader economic, political, and cultural environments (Antonelli, 2015; Duyen & Tinh, 2024; Kostis, 2021; Oh et al., 2016; Schumpeter, 1934). Innovation ecosystems provide a useful perspective for understanding these interactions by emphasizing that knowledge creation, technology development, and innovation depend on the coordinated efforts of multiple actors whose relationships evolve. Likewise, the Triple Helix and Quadruple Helix frameworks explain how collaboration among government, universities, industry, and, increasingly, community actors shapes innovation processes, governance arrangements, and ecosystem development.

Across the reviewed literature, a common theme emerges: the effectiveness of innovation systems depends less on the presence of individual institutions than on the quality of the relationships that connect them. Institutional coordination, supportive governance, knowledge exchange, human capital development, and innovation intermediaries all influence how effectively innovation systems function. At the same time, the literature recognizes that innovation systems vary across countries because they are shaped by differences in institutional capacity, governance structures, economic conditions, and levels of societal participation. As a result, no single innovation configuration can be considered universally applicable, and interaction models must be interpreted within their respective national and institutional contexts.

Studies examining developing countries further suggest that strengthening innovation systems requires more than policy reforms alone. Although governments often play a central coordinating role, sustainable innovation also depends on active participation from universities, industry, innovation intermediaries, and broader societal actors. Emerging evidence likewise indicates that community participation is becoming increasingly important in innovation processes, particularly through co-creation, user engagement, knowledge exchange, and locally grounded innovation initiatives. These developments have contributed to growing interest in the Quadruple Helix as an extension of the traditional Triple Helix framework, particularly in developing-country contexts where innovation ecosystems continue to evolve.

Within the Philippine context, existing studies have documented important developments in innovation policy, startup ecosystems, technology business incubators, and national innovation programs. The enactment of the Philippine Innovation Act (Republic Act No. 11293) and the Innovative Startup Act (Republic Act No. 11337) established stronger institutional foundations for innovation governance,

while more recent studies have examined the country's innovation performance, entrepreneurial ecosystem, and intermediary organizations. However, much of the existing literature remains descriptive, focusing primarily on policy initiatives, institutional programs, innovation outputs, or individual sectors. Comparatively fewer studies have examined how interactions among government, universities, industry, and community actors are represented across different innovation settings, how these relationships vary among cases, or how they have evolved following the 2019 innovation reforms.

Another gap concerns the limited synthesis of interaction patterns reported across the existing body of literature. Although individual studies describe various forms of collaboration, there has been little effort to systematically compare interaction models, identify recurring innovation configurations, or interpret structural, functional, and relational characteristics across multiple cases. Likewise, the emerging participation of community actors has received relatively limited attention despite increasing recognition of their role within contemporary innovation ecosystems. These limitations make it difficult to develop a broader understanding of how the Philippine innovation ecosystem is represented in the published literature and whether emerging Quadruple Helix characteristics are becoming more evident.

This study addresses these gaps by conducting a qualitative meta-analysis of published studies on the Philippine innovation ecosystem using the Quadruple Helix framework as its primary analytical lens. Rather than measuring innovation performance or evaluating policy effectiveness, the study systematically synthesizes published evidence to identify key actors, characterize multisectoral interactions, classify interaction models and innovation configurations, and compare how these patterns are represented before and after the Philippine innovation reforms of 2019.

Through this case-based synthesis, the study seeks to generate contextually grounded conceptual insights into the structure, dynamics, and governance of the Philippine innovation ecosystem while contributing to broader discussions on innovation ecosystems, Quadruple Helix interactions, and innovation governance in developing-country settings.

Conceptual Framework

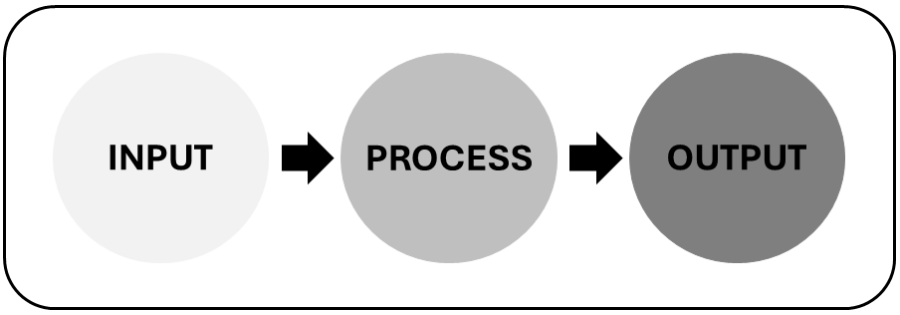
Building on the research questions and objectives, this study adopts an integrated conceptual framework that combines the Input–Process–Output (IPO) Model, the Triple Helix Innovation Model (THIM), and the Quadruple Helix Framework within the broader perspective of the innovation ecosystem. The IPO model provides the overall structure for organizing the qualitative meta-analysis; the Triple Helix explains the institutional relationships among government, universities, and industry that underpin innovation systems, while the Quadruple Helix serves as the primary analytical framework for examining the emerging participation of community actors and the broader dynamics of multisectoral collaboration within the Philippine innovation ecosystem. Together, these complementary perspectives provide a systematic approach for interpreting how innovation interactions are represented across the published literature.

The Input–Process–Output (IPO) Model (McGrath, 1964) serves as the organizing structure of the study by guiding the movement from documented evidence to conceptual synthesis (see Figure 2.1). Rather than measuring innovation performance quantitatively, the IPO model provides a logical framework for organizing and interpreting qualitative evidence across the reviewed studies.

Within this framework, the inputs consist of the published studies selected through the systematic review process, together with the institutional settings, governance arrangements, policy environments, actor characteristics, and innovation activities described in each analytical case. These documented cases provide the empirical basis for examining how multisectoral interactions are represented in the Philippine innovation ecosystem.

The process involves qualitative synthesis of the analytical cases. During this stage, the study identifies the key actors involved in each case, examines the relationships among government, universities, industry, and community actors, characterizes interaction patterns, classifies interaction models and innovation configurations, and interprets the structural, functional, and relational dimensions of collaboration. The analysis also considers enabling factors, barriers, governance mechanisms, and institutional arrangements reported in the literature, while comparing interaction patterns between the pre-policy period (2013–2018) and the post-policy period (2020–2025) following the enactment of the Philippine Innovation Act and the Innovative Startup Act in 2019.

Figure 2.1. The Input-Process-Output (IPO) model.



The outputs consist of a synthesized understanding of the Philippine innovation ecosystem as represented in the published literature. These include the identification of recurring interaction patterns, emerging innovation configurations, structural and

relational characteristics, and conceptual insights regarding the organization and governance of multisectoral collaboration. Rather than serving as measures of innovation performance or policy effectiveness, these outputs provide an interpretive reconstruction of how innovation relationships are documented across different institutional contexts.

Complementing the IPO structure, the Triple Helix Innovation Model provides the theoretical foundation for examining institutional relationships among government, universities, and industry. The framework explains how these three institutional spheres interact through knowledge generation, technology transfer, research collaboration, commercialization, and innovation governance. It also provides the conceptual basis for interpreting different interaction models, including Statist, Laissez-faire, and Balanced configurations, thereby allowing institutional relationships to be understood within broader governance and development contexts.

Recognizing that contemporary innovation increasingly extends beyond these three institutional spheres, the study adopts the Quadruple Helix Framework as its principal analytical lens. By incorporating communities, civil society organizations, users, and other societal actors into the analysis, the Quadruple Helix makes it possible to examine how broader forms of participation contribute to innovation processes. This perspective is particularly relevant to the Philippine innovation ecosystem, where community participation and other forms of societal engagement are becoming increasingly visible in innovation initiatives. The framework therefore enables the study to identify emerging Quadruple Helix characteristics while remaining grounded in the institutional relationships explained by the Triple Helix.

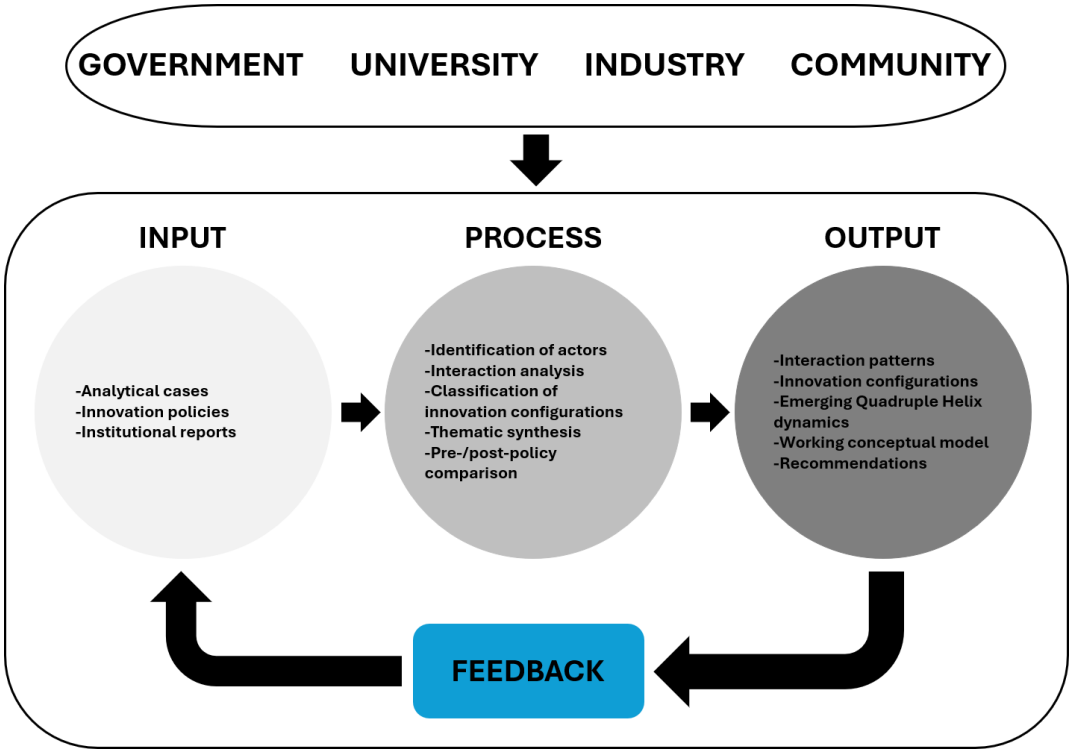
The integrated framework supports the study's qualitative meta-analysis in two complementary ways. First, each publication is treated as an analytical case, allowing

documented interactions, governance arrangements, collaboration mechanisms, enabling conditions, barriers, and innovation activities to be examined systematically. Second, findings from individual cases are synthesized through interpretive thematic analysis, making it possible to identify recurring patterns, compare innovation configurations, examine changes across policy periods, and reconstruct the broader dynamics of the Philippine innovation ecosystem. Quantitative indicators reported in the reviewed studies, such as research outputs, patent counts, startup numbers, or innovation rankings, are interpreted only as contextual evidence supporting the qualitative analysis rather than as direct measures of innovation performance.

To strengthen analytical rigor, the study incorporates several complementary strategies. Evidence is triangulated across multiple studies representing different sectors, institutional settings, and policy periods. Emerging themes are compared across analytical cases to identify both convergent and divergent patterns of interaction. The resulting interpretations are further situated within the broader international literature on innovation ecosystems, Triple Helix, and Quadruple Helix frameworks while remaining grounded in the Philippine context.

Overall, the integrated conceptual framework provides a coherent structure for examining how multisectoral interactions are represented in the Philippine innovation ecosystem (see Figure 2.2). By combining the organizational logic of the IPO model, the institutional perspective of the Triple Helix, and the broader analytical lens of the Quadruple Helix, the framework enables the study to interpret interaction patterns, classify innovation configurations, compare developments before and after the 2019 innovation reforms, and generate contextually grounded conceptual insights into innovation governance and ecosystem development without extending beyond the evidence contained in the published literature.

Figure 2.2. Integrated Conceptual Framework of the Study Combining the Input–Process–Output Model, the Triple Helix Innovation Model, and the Quadruple Helix Framework.



Theoretical Assumptions and Conceptual Illustration

This study is guided by the assumption that multisectoral interactions within the Philippine innovation ecosystem can be meaningfully examined through the integration of the Innovation Ecosystem perspective, the Triple Helix Innovation Model (THIM), the Quadruple Helix Framework, and the Input–Process–Output (IPO) model. Collectively, these perspectives provide a structured basis for interpreting how interactions among institutional and societal actors are represented in the published literature and how recurring patterns, innovation configurations, and governance characteristics can be synthesized across analytical cases.

The study assumes that innovation is a relational and context-dependent process. The nature of collaboration among government, universities, industry, and community actors is influenced by historical, institutional, economic, cultural, and policy conditions that shape the Philippine innovation ecosystem. Consequently, interaction patterns observed in one setting may differ from those reported in another, reflecting differences in governance arrangements, institutional capacity, and sectoral contexts.

More specifically, the study is based on the following assumptions:

- Multisectoral interactions are context-specific. Relationships among government, universities, industry, and community actors are influenced by the institutional, political, economic, and socio-cultural conditions under which innovation activities take place.
- Published studies provide meaningful representations of innovation interactions. Although the reviewed literature does not capture every innovation activity occurring in practice, it contains sufficient evidence to identify recurring interaction patterns, innovation configurations, enabling factors, barriers, and governance characteristics across different innovation settings.
- The integrated IPO framework provides an appropriate structure for qualitative synthesis. Within this study:
    - Inputs consist of published research, policy documents, and other documentary evidence describing innovation actors, institutional arrangements, governance mechanisms, and innovation activities.
    - Processes involve the qualitative synthesis of analytical cases through the identification of key actors, characterization of multisectoral

interactions, classification of interaction models and innovation configurations, and interpretation of structural, functional, and relational dimensions of collaboration.

  - Outputs consist of synthesized conceptual insights, recurring interaction patterns, emerging Quadruple Helix characteristics, a working conceptual model of the Philippine innovation ecosystem, and context-sensitive recommendations for future policy, institutional practice, and research.

- The Triple Helix and Quadruple Helix frameworks provide complementary perspectives for analysis. The Triple Helix serves as the theoretical foundation for understanding institutional relationships among government, universities, and industry, while the Quadruple Helix extends this perspective by incorporating community and civil society actors into the analysis. Together, these frameworks enable a broader interpretation of innovation governance and multisectoral collaboration within the Philippine innovation ecosystem.

Figure 2.3 illustrates the integrated conceptual framework adopted in this study, demonstrating how documentary evidence serves as the primary input for the qualitative meta-analysis, how analytical cases are systematically synthesized through interpretive and thematic analysis, and how this process generates conceptual insights into the Philippine innovation ecosystem.

Specifically:

- Inputs include published studies and documentary evidence describing innovation actors, governance arrangements, institutional relationships, and innovation activities within the Philippine context.

- Processes involve the systematic identification of key actors, analysis of interaction patterns, classification of innovation configurations, comparison of analytical cases across the pre-policy (2013–2018) and post-policy (2020–2025) periods, and interpretation of structural, functional, and relational characteristics of multisectoral collaboration.
- Outputs include synthesized interaction patterns, identified innovation configurations, emerging Quadruple Helix characteristics, a working conceptual model of the Philippine innovation ecosystem, and context-sensitive conceptual insights and recommendations derived from the qualitative synthesis.

Overall, this framework operationalizes the study's qualitative meta-analysis by treating each publication as an analytical case and systematically integrating evidence across multiple studies. Rather than measuring innovation performance or evaluating policy effectiveness, the framework provides a structured approach for interpreting how multisectoral interactions are represented in the literature and how these interactions contribute to a deeper understanding of innovation governance, ecosystem development, and the evolving role of community participation within the Philippine innovation ecosystem.

Figure 2.3. Operationalization of the Integrated Conceptual Framework for Analyzing Multisectoral Interactions in the Philippine Innovation Ecosystem.



Operational Definitions

In this study, the following terms are operationally defined as they are used within the context of the Philippine innovation ecosystem.

Innovation: The creation, adaptation, or improvement of products, services, processes, organizational methods, or institutional arrangements that generate economic, social, or technological value. In this study, innovation is understood as a collaborative and knowledge-based process that emerges through interactions among multiple actors within the innovation ecosystem rather than solely as an outcome measured through quantitative indicators.

Innovation Ecosystem: The dynamic network of actors, institutions, policies, resources, and relationships that collectively facilitate the creation, exchange, diffusion, and application of knowledge and innovation. It represents the broader institutional, economic, and societal environment within which innovation activities occur. In this study, the Philippine innovation ecosystem provides the overarching context for examining multisectoral interactions and innovation governance.

Triple Helix Innovation Model (THIM): A theoretical framework that explains innovation through interactions among government, universities, and industry. It emphasizes collaborative knowledge production, technology transfer, institutional learning, and innovation governance, while recognizing that the three institutional spheres increasingly perform complementary and overlapping roles. In this study, the Triple Helix serves as the principal theoretical foundation for understanding institutional relationships within the Philippine innovation ecosystem.

Quadruple Helix Framework (QHF): Extends the Triple Helix by incorporating community and civil society as a fourth institutional sphere alongside government,

universities, and industry. It recognizes innovation as a collaborative process that integrates scientific knowledge, market activities, public governance, and societal participation. In this study, the Quadruple Helix serves as the primary analytical framework for examining multisectoral interactions and identifying emerging innovation configurations within the Philippine innovation ecosystem.

Quadruple Helix Actors in the Philippine Context:

- Government: National and local public institutions responsible for developing policies, allocating resources, regulating innovation activities, and coordinating science, technology, and innovation (STI) initiatives. Within the Philippine context, these include agencies such as the Department of Science and Technology (DOST), the Department of Trade and Industry (DTI), the Department of Information and Communications Technology (DICT), and other public institutions involved in innovation governance.
- University: Higher education institutions and research organizations engaged in knowledge creation, research and development (R&D), human capital development, technology transfer, and innovation support. Within this study, universities function as knowledge producers and collaborative partners that facilitate interactions among government, industry, and community actors.
- Industry: Private enterprises, startups, business organizations, and commercial entities that transform knowledge into products, services, technologies, and market innovations. Their contributions include commercialization, technology adoption, entrepreneurship, investment, and collaborative innovation activities.
- Community: Civil society organizations, non-government organizations, local communities, professional associations, end users, grassroots organizations, and other societal stakeholders that participate in innovation processes. Their

roles include identifying societal needs, contributing contextual knowledge, participating in co-creation, validating innovations, supporting knowledge exchange, and facilitating innovation adoption.

Multisectoral Interactions: Collaborative relationships and exchange processes among government, universities, industry, and community actors within the innovation ecosystem. These interactions include knowledge exchange, joint research, technology transfer, policy coordination, capacity building, community engagement, resource sharing, and other forms of collaboration documented in analytical cases.

Analytical Cases: Published studies included in the qualitative meta-analysis. Each publication is treated as a distinct unit of analysis from which actor relationships, interaction patterns, innovation configurations, governance characteristics, enabling factors, and barriers are identified and synthesized.

Interaction Model: The dominant patterns of relationships among innovation actors identified within each analytical case. They describe how institutional and societal actors collaborate, coordinate activities, and share responsibilities in supporting innovation. Interaction models are interpreted based on actor composition, governance arrangements, collaboration mechanisms, and the nature of multisectoral relationships.

Innovation Configuration: The overall structural organization of interactions among innovation actors within an analytical case. These configurations describe how the innovation system is organized and are interpreted according to the characteristics of Statist, Balanced, or Laissez-faire Triple Helix models, as well as emerging Quadruple Helix manifestations through community participation.

Collaboration Dynamics: The processes through which innovation actors establish, maintain, and strengthen collaborative relationships. These include formal partnerships, joint research, technology transfer, policy coordination, funding arrangements, knowledge exchange, community participation, and informal networks. In this study, collaboration dynamics are interpreted through recurring structural, functional, and relational patterns identified across analytical cases.

Structural Gaps: Deficiencies in institutional arrangements, governance structures, or actor linkages that constrain effective collaboration within the innovation ecosystem. These are identified from findings explicitly reported in the reviewed studies and interpreted using the structural dimensions of the Triple Helix and Quadruple Helix frameworks.

Functional Barriers: Obstacles that limit the implementation or effectiveness of collaborative innovation activities. These include constraints related to funding, policy implementation, organizational capacity, technology transfer, coordination mechanisms, and resource availability, as documented in the reviewed studies.

Relational Challenges: Factors that affect trust, communication, coordination, and sustained collaboration among innovation actors. These challenges are interpreted from documented evidence describing the quality and effectiveness of multisectoral relationships across analytical cases.

Innovation Outputs: Products, services, technologies, research outputs, commercialization activities, policy initiatives, and other innovation-related outcomes documented in the reviewed studies. In this study, these outputs are interpreted qualitatively as indicators of collaborative processes and innovation system

functioning rather than as measures of organizational or national innovation performance.

Conceptual Insights: The theoretical understanding generated through the qualitative synthesis of evidence across multiple analytical cases. Rather than evaluating policy effectiveness or establishing causal relationships, these insights explain how multisectoral interactions, innovation configurations, governance arrangements, and collaboration patterns characterize the Philippine innovation ecosystem and contribute to broader discussions on innovation ecosystems, Triple Helix, and Quadruple Helix frameworks.

Input–Process–Output (IPO) Model: The analytical framework used to organize and synthesize the qualitative evidence. Inputs include documentary evidence on innovation actors, policies, institutional arrangements, governance structures, and contextual conditions. Processes involve synthesizing actor interactions, collaboration mechanisms, interaction models, innovation configurations, enabling factors, and barriers across analytical cases. Outputs comprise synthesized interaction patterns, conceptual insights, a working model of the Philippine innovation ecosystem, and context-sensitive recommendations. The IPO model serves solely as an organizing framework and does not imply quantitative measurement or causal inference.

CHAPTER III

RESEARCH METHODOLOGY

Research Design and Methodological Approach

This study employed a qualitative meta-analysis to examine how multisectoral interactions within the Philippine innovation ecosystem are represented and interpreted in the published literature. Rather than measuring innovation activities or institutional relationships directly, the study focused on documented accounts of interactions among government, universities, industry, and community actors as reported in peer-reviewed research. The analysis was therefore concerned with the representation, interpretation, and synthesis of existing evidence rather than with establishing causal relationships or evaluating policy effectiveness.

The study was anchored in the broader innovation ecosystem perspective, with the Triple Helix Innovation Model (THIM) serving as the theoretical foundation for understanding institutional relationships among government, universities, and industry, and the Quadruple Helix Framework providing the primary analytical lens for examining the emerging participation of community actors and broader multisectoral collaboration. This integrated perspective makes it possible to examine not only institutional relationships but also the structural, functional, and relational characteristics of the Philippine innovation ecosystem as reflected in the published literature.

Each selected publication was treated as an analytical case from which actor relationships, collaboration mechanisms, interaction patterns, innovation configurations, governance arrangements, enabling factors, and barriers are identified and interpreted. Through comparative analysis across multiple analytical cases, the

study synthesizes recurring patterns while remaining attentive to variations arising from differences in institutional settings, sectors, and policy contexts. Because published studies represent only a portion of innovation activities occurring in practice, the analysis also recognizes the possibility of publication bias and visibility bias, acknowledging that the absence of documented interactions should not be interpreted as evidence that collaboration does not occur.

The qualitative meta-analysis combined case-based analysis with interpretive thematic synthesis to generate contextually grounded conceptual insights. Rather than aggregating findings statistically, the study compared documented interactions across cases to identify recurring innovation patterns, classify interaction models and innovation configurations, examine structural, functional, and relational dimensions of collaboration, and interpret the broader dynamics of the Philippine innovation ecosystem. This interpretive approach enabled the reconstruction of patterns across diverse innovation settings while remaining faithful to the evidence reported in the original studies.

To ensure methodological rigor and transparency, the study followed a systematic scoping review protocol guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) (Tricco et al., 2018). The PRISMA-ScR framework provided a structured and transparent procedure for identifying, screening, selecting, and documenting relevant studies included in the qualitative meta-analysis. Within this study, PRISMA-ScR functioned as a methodological framework for evidence identification and selection rather than as a procedure for quantitative synthesis.

Finally, the study incorporated a temporal perspective by comparing analytical cases across two periods: the pre-policy period (2013–2018) and the post-policy

period (2020–2025) following the enactment of the Philippine Innovation Act (Republic Act No. 11293) and the Innovative Startup Act (Republic Act No. 11337) in 2019. This comparison was intended to examine how multisectoral interactions, interaction models, and innovation configurations were represented across the published literature before and after the introduction of these major innovation policies. Given the qualitative nature of the study and differences in the composition of analytical cases across the two periods, the comparison was interpreted as an exploration of emerging patterns and tendencies rather than as evidence of causal policy effects.

Ontological and Epistemological Position

This study was grounded in an interpretivist epistemology and a critical realist ontological perspective. From a critical realist standpoint, innovation systems and multisectoral interactions are understood to exist independently of their documentation; however, they are accessible to this study only through representations reported in the published literature. Consequently, the study did not seek to measure actual interactions directly but rather to interpret how these interactions were described, represented, and understood across different innovation contexts.

Consistent with an interpretivist epistemology, the study assumed that knowledge about the Philippine innovation ecosystem is socially constructed and context-dependent. The meanings attached to collaboration, innovation, and institutional relationships were shaped by the perspectives of researchers, organizations, and stakeholders who produced the original studies. Accordingly, the qualitative meta-analysis synthesized these documented interpretations to generate a broader conceptual understanding of multisectoral interactions rather than to establish universal or causal explanations.

The analysis also acknowledged the possibility of publication bias, visibility bias, and endogeneity. Because the study relied exclusively on published literature, documented interactions represent only a portion of innovation activities occurring within the Philippine innovation ecosystem. The absence of published evidence should therefore not be interpreted as evidence that collaboration does not occur. Instead, variations in documentation may reflect differences in publication practices, research priorities, institutional visibility, or reporting across sectors and organizations.

The Triple Helix Innovation Model served as the theoretical foundation for interpreting institutional relationships among government, universities, and industry, while the Quadruple Helix Framework functioned as the primary analytical lens for examining the broader participation of community and civil society actors within the innovation ecosystem. These complementary perspectives guide the interpretation of the following: the composition and roles of innovation actors; the nature of multisectoral interactions and collaboration mechanisms; governance arrangements and institutional coordination; interaction models and innovation configurations; and the structural, functional, and relational dimensions of the Philippine innovation ecosystem.

Rather than assuming that innovation systems conform to a single ideal configuration, the study recognized that interactions among government, universities, industry, and community actors are shaped by historical, institutional, political, economic, and socio-cultural conditions unique to the Philippine context. Consequently, the identified interaction patterns and innovation configurations were interpreted as context-specific representations derived from the published literature rather than as definitive descriptions of the Philippine innovation ecosystem.

Sensitizing Concepts

To guide the interpretation of multisectoral interactions without imposing predetermined categories, this study adopted a set of sensitizing concepts that provide flexible analytical direction throughout the qualitative meta-analysis (Bowen et al., 2020; Tavory & Timmermans, 2022). Rather than functioning as fixed variables or hypotheses, these concepts served as interpretive guides that help identify recurring patterns, similarities, and differences across the analytical cases while remaining responsive to the context of each study.

The following sensitizing concepts informed the analysis:

- Structural gaps: Deficiencies in the institutional arrangements, governance structures, or linkages among government, universities, industry, and community actors that constrain effective collaboration within the innovation ecosystem. These may include missing intermediary organizations, fragmented coordination mechanisms, weak innovation networks, or limited institutional integration.
- Relational challenges: Constraints that limit the implementation or effectiveness of collaborative innovation activities. These include challenges related to policy implementation, funding, organizational capacity, technology transfer, commercialization, resource availability, regulatory processes, and other operational conditions affecting innovation.
- Functional imbalances: Difficulties that influence the quality of interactions among innovation actors, including limited trust, weak communication, fragmented knowledge exchange, insufficient stakeholder engagement, and low levels of sustained collaboration across sectors.

These sensitizing concepts provided an interpretive framework for examining how multisectoral interactions were represented in the published literature. Rather than predetermining the findings, they supported the identification of recurring interaction patterns, innovation configurations, governance tendencies, and ecosystem characteristics that emerge inductively from the analytical cases. In doing so, they contributed to a contextually grounded understanding of the Philippine innovation ecosystem while remaining consistent with the study's interpretive qualitative meta-analysis approach.

Review Phases

The review followed a systematic and sequential process adapted from the scoping review frameworks (Arksey & O'malley, 2005; Peters et al., 2015). Although these frameworks are commonly used for scoping reviews, they were adapted in this study to support a qualitative meta-analysis in which each included publication was treated as an analytical case. The review consisted of four major phases: (1) formulation of the research questions and search strategy, (2) screening and analytical case selection, (3) data extraction and analytical case development, and (4) qualitative synthesis and interpretation.

Phase 1: Formulation of Research Questions and Search Strategy

The first phase involved defining the scope of the review and developing research questions that were aligned with the study objectives. The Population–Intervention–Comparison–Outcome–Context (PICOC) framework (Petticrew & Roberts, 2008) was used to structure the review questions and guide the development of the search strategy (see Table 3.1).

Table 3.1.

Population–Intervention–Comparison–Outcome–Context (PICOC) framework for analyzing the Quadruple Helix Framework within the Philippine innovation ecosystem.

Elements	Description
P (Population)	Peer-reviewed studies and scholarly publications examining the Philippine innovation ecosystem, focusing on interactions among government, universities, industry, and community actors. Each publication was treated as an analytical case for qualitative meta-analysis.
I (Intervention)	Application or discussion of the Quadruple Helix Framework, including interactions among government, universities, industry, and communities in innovation governance, knowledge exchange, technology transfer, commercialization, community engagement, and the role of innovation intermediaries (e.g., technology transfer offices, incubators, innovation hubs, and Living Labs).
C (Comparison)	Comparison of multisectoral interaction patterns and innovation configurations between the pre-policy period (2013–2018) and the post-policy period (2020–2025) to examine how interactions evolved following the enactment of the Philippine Innovation Acts and related innovation reforms.
O (Outcome)	Qualitative evidence on: (a) multisectoral interaction patterns and innovation configurations; (b) structural, functional, and relational dimensions of collaboration; (c) enabling factors and barriers to ecosystem integration; (d) emerging Quadruple Helix characteristics; and (e) conceptual insights and appropriately qualified policy implications for strengthening the Philippine innovation ecosystem.
C (Context)	The Philippine innovation ecosystem, considering national and local innovation policies (e.g., RA 11293 and RA 11337), institutional and governance arrangements, sectoral innovation contexts, and the two analytical periods (2013–2018 and 2020–2025).

Boolean search strings targeting innovation ecosystems, Triple and Quadruple Helix interactions, multisectoral collaboration, innovation governance, and the Philippine context were consistently applied across databases to ensure comprehensive and relevant retrieval (Table 3.2).

Table 3.2

Sequential screening of studies based on the "Lens.org" search strategy.

Search Terms	Screening Stage	Number of Studies
Core Innovation System Interactions (RQ1)	Initial search (records identified before screening)	n=38,851
("Triple Helix Innovation" OR ("government" AND ("university" OR "academe") AND "industry")) AND ("innovation" OR "research" OR "technology transfer" OR "commercialization") AND Philippines	Stage 1: Source credibility screening	*Excluded (n=7,119)* Retained (n=31,732)
	Stage 2: Relevance and contextual alignment	*Excluded (n=30,516)* Retained (n=1,216) 314 (2013-2018); 902 (2020-2025)
	Records retained after full-text verification	*Excluded (n=17)* Retained n=1,199 302 (2013-2018); 897 (2020-2025)
Interaction Mechanisms, Enablers, and Barriers (RQ2)	Initial search (records identified before screening)	n=25,774
("Triple Helix Innovation" OR ("government" AND ("university" OR "academe") AND "industry")) AND ("interaction" OR "collaboration" OR "coordination" OR "knowledge exchange" OR "technology transfer" OR "research collaboration") AND ("barrier" OR "enabler" OR "challenge" OR "governance" OR "institutional capacity" OR "structural gap" OR "relational dynamic") AND Philippines	Stage 1: Source credibility screening	*Excluded (n=6,005)* Retained (n=19,769)
	Stage 2: Relevance and contextual alignment	*Excluded (n=19,117)* Retained (n=652) 168 (2013-2018); 484 (2020-2025)
	Records retained after full-text verification	*Excluded (n=24)* Retained (n=628) 152 (2013-2018); 476 (2020-2025)
Policy Evolution and Conceptual Model Development (RQ3–RQ4)	Initial search (records identified before screening)	n=4,404
("Triple Helix Innovation" OR ("government" AND ("university" OR "academe") AND "industry")) AND ("innovation policy" OR "Philippine Innovation Act" OR "Innovative Startup Act" OR	Stage 1: Source credibility screening	*Excluded (n=1,703)* Retained (n=2,701)
	Stage 2: Relevance and contextual alignment	*Excluded (n=2,657)* Retained (n=44) 15 (2013-2018); 29 (2020-2025)

"policy reform" OR "institutional change") AND ("framework" OR "model" OR "conceptual" OR "system") AND Philippines	Records retained after full-text verification	*Excluded (n=10)* Retained (n = 34) 9 (2013-2018); 25 (2020-2025)
Broad evidence base	Total records retained after full-text verification	n=1,861 463 (2013–2018); 1,398 (2020–2025)
Period-specific analytical screening	Repeated/duplicate records removed before analytical screening	n=641 154 (2013–2018); 487 (2020–2025)
	Records retained for period-specific analytical screening	n=1,220 309 (2013–2018); 911 (2020–2025)
THIM and Emerging Quadruple Helix Analytical Screening and Inclusion	Records excluded during analytical screening	n=1,189 289 (2013–2018); 900 (2020–2025)
	Analytical cases retained for qualitative synthesis	n=31 20 (2013–2018); 11 (2020–2025)

Note: Following full-text verification, all retained studies underwent an additional classification as Included, Conditionally Included, or Excluded to support the final network analytical coding. The complete identification, screening, eligibility, and inclusion process is presented in the PRISMA flow diagram (Figure 3.1). Although the literature search employed Triple Helix search terms, the subsequent qualitative synthesis and network analysis examined interactions among government, universities, industry, and community actors, enabling interpretation through the Quadruple Helix Framework. This approach reflects the use of Triple Helix terminology for literature retrieval and the Quadruple Helix framework for the final analytical interpretation.

Phase 2: Screening and Analytical Case Selection

A multi-stage screening procedure was employed to ensure that the included studies were academically credible, contextually relevant, and analytically suitable for qualitative synthesis.

Stage 1: Source Credibility

Studies were retrieved through Lens.org (Lens.org, 2021), an open-access scholarly discovery platform that indexes peer-reviewed publications and other research outputs from international and Philippine sources. Eligible documents

included peer-reviewed journal articles, conference papers, dissertations, theses, and preprints that contained sufficient methodological and analytical detail. Preprints were retained only when their methodological quality was comparable to peer-reviewed studies. Books, book chapters, editorials, commentaries, opinion papers, and other non-research publications were excluded.

Rather than relying solely on publication venue, source credibility was assessed according to methodological rigor; analytical coherence; transparency of the research process; relevance to innovation ecosystem, Triple Helix, or Quadruple Helix research; and evidence of scholarly review or validation. This approach ensured consistency while minimizing publication bias arising from database selection alone.

Stage 2: Contextual Relevance

Studies passing the initial quality assessment were screened against the following inclusion criteria: focused primarily on the Philippine innovation ecosystem; reported original empirical research; written in English and available in full text; included at least one author affiliated with a Philippine institution; and fell within either the pre-policy (2013–2018) or post-policy (2020–2025) period. The literature search was conducted from 13–17 February 2026, and only studies retrieved during this period were considered. Complete bibliographic information for all retrieved studies is presented in Appendices A and C, while the screening outcomes are summarized in Appendices B and D. (The complete dataset for the appendices has been deposited in the Open Science Framework (OSF) repository.

Stage 2a: Analytical Case Qualification

Following full-text review, each publication underwent an additional analytical assessment to determine its suitability as a case for qualitative meta-analysis. This

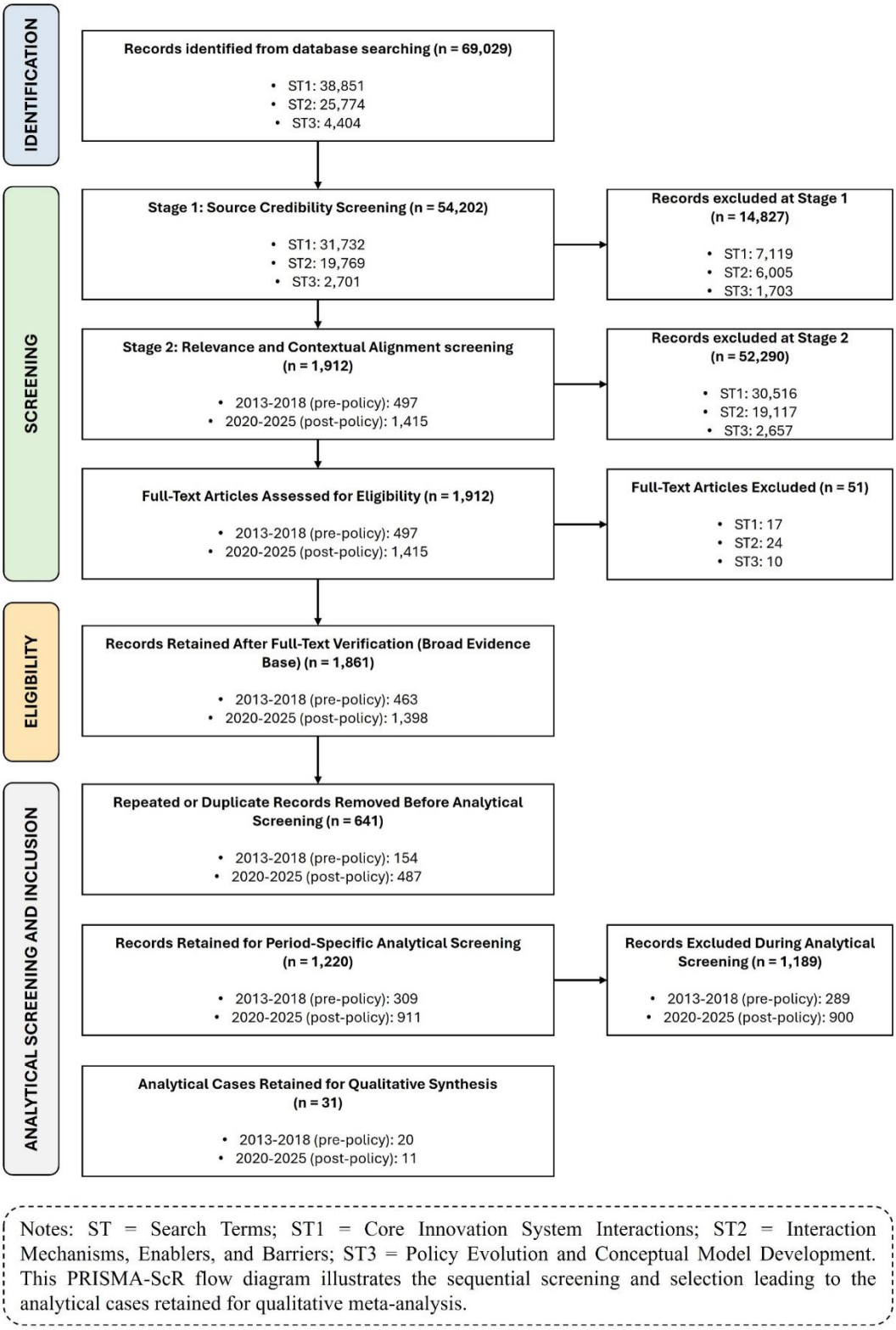
stage was not intended to determine publication quality but rather the extent to which each study contributed evidence relevant to the study objectives. Each publication was examined to determine whether it documented or provided sufficient evidence of interactions among government, universities, industry, and, where applicable, community actors.

Studies were classified as:

- *Included:* clearly documented multisectoral interactions; contained sufficient empirical or analytical evidence to support interpretation of actor relationships, governance arrangements, or innovation configurations.
- *Conditionally included*: addressed innovation or institutional collaboration but contained only partial evidence of multisectoral interaction; were retained to support contextual interpretation or analytical triangulation.
- *Excluded:* lacked evidence of meaningful actor interaction; remained sector-specific; or described innovation activities without discussing collaborative relationships.

This classification ensured transparency while preserving analytically useful studies that contributed contextual understanding.

Figure 3.1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram for the study selection.



Note: Reproduced from Peters et al., 2015.

Phase 3: Data Extraction and Analytical Case Development

Following case selection, relevant information was extracted systematically from each included study using a structured extraction matrix. Information recorded included: study characteristics; theoretical framework(s); actors involved; interaction mechanisms; governance arrangements; innovation activities; documented outputs; enabling factors; barriers and constraints; and reported findings relevant to multisectoral interaction.

The emphasis was placed on qualitative interpretation rather than quantitative aggregation. Numerical indicators reported in the original studies (e.g., patents, publications, startup counts, funding amounts) were interpreted as contextual evidence supporting interaction patterns rather than statistical variables.

Phase 3a: Bibliographic Documentation

Complete bibliographic information and screening characteristics for all retrieved publications are presented in Appendices A and C. These appendices provide a transparent audit trail of the literature identification process. *(The complete dataset for the appendices has been deposited in the OSF repository.)*

Phase 3b: Analytical Screening

The analytical screening results are presented in Appendices B and D, where each publication is coded according to its inclusion status: Green (Included); Orange (Conditionally Included); Gray (Excluded). This coding system documents how each study contributed to the qualitative synthesis. *(The complete dataset for the appendices has been deposited in the OSF repository.)*

Phase 3c: Extraction of Actor Engagement

Each analytical case was coded to identify the participation of: Government, University, Industry, and Community. Actor engagement was categorized as: Central, Supporting, Peripheral. Interactions, governance arrangements, collaboration mechanisms, and innovation activities were also extracted. The resulting dataset forms the basis for the interaction analysis presented in Table 4.1.

Phase 3d: Network Mapping of Multisectoral Interactions

To visualize the structural relationships among actors, the extracted data were converted into network datasets using Gephi version 0.11 (Bastian et al., 2009). Each actor was represented as a node classified according to the Quadruple Helix: Government, University, Industry, and Community. Nodes were assigned unique identifiers, institutional labels, documented roles, engagement level, and case number. Edges represented explicitly documented interactions, including funding, policy coordination, knowledge transfer, mentorship, research collaboration, technology transfer, implementation, and community engagement. Interaction weights ranged from 1 to 3 according to the reported strength of collaboration. Complete node and edge datasets are provided in Appendices E–H. *(The complete dataset for the appendices has been deposited in the OSF repository.)*

Phase 3e: Network Descriptive Measures

Descriptive network measures were generated using Gephi to characterize the structural properties of the documented innovation networks. The analysis examined four dimensions: Connectivity (Graph density, Average degree); Fragmentation (Connected components, Modularity); Structural Flow (Average path length, Clustering coefficient); Interaction Intensity (Average weighted degree). Network diameter was included as a supplementary indicator where appropriate. These

measures were interpreted descriptively to support qualitative interpretation rather than inferential statistical analysis.

Phase 4: Qualitative Synthesis and Interpretation

The final phase involved synthesizing evidence across all analytical cases using thematic synthesis and comparative interpretation. The analysis focused on identifying recurring interaction patterns, dominant interaction models, innovation configurations, governance arrangements, structural gaps, functional barriers, relational challenges, and emerging Quadruple Helix characteristics.

Comparisons were made between the pre-policy (2013–2018) and post-policy (2020–2025) periods to examine how multisectoral interactions were represented following the enactment of the Philippine Innovation Act and the Innovative Startup Act in 2019. Thematic findings were interpreted alongside the descriptive network analysis, enabling comparison of connectivity, fragmentation, interaction intensity, and structural flow across the analytical cases. Rather than evaluating policy effectiveness or measuring actual collaboration, the synthesis generated a contextually grounded interpretation of how multisectoral interactions are represented in the published literature. The resulting synthesis informed the identification of interaction models, innovation configurations, and conceptual insights regarding the structure, dynamics, and governance of the Philippine innovation ecosystem.

Collaboration Typology

To preserve the diversity of multisectoral interactions documented across the analytical cases, collaboration was classified according to the dominant interaction mechanisms reported in each study. These categories served as interpretive guides during data extraction and thematic synthesis rather than as mutually exclusive

classifications. Because multiple forms of collaboration frequently occurred within a single case, studies could be coded under more than one interaction type.

The following collaboration typology was used:

- Formal institutional arrangements: Structured collaborations established through official agreements, policies, funding mechanisms, research partnerships, memoranda of understanding (MOUs), interagency programs, and other formal governance arrangements.
- Knowledge co-production: Collaborative activities involving the joint creation, exchange, or dissemination of knowledge, including research collaborations, co-authored publications, collaborative training, capacity-building initiatives, workshops, and other shared learning activities.
- Transactional engagement: Interaction mechanisms centered on the exchange or application of knowledge, expertise, or resources, including technology transfer, consultancy, contract research, internships, technical assistance, commercialization activities, licensing, and other service-oriented collaborations.
- Informal networks: Less formal relationships that facilitate collaboration through professional networks, mentoring, advisory roles, peer learning, community engagement, personal connections, and other informal channels that support knowledge exchange and innovation.

Each interaction type was examined individually before being synthesized across cases to identify recurring collaboration patterns, interaction models, and innovation configurations within the Philippine innovation ecosystem. This approach preserved the contextual diversity of the documented interactions while supporting

systematic comparison across the analytical cases and between the pre-policy (2013–2018) and post-policy (2020–2025) period.

Ensuring Robustness and Reflexivity

The rigor of this qualitative meta-analysis was established through a systematic, transparent, and replicable review process. Methodological consistency was maintained throughout the study by applying the procedures described in the preceding review phases, from the development of the search strategy to the synthesis and interpretation of the analytical cases.

Systematicity was achieved through the use of the PRISMA-ScR framework (Tricco et al., 2018) (Tricco et al., 2018), which guided the identification, screening, and selection of relevant studies. A structured search strategy based on the PICOC framework and predefined Boolean search terms ensured a comprehensive and reproducible retrieval of literature relevant to the Philippine innovation ecosystem, multisectoral interactions, and the Triple Helix and Quadruple Helix frameworks. The credibility of the analytical cases was strengthened through a multi-stage screening process that evaluated both methodological quality and contextual relevance. Beyond the initial eligibility assessment, each publication underwent analytical case qualification to determine the extent to which it documented meaningful interactions among government, universities, industry, and community actors. This process enhanced the analytical relevance of the evidence included in the synthesis while maintaining transparency regarding studies that were conditionally included or excluded.

Consistency during data extraction was supported by a structured coding protocol that systematically documented actor participation, interaction mechanisms,

governance arrangements, innovation activities, enabling factors, barriers, and reported outcomes. Treating each publication as an analytical case facilitated systematic comparison across studies while preserving the contextual characteristics of individual innovation settings. The subsequent network analysis provided an additional layer of structural interpretation by visualizing documented relationships among actors and describing patterns of connectivity, fragmentation, interaction intensity, and network structure within the Philippine innovation ecosystem.

To enhance the trustworthiness of the findings, the study employed triangulation across multiple sources of evidence, innovation contexts, and policy periods. Findings from individual analytical cases were compared through thematic synthesis and interpreted alongside descriptive network measures, allowing recurring interaction patterns, innovation configurations, and governance tendencies to be examined from complementary analytical perspectives. The study also adopted a reflexive stance throughout the analytical process. Because the synthesis relied exclusively on published literature, the analysis recognizes the possibility of publication bias, visibility bias, and endogeneity. Documented interactions represent only those reported in the available literature and should not be interpreted as a complete representation of all innovation activities occurring in practice. Likewise, the absence of documented collaboration should not be construed as evidence that collaboration did not occur.

Finally, interpretation of the findings remained sensitive to the historical, institutional, political, economic, and socio-cultural contexts within which the reviewed studies were conducted. Rather than seeking universal explanations or causal conclusions, the analysis focused on generating contextually grounded conceptual insights into multisectoral interactions, interaction models, innovation configurations, and the evolving governance of the Philippine innovation ecosystem. This approach is

consistent with the interpretive orientation of qualitative meta-analysis and the study's objective of understanding how innovation relationships are represented in the published literature.

Methodological Contribution

This study demonstrated the value of qualitative meta-analysis for examining multisectoral interactions within a developing-country innovation ecosystem using published literature as the primary source of evidence. By integrating systematic literature review procedures, qualitative meta-synthesis, interaction typology, comparative analysis across policy periods, and descriptive network analysis, the study provided a structured approach for examining how innovation relationships are represented and interpreted across diverse institutional contexts.

Methodologically, the study extended existing applications of the Triple Helix and Quadruple Helix frameworks by treating each publication as an analytical case and synthesizing documented interactions into broader interaction models and innovation configurations. The integration of thematic synthesis with network visualization further strengthened the analysis by combining qualitative interpretation with structural descriptions of actor relationships, enabling a more comprehensive understanding of collaboration patterns within the Philippine innovation ecosystem.

The methodology generated contextually grounded insights into the structure, dynamics, and governance of the Philippine innovation ecosystem rather than assessing policy effectiveness or innovation performance. It also provides a transparent, replicable framework for future studies of multisectoral interactions and Quadruple Helix configurations in the Philippines and other developing countries.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter presents and discusses the findings of the qualitative meta-analysis of published studies examining multisectoral interactions within the Philippine innovation ecosystem. Guided by the Quadruple Helix framework, the analysis explores how interactions among government, universities, industry, and community actors are represented and interpreted in the literature. Rather than measuring actual collaboration or evaluating policy effectiveness, the chapter synthesizes documented evidence to identify recurring interaction patterns, interaction models, innovation configurations, governance arrangements, and ecosystem characteristics across diverse innovation contexts.

The analysis covered two policy periods: the pre-policy period (2013–2018) and the post-policy period (2020–2025). This temporal organization provides a basis for examining how documented multisectoral interactions and innovation configurations were represented before and after the enactment of the Philippine Innovation Act (Republic Act No. 11293) and the Innovative Startup Act (Republic Act No. 11337) in 2019. The comparison was intended to identify emerging patterns and tendencies in the published literature rather than to establish causal relationships or determine the effectiveness of these policy reforms.

Within each policy period, the findings were presented as analytical cases derived from the selected studies. Consistent with the methodology described in Chapter III, each publication was treated as a separate analytical case from which actor participation, interaction mechanisms, governance arrangements, enabling factors, barriers, and innovation activities were extracted and synthesized. Although

studies were classified as fully included or conditionally included during the analytical screening process, this classification was retained primarily for methodological transparency. It did not determine the overall organization of the findings.

Each analytical case described the configuration of government, university, industry, and, where applicable, community actors, together with the interaction mechanisms through which they collaborate. Particular attention was given to formal institutional arrangements, knowledge co-production, transactional engagement, and informal networks, as well as to the structural, functional, and relational dimensions of multisectoral collaboration. These documented interactions were subsequently interpreted to identify the interaction model or innovation configuration that best characterizes each analytical case.

Following the case-level analyses, the chapter synthesizes findings across studies to identify recurring patterns, similarities, and differences within the Philippine innovation ecosystem. Cross-case comparison highlights structural gaps, functional barriers, relational challenges, and emerging governance tendencies while examining the extent to which the documented cases exhibit characteristics associated with the Statist, Balanced, and Laissez-faire Triple Helix configurations, together with emerging manifestations of the Quadruple Helix through community participation and broader societal engagement.

To complement the qualitative synthesis, the extracted actor relationships were transformed into network representations using Gephi. The resulting network analysis provides a structural description of the documented multisectoral interactions by illustrating actor connectivity, interaction intensity, network fragmentation, and governance structures across the analytical cases. These descriptive network

measures support the qualitative interpretation by providing an additional perspective on the organization and evolution of the Philippine innovation ecosystem.

The chapter begins with the analytical cases from the pre-policy period (2013–2018), followed by those from the post-policy period (2020–2025). Within each period, studies were presented according to their analytical inclusion status to maintain transparency in case selection while facilitating systematic comparison across cases. A summary of actor engagement and documented interaction mechanisms is first presented in Table 4.1, which provides the foundational dataset for the subsequent network analysis and comparative interpretation of multisectoral relationships.

The chapter concludes by integrating the findings from the analytical cases, thematic synthesis, and network analysis to develop a contextually grounded interpretation of the Philippine innovation ecosystem. Rather than presenting a definitive representation of the national innovation system, the analysis identifies recurring interaction patterns, innovation configurations, and governance tendencies reflected in the published literature. These findings provide the basis for the conceptual insights discussed in Chapter V and contribute to a broader understanding of multisectoral collaboration, innovation governance, and the evolving role of the Quadruple Helix within the Philippine innovation ecosystem.

Table 4.1

Summary of the analytical cases, actor engagement, innovation configurations, and structural, functional, and relational dimensions of multisectoral interactions within the Philippine innovation ecosystem (2013–2018 and 2020–2025).

Analytical Case (Study ID)	Analytical Inclusion	Government Actors	University Actors	Industry Actors	Community Actors	Structural Dimension	Functional Dimension	Relational Dimension
STUDIES BELOW ARE EXTRACTED FROM 2013–2018 PUBLICATIONS (coded as SID-a)								
1 (SID-a90)	Included	Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD): Strategic funder, policy enabler, and system coordinator through funding, infrastructure provision,	State Universities and Colleges (SUCs): Knowledge producers, innovation implementers, and intermediaries through curriculum enhancement, faculty training-of-trainers (TOTs), enterprise-based learning, and institutional	Industry partners and enterprises: Practice partners providing mentorship, enterprise incubation support, market feedback, and opportunities for commercialization and workforce development.	Local communities and enterprise beneficiaries: End-users and collaborators participating in community-based enterprise development, technology application, and innovation adoption.	Strong. Clearly defined institutional roles, formal funding mechanisms, infrastructure investment, and coordinated multi-university collaboration established a well-structured innovation system.	Strong. Effective integration of technical training, entrepreneurship education, faculty capacity building, and market-oriented enterprise development produced demonstrable innovation and employability outcomes.	Strong. Structured mentorship, networking, field-based collaboration, and continuous communication fostered trust, sustained engagement, and long-term collaborative relationships among government, universities, industry, and

		equipment support, and alignment with national STI priorities.	linkage facilitation.					community actors.
2 (SID-a133)	Included	National and local government agencies: Facilitators and enabling institutions that provided technical guidance, institutional coordination, production inputs (e.g., seeds and rain shelters), cluster support, and linkages to development partners and markets.	Higher education institutions: Knowledge intermediaries and technical facilitators responsible for farmer training, crop selection, pest management, production planning, quality assurance, and marketing support.	Institutional buyers, development partners, microfinance institutions, and non-government organizations (NGOs): Market and support partners that facilitated financing, market access, enterprise development, and complementary technical assistance.	Farmer clusters and local communities: Primary implementers that adopted production technologies, shared resources, participated in collective decision-making, and engaged in cluster-based production and collaborative marketing.	Strong. Clearly defined institutional roles, coordinated cluster governance, and complementary support from government, universities, industry partners, and community organizations established a well-structured collaborative innovation system.	Strong. Effective integration of technical extension services, capacity-building, production support, collective marketing, and institutional partnerships enhanced productivity, market access, and enterprise development.	Strong. Cluster-based collaboration, continuous technical assistance, shared decision-making, and collective marketing strengthened trust, knowledge exchange, and sustained partnerships among government, universities, industry, and community actors beyond the

								formal project period.
3 (SID-a177)	Included	Commission on Higher Education (CHED), Department of Tourism (DOT), and international development partners: Regulatory and enabling institutions responsible for accreditation standards, practicum policies, technical guidance, quality assurance, workforce development initiatives, and institutional support.	Higher education institutions: Coordinators of academic and experiential learning through pre-practicum orientation, faculty supervision, curriculum implementation, student assessment, alternative placement arrangements, and alignment of graduate competencies with industry standards.	Tourism establishments and industry partners: Providers of experiential learning, workplace training, structured mentorship, practical exposure, and logistical support that facilitate students' professional development and industry readiness.	Professional associations and community-based tourism organizations: Supporting partners that facilitate practicum placements, coordinate stakeholder participation, monitor training quality, and strengthen linkages between educational institutions and local tourism communities.	Strong. Clearly defined institutional roles, supported by regulatory standards, coordinated practicum governance, and active collaboration among government, universities, industry, and community partners established a well-structured workforce development system.	Strong. Effective integration of academic preparation, experiential learning, industry mentorship, and regulatory oversight strengthened competency development, graduate employability, and alignment between higher education and workforce requirements.	Strong. Continuous collaboration through pre-practicum orientation, faculty supervision, structured industry mentorship, stakeholder coordination, and iterative feedback mechanisms fostered trust, institutional learning, and sustained partnerships among government, universities, industry, and community actors.

4 (SID-a180)	Included	National government agencies (NGAs) and local government units (LGUs): Providers of funding, administrative oversight, logistical support, data validation, and policy integration. Government agencies coordinated project implementation and incorporated geospatial outputs into national and local planning initiatives.	Higher education institutions: Knowledge producers and technical implementers responsible for developing LiDAR and GIS workflows, training personnel, processing geospatial data, generating resource maps, conducting technical workshops, and strengthening human capital.	Private sector organizations: Technology and application partners that supported the utilization, validation, and adoption of geospatial products for planning, resource management, and decision-making.	Local government units, non-government organizations (NGOs), and local communities: End-users and collaborative partners that participated in capacity-building activities, map validation, knowledge sharing, and the application of geospatial outputs to local development initiatives.	Strong. Clearly defined institutional roles, supported by coordinated governance, sustained government investment, university-led technical expertise, and active participation of industry and community stakeholders, established a well-structured collaborative innovation system.	Strong. Effective integration of LiDAR technology, geospatial research, technical training, collaborative workflows, and institutional coordination resulted in high-quality resource maps, enhanced human capital, and evidence-based decision-support tools for national and local planning.	Strong. Sustained collaboration through technical workshops, mentoring, collaborative mapping, data validation, and continuous knowledge exchange fostered trust, strengthened institutional capacity, and promoted the long-term adoption of geospatial innovations among government, universities, industry, and community actors.

5 (SID-a12)	Conditionally Included	Municipal Disaster Risk Reduction and Management Office (MDRRMO) and the Department of Science and Technology (DOST): Operational and enabling institutions that provided geospatial datasets, local coordination, technical guidance, access to LiDAR resources, and capacity-building support for disaster risk	Cagayan State University (CSU): Knowledge producer and technical implementer responsible for generating digital terrain and surface models (DTMs/DSMs), developing hazard maps and the Flood EViDEns decision-support tool, and conducting technical training for MDRRMO personnel.	No significant industry participation was documented. Private-sector actors were not reported to have substantive roles in technology development, implementation, or commercialization within the project.	Local communities: End-users of hazard information who indirectly benefited from improved disaster preparedness. Community participation was largely limited to the utilization of project outputs, with minimal involvement in planning, implementation, or decision-making.	Moderate. Institutional roles between government and the university were clearly defined, supporting effective technical collaboration; however, the limited participation of industry and community actors constrained broader multisectoral integration within the innovation ecosystem.	Moderate. The integration of geospatial technologies, technical expertise, and local governance strengthened municipal disaster preparedness and decision-making, although innovation activities remained focused on hazard mapping and decision-support applications.	Moderate. Sustained collaboration and mutual trust were evident between the university and local government through technical training, knowledge exchange, and project implementation. However, interactions with industry and broader community stakeholders were limited, resulting in a relatively narrow collaborative network centered on project-

		management.						based activities.
6 (SID-a23)	Conditionally Included	Philippine port authorities and the ASEAN Secretariat: Facilitating and coordinating institutions that provided logistical support, access to port facilities, regional coordination, and technical guidance for implementing the biofouling monitoring program.	University of the Philippines (UP), National University of Singapore (NUS), and CSIR–National Institute of Oceanography (India): Knowledge producers and scientific implementers responsible for developing research protocols, conducting field surveys, analyzing biofouling organisms, and providing	No substantial industry participation was documented. Although port operations were the setting of the study, shipping companies and other private-sector stakeholders were not reported to have direct roles in research implementation, innovation development, or decision-making.	Port personnel: Operational participants who received technical training and contributed to field implementation. Broader community and civil society participation was not documented.	Moderate. Institutional roles between government and research institutions were clearly established and supported effective scientific collaboration; however, the limited participation of industry and community actors constrained broader multisectoral integration within the innovation ecosystem.	Moderate. Collaboration produced baseline biofouling data, standardized monitoring protocols, and strengthened technical capacity among port personnel. Nevertheless, innovation activities remained focused on environmental monitoring, with limited evidence of broader technological, policy, or commercialization outcomes.	Moderate. Productive collaboration and knowledge exchange were established between research institutions and government agencies through joint fieldwork, technical training, and regional cooperation. However, limited engagement with industry and community stakeholders resulted in relatively narrow and

			technical expertise and capacity-building activities.					project-based collaborative networks with limited long-term institutionalization.
7 (SID-a24)	Conditionally Included	National government agencies and local government units (LGUs): Lead institutions responsible for formulating, regulating, coordinating, and implementing REDD+ initiatives, forest protection policies, and other enabling governance	Universities and research institutions: Knowledge providers that contributed through carbon stock assessment, biodiversity monitoring, environmental evaluation, and policy analysis. Their participation was primarily research-oriented, with limited involvement	No substantial industry participation was documented. Private-sector engagement in forest conservation, technology development, or innovation activities was minimal and occurred only on a limited or project-specific basis.	Local communities, indigenous peoples, and community-based forest management (CBFM) organizations: Primary implementers and stewards of forest resources, actively participating in forest conservation, customary management practices, biodiversity protection,	Moderate. The innovation system was primarily structured around government leadership and strong community participation, supported by research institutions. However, limited industry involvement and the relatively peripheral role of universities	Moderate. Government policies, regulatory mechanisms, community-based forest management, and scientific assessments contributed to environmental governance and conservation outcomes. Nevertheless, innovation activities focused largely on policy implementation and	Moderate. Strong collaborative relationships were evident between government agencies and local communities through participatory forest management and conservation initiatives. However, weaker integration with universities and minimal industry

		mechanisms supporting sustainable forest management.	in implementation or coordination.		and local environmental governance.	constrained broader multisectoral integration.	resource management, with limited evidence of technological development, commercialization, or entrepreneurial innovation.	participation limited cross-sector knowledge exchange, collaborative learning, and broader innovation diffusion within the ecosystem.
8 (SID-a29)	Conditionally Included	Government research agencies: Institutional partners that provided laboratories, research facilities, equipment, fieldwork sites, professional supervision, and operational support in accordance with national research and	Philippine Normal University (PNU): Knowledge provider and academic coordinator responsible for designing, implementing, supervising, and evaluating the on-the-job training (OJT) program	No substantial industry participation was documented. Partner organizations were primarily public or government-affiliated research institutions, with no evidence of private-sector involvement	Limited community participation was documented. Community actors were not directly involved in program design, implementation, or collaborative innovation activities.	Moderate. Institutional collaboration between government research agencies and the university was well established and supported effective academic training. However, the absence of industry participation	Moderate. Collaboration strengthened workforce preparation, research training, and experiential learning through structured OJT and institutional support. Nevertheless, the activities focused primarily on educational and capacity-	Moderate. Sustained collaboration between the university and government agencies facilitated practical training, supervision, and knowledge exchange. However, limited industry involvement, minimal

		science education mandates.	while integrating classroom instruction with practical research experience.	in training, innovation, or technology transfer.		and minimal community engagement limited broader multisectoral integration within the innovation ecosystem.	building objectives, with limited evidence of technology transfer, commercialization, or broader innovation outcomes.	community participation, and the absence of co-creation or broader cross-sector learning constrained the depth and diversity of collaborative relationships.
9 (SID-a33)	Conditionally Included	Commission on Higher Education (CHED): Provided standardized tracer study instruments and institutional guidance but had limited involvement in program implementation, curriculum	College of Nursing: Knowledge provider and academic evaluator responsible for designing and administering the tracer study, analyzing graduate outcomes, identifying curricular	No substantial industry participation was documented. Hospitals, healthcare institutions, and employers were not actively involved in curriculum development,	Alumni: Primary respondents who contributed employment experiences and feedback that informed curriculum evaluation. Broader community and civil society participation	Weak. The analytical case was largely university-driven, with limited government involvement and minimal participation from industry and community actors, resulting in weak	Moderate. The tracer study generated evidence to support curriculum evaluation, program improvement, and graduate outcome assessment. However, collaboration remained primarily	Weak. Functional relationships between the university and its alumni supported institutional learning and curriculum enhancement. Nevertheless, limited engagement with

		development, or innovation governance.	strengths and gaps, and supporting evidence-based curriculum improvement.	collaborative research, or innovation activities beyond indirect employment of graduates.	was not documented.	multisectoral integration within the innovation ecosystem.	academic, with limited evidence of technology transfer, innovation activities, or broader socioeconomic impact.	government agencies, healthcare employers, and broader community stakeholders constrained cross-sector collaboration and long-term relational development.
10 (SID-a34)	Conditionally Included	Laguna Lake Development Authority (LLDA), Bureau of Fisheries and Aquatic Resources (BFAR), and Municipal Government: Provided policy direction, technical assistance, funding	University of the Philippines Los Baños (UPLB): Potential knowledge partner with geographic proximity and technical expertise; however, participation was limited and largely	No substantial industry participation was documented. Private-sector organizations and commercial fisheries were largely absent from governance, innovation, or resource	Barangay Fisheries and Aquatic Resources Management Councils (BFARMCs) and local fishing communities: Participated in fisheries governance, resource stewardship, and community-	Weak. The innovation structure was predominantly government-led, with limited university engagement, no meaningful industry participation, and community	Weak. Collaboration supported fisheries governance, environmental stewardship, and community resource management but showed limited evidence of innovation, technology development,	Weak. Government–community relationships facilitated local resource management and capacity-building activities; however, interactions remained weakly institutionaliz

		support, capacity-building activities, and institutional legitimacy for fisheries governance and resource management.	advisory, with no sustained involvement in collaborative research, extension, or innovation activities.	management activities.	based management, although engagement remained relatively weak and inconsistently institutionalized.	involvement confined primarily to local resource management, resulting in weak multisectoral integration.	knowledge commercialization, or broader institutional learning across sectors.	ed, while sustained collaboration with universities and industry was largely absent, limiting knowledge exchange and long-term multisectoral partnerships.
11 (SID-a47)	Conditionally Included	Food and Drug Administration (FDA): Served as the regulatory authority by supervising pharmaceutical transactions, maintaining product registries, issuing digital	University of the Philippines (UP) and the National Institutes of Health (NIH): Functioned as knowledge producers and technical collaborators by designing the blockchain	Pharmaceutical manufacturers, wholesalers, and retailers: Participated as operational users by implementing product traceability, supply chain verification, and authenticate	Consumers: Participated as end users by verifying product authenticity through digital scanning, thereby contributing to product validation, transparency, and post-market surveillance.	Moderate. Government occupied the central coordinating role, while universities provided technical expertise and industry actors implemented operational functions. Community participation	Strong. The system integrated blockchain technology, smart contracts, GS1 standards, pharmaceutical traceability, anomaly detection, and consumer verification into a	Moderate. Collaboration was primarily mediated through the blockchain platform, enabling structured information exchange and transaction verification among actors.

		credentials, monitoring anomalies, and ensuring regulatory compliance and system legitimacy.	architecture, integrating GS1 standards, conducting simulation testing, and providing research and technical expertise.	d transaction recording within the blockchain-enabled system.		was limited to end-user verification, resulting in partial Quadruple Helix integration.	coordinated innovation platform, demonstratin g strong technological and functional integration among participating actors.	However, interactions were largely demonstrate d through simulation, with limited empirical evidence of sustained cross-sector collaboration under real-world implementati on conditions.
12 (SID-a55)	Condition ally Included	Philippine Statistics Authority (PSA): Indirectly supported the study by providing nationally representativ e datasets (Annual Poverty Indicators Survey	Research team: Functioned as knowledge producers by analyzing national survey data, conducting descriptive and regression analyses, and	No substantial industry participation was documented. Private-sector organization s were not involved in data generation, analysis, intervention	Surveyed households: Participated as data providers by contributing information through national household surveys, forming the empirical basis for the analysis	Weak. The analytical structure was primarily characterize d by a government–university relationship, with government providing data infrastructure and	Moderate. The study generated evidence on poverty patterns, socioeconomi c determinants, and household vulnerability that may inform policy discussions.	Weak. Interaction was largely limited to the use of government-generated datasets for academic analysis. There was little evidence of sustained collaboration

		[APIS] and Family Income and Expenditure Survey [FIES]) that served as the primary source of empirical evidence; no active involvement in research design, policy implementation, or intervention development was documented.	generating evidence on the socioeconomic determinants of poverty and household vulnerability.	design, or knowledge application.	without direct involvement in interpreting findings or developing policy and innovation responses.	universities generating knowledge. Industry participation was absent, while community involvement was limited to data provision, resulting in weak multisectoral integration.	However, it did not extend to collaborative intervention design, innovation development, technology transfer, or implementation involving multiple sectors.	, knowledge co-production, or iterative engagement among government, universities, industry, or community actors beyond the data collection process.
13 (SID-a58)	Conditionally Included	Local Government Units (LGUs), Bureau of Fisheries and Aquatic Resources (BFAR), Department	Mindanao State University–General Santos City (MSU-GSC): Functioned as a knowledge producer by	No substantial industry participation was documented. Private-sector involvement was limited,	Community-based organizations (CBOs), coastal communities, and non-government organizations (NGOs):	Moderate. Community organizations occupied a central role, supported by government agencies and academic	Moderate. Collaboration generated practical outcomes in coastal resource management, environmental	Moderate. Strong collaborative relationships were evident among community organizations, government

of Environment and Natural Resources (DENR), Department of Labor and Employment (DOLE), and Community Environment and Natural Resources Office (CENRO): Provided technical assistance, funding, legal support, capacity-building, monitoring, and institutional support for community-based coastal resource management	documenting and analyzing community-based organization (CBO) initiatives, conducting key informant interviews and archival research, and identifying enabling and constraining factors affecting CRM implementation.	although some private foundations provided financial or programmatic support without actively participating in innovation or governance processes.	Served as the primary implementers of coastal resource management activities, including marine sanctuary management, Bantay-Dagat operations, coastal clean-up initiatives, environmental stewardship, and alternative livelihood programs.	institutions. However, limited industry participation and the absence of formal multisectoral integration constrained the development of a fully institutionalized Quadruple Helix configuration.	conservation, community participation, and livelihood development. Nevertheless, there was limited evidence of technological innovation, formal knowledge co-production, or integrated innovation governance across sectors.	agencies, and supporting institutions, facilitating knowledge sharing and collective action. However, sustained university–government–industry collaboration remained limited, and knowledge exchange was primarily descriptive rather than co-creative or innovation-driven.

		(CRM) initiatives.						
14 (SID-a59)	Conditionally Included	Local Government Units (LGUs) and the Bureau of Fisheries and Aquatic Resources (BFAR): Facilitated project implementation by providing regulatory oversight, legal permits, access to mangrove areas, and institutional coordination. Their involvement primarily supported implementation rather than	Southeast Asian Fisheries Development Center/Aquaculture Department (SEAFDEC/AQD) and academic partners: Functioned as knowledge producers and technical implementers by designing the pond nursery system, delivering season-long training, monitoring production and survival	No substantial private-sector participation was documented. Market actors and commercial enterprises had limited involvement in technology commercialization, value-chain development, or innovation scaling.	People's Organizations (POs), smallholder mud crab growers, and non-government organizations (NGOs): Participated as primary implementers by adopting sustainable aquaculture practices, managing pond nurseries, participating in capacity-building activities, and facilitating community participation, microfinance	Moderate. Universities provided technical leadership, government facilitated implementation and regulatory support, and community organizations served as primary adopters. However, limited industry participation constrained broader multisectoral integration within the innovation ecosystem.	Moderate. Collaboration enhanced sustainable aquaculture practices, community livelihoods, technical capacity, and environmentally responsible resource management. Nevertheless, there was limited evidence of technological commercialization, policy innovation, or scalable cross-sector innovation mechanisms.	Moderate. Strong collaborative relationships developed among researchers, government agencies, NGOs, and community organizations through training, technical support, and continuous engagement. However, weak linkages with private-sector actors and broader market networks limited opportunities for sustained innovation

		technology co-development or long-term innovation governance.	rates, and evaluating the financial viability of mud crab farming.		access, and local livelihood development.			diffusion and ecosystem-wide collaboration.
15 (SID-a69)	Conditionally Included	Department of Science and Technology–Philippine Council for Industry, Energy and Emerging Technology Research and Development (DOST-PCIEERD): Provided research funding, strategic oversight, policy support, and capacity-building initiatives that enabled	University of the Philippines Diliman, in collaboration with Hokkaido University: Functioned as knowledge producers and technical developers by designing the DPAD system architecture, developing data-processing pipelines, integrating free and open-source	No substantial industry participation was documented. Private-sector organizations were not actively involved in system development, technology commercialization, or operational deployment.	Government agencies, GIS practitioners, researchers, and the general public: Participated as intended end users of the platform by utilizing geospatial data services and digital infrastructure, although their involvement was largely limited to prospective application rather than	Moderate. Universities led knowledge generation and technical development, while government provided funding and institutional support. Limited participation from industry and community actors resulted in only partial integration of the broader innovation ecosystem.	Moderate. The collaboration produced digital research infrastructure, strengthened technical capacity, and expanded access to geospatial information through open-source technologies. However, evidence of technology commercialization, broad policy implementation, or measurable	Moderate. Strong collaboration was evident between universities and government research agencies through joint research and capacity-building activities. However, sustained engagement with private-sector organizations, operational government agencies, and broader

		the development of the Distributed Parallel and Distributed (DPAD) system, with limited involvement in downstream implementation or technology adoption.	software (FOSS), and strengthening technical capacity through research and infrastructure development.		collaborative development or co-creation.		socioeconomic impact remained limited.	community users remained limited, constraining wider knowledge exchange and innovation diffusion.
16 (SID-a71)	Conditionally Included	National, provincial, and local government agencies: Provided regulatory oversight, marine protected area (MPA) designation, zoning approvals, policy implementati	Universities and research institutions: Functioned as knowledge producers and technical advisers by conducting biodiversity assessments, ecological modeling, systematic	Private-sector stakeholders, including fisheries and tourism operators: Participated primarily as regulated users of marine resources, with limited involvement in	Local communities, people's organizations, and non-government organizations (NGOs): Actively participated in stakeholder consultations, marine spatial planning,	Moderate. Government agencies, universities, and community organizations formed the primary collaborative structure, while private-sector participation remained	Moderate. Collaboration supported participatory governance, evidence-based conservation planning, biodiversity management, and capacity building through the integration of scientific and	Moderate. Strong collaborative relationships existed among government agencies, universities, NGOs, and local communities through participatory planning, knowledge

		on, and integration of conservation initiatives into biodiversity and coastal resource management strategies. Their role was primarily facilitative, relying on academic institutions and non-government organizations for technical expertise and implementation support.	conservation planning (e.g., Marxan), and capacity-building activities that informed evidence-based marine conservation planning.	collaborative planning, innovation development, or knowledge co-production.	zoning, resource monitoring, enforcement, and community-based conservation initiatives, contributing local knowledge and supporting implementation at the community level.	largely peripheral. Consequently, the innovation ecosystem demonstrated only partial integration of Quadruple Helix actors.	local knowledge. However, there was limited evidence of technological innovation, commercialization, or broader institutional innovation beyond environmental governance.	sharing, and conservation activities. However, limited engagement with private-sector actors constrained broader multisectoral collaboration, innovation diffusion, and long-term ecosystem integration.
17 (SID-a76)	Conditionally Included	Municipal, provincial, and national government agencies: Provided institutional	Universities and research institutions: Functioned as knowledge producers	No substantial industry participation was documented. Agribusiness	Farmers, farm workers, local communities, and community-	Strong. Government agencies, universities, and community actors were	Moderate. Collaboration supported knowledge co-production, participatory	Moderate. Strong collaborative relationships and trust were established

legitimacy, regulatory support, stakeholder coordination, and access to implementation sites. Their participation primarily facilitated project implementation, although engagement varied across governance levels and showed limited evidence of policy innovation or long-term institutional commitment.	and technical facilitators by developing ecological engineering approaches, conducting stakeholder analyses, coordinating participatory research, and facilitating knowledge co-production and capacity-building activities.	es and other private-sector organizations had limited involvement and did not actively participate in collaborative innovation, technology development, or implementation processes.	based organizations: Served as primary collaborators by participating in interviews, focus group discussions, training activities, citizen science initiatives, and the co-development of locally appropriate ecological engineering practices.	well integrated through structured participatory mechanisms. However, limited industry participation prevented the formation of a fully balanced Quadruple Helix innovation configuration.	learning, ecological engineering, and local capacity building. Nevertheless, evidence of technological commercialization, broader policy innovation, or sustained economic innovation outcomes remained limited.	among universities, government agencies, and local communities through continuous stakeholder engagement and participatory research. However, weaker connections with private-sector organizations and limited integration across higher levels of governance constrained broader multisectoral collaboration and innovation diffusion.

18 (SID-a93)	Conditionally Included	Department of Science and Technology–Philippine Council for Industry, Energy and Emerging Technology Research and Development (DOST-PCIEERD), Department of Transportation (DOTr), and Metropolitan Manila Development Authority (MMDA): Provided research funding, transport data, institutional support, and	University research team: Functioned as knowledge producers by designing travel surveys, developing and estimating logit models, integrating analytical outputs into EMME4 transport network simulations, and generating evidence to support transportation planning and decision-making.	No substantial industry participation was documented. Transport operators and private-sector organizations were not actively involved in model development, implementation, or collaborative innovation activities.	Private vehicle users: Participated as survey respondents by providing travel behavior data that informed model development, but their involvement was limited to data provision without participation in knowledge co-production or decision-making processes.	Moderate. Collaboration was primarily characterized by strong government–university linkages supported through research funding and data sharing. However, limited participation from industry and community actors resulted in only partial integration of the broader innovation ecosystem.	Moderate. The collaboration produced advanced transport modeling tools, analytical evidence, and decision-support outputs that can inform transportation planning. Nevertheless, there was limited evidence of operational deployment, institutionalization, technology transfer, or broader innovation across multiple sectors.	Weak. Interactions were largely unidirectional, with universities generating research outputs for government use. Opportunities for sustained knowledge co-production, iterative collaboration, and meaningful engagement with industry and community stakeholders remained limited, resulting in weak multisectoral integration.

		policy alignment that enabled the study, although their involvement was primarily facilitative rather than collaborative in system design, implementation, or policy innovation.						
19 (SID-a99)	Conditionally Included	Commission on Higher Education (CHED): Provided the regulatory framework for internship programs by establishing national practicum requirements and academic standards.	University: Functioned as the primary knowledge producer by designing and administering the survey, analyzing student and industry perceptions of workforce competencie	Industry partners: Participated as internship providers, workplace supervisors, and survey respondents by offering practical training opportunities and feedback on graduates'	Students: Participated as respondents by sharing internship experiences and perceptions of workforce preparedness, contributing empirical evidence for the	Moderate. The case demonstrated established university–industry linkages through structured internship programs supported by a government regulatory	Moderate. The collaboration generated evidence that can inform curriculum improvement, workforce preparation, and university–industry alignment. However, there was	Weak. Interactions were primarily transactional, centering on internship implementation and feedback collection. Opportunities for long-term knowledge co-

		Its role was primarily enabling, with no direct participation in curriculum development, research implementation, or evaluation.	s, and generating evidence to inform curriculum enhancement and program improvement.	competencies, although their involvement remained limited to implementation and evaluation rather than collaborative curriculum development.	assessment of university–industry alignment without direct involvement in decision-making or curriculum co-creation.	framework. However, community participation remained limited, resulting in only partial integration of the broader innovation ecosystem.	limited evidence of broader innovation outcomes, policy implementation, technology transfer, or sustained multisectoral collaboration.	production, participatory curriculum design, and sustained collaboration among government, universities, industry, and community actors remained limited.
20 (SID-a276)	Conditionally Included	Department of Science and Technology–Philippine Council for Industry, Energy and Emerging Technology Research and Development (DOST-PCIEERD), national government agencies	University of the Philippines Diliman (UPD), in collaboration with 15 partner universities: Functioned as the primary knowledge producer and technical coordinator by designing	No substantial industry participation was documented. Private-sector organizations were not actively involved in system development, technology commercialization, or collaborative	Research assistants, local communities, and LGUs: Participated through field data collection, local implementation, validation activities, and operational support. Community	Strong. A well-defined government–university network supported nationwide collaboration through coordinated roles, shared research infrastructure, and institutional partnerships across multiple	Moderate. Collaboration generated standardized geospatial workflows, national mapping datasets, methodological innovations, and substantial human-capacity development. However,	Moderate. Strong knowledge exchange and collaborative learning occurred among universities, research assistants, LGUs, and government agencies through mentoring, technical

		(NGAs), and local government units (LGUs): Provided research funding, strategic direction, policy support, access to geospatial data, technical mentorship, and field coordination that enabled nationwide implementation of the mapping initiative.	and standardizing mapping workflows, developing high-resolution geospatial methodologies, training more than 200 research assistants, and facilitating knowledge dissemination and capacity building across participating institutions.	innovation activities.	participation was primarily indirect and implementation-oriented rather than centered on knowledge co-production or collaborative innovation.	universities and government agencies. However, limited industry participation resulted in only partial integration of the broader Quadruple Helix innovation ecosystem.	there was limited evidence of technology commercialization, large-scale policy transformation, or broader socioeconomic innovation outcomes.	training, and research coordination. Nevertheless, limited engagement with private-sector organizations and relatively indirect community participation constrained broader multisectoral collaboration and long-term innovation diffusion.
STUDIES BELOW ARE EXTRACTED FROM 2020–2025 PUBLICATIONS (SID-b)								
1 (SID-b100)	Included	Department of Health (DOH), Department of Science and	National Telehealth Center (NTHC), University of the	SMART Communications, SHINE OS+, technology developers,	Patients, healthcare professionals, local health workers, and	Strong. Clearly institutionalized roles among government,	Strong. The collaboration achieved comprehensive integration of policy	Strong. Sustained and institutionalized collaboration

Technology (DOST), Philippine Health Insurance Corporation (PhilHealth), Local Government Units (LGUs), Advanced Science and Technology Institute (ASTI), and Philippine Research, Education and Government Information Network (PREGINET): Served as policy architects, regulators, funders, and system implementers by leading	Philippines Manila (UP Manila), University of the Philippines–Philippine General Hospital (UP-PGH), and Ateneo de Manila University (ADMU): Functioned as knowledge producers, system designers, and technical integrators by developing CHITS and RxBox technologies, supporting telehealth implementation,	hospitals, and healthcare providers: Contributed technological infrastructure, digital platforms, clinical implementation support, referral services, and operational expertise that enabled the deployment and scaling of telemedicine services across healthcare facilities.	partner healthcare institutions: Participated as end users, service providers, and beneficiaries by utilizing telemedicine services, supporting local implementation, facilitating patient referrals, and contributing to the adoption and operationalization of digital health innovations.	universities, industry, and community actors were supported through formal national programs, dedicated funding mechanisms, interoperable ICT infrastructure, and coordinated implementation across multiple levels of the healthcare system, reflecting a highly integrated innovation ecosystem.	development, research and development, digital infrastructure, technology innovation, interoperability, financing, capacity building, and healthcare service delivery. These coordinated activities enabled the nationwide implementation and operationalization of eHealth innovations.	was evident through long-term partnerships among government agencies, universities, industry, healthcare providers, and local communities. Continuous knowledge exchange, joint technology development, interoperable digital platforms, referral networks, and coordinated implementation across LGUs and healthcare institutions

		the National Telehealth Service Program (NTSP), supporting the Philippine Health Information Exchange (PHIE), providing ICT infrastructure, integrating financing mechanisms, and aligning national initiatives with international eHealth frameworks.	advancing electronic medical record (EMR) systems, providing specialist teleconsultation services, and strengthening national eHealth research, training, and policy development.					fostered stable multisectoral relationships and a mature innovation ecosystem.
2 (SID-b171)	Included	Department of Science and Technology–Philippine Council for	Southeast Asian Fisheries Development Center–Aquaculture	Hatchery operators, grow-out operators, fry suppliers, and other	Fish farmers, local aquaculture practitioners, and consumers:	Strong. Clearly defined institutional roles, formal funding	Strong. Collaboration supported a complete innovation pathway	Strong. Sustained collaboration was evident through long-term

Agriculture, Aquatic and Natural Resources Research and Development (DOST-PCAARRD), Bureau of Fisheries and Aquatic Resources (BFAR), Philippine Statistics Authority (PSA), and National Inland Fisheries Technology Development Center (NIFTDC): Served as strategic funders, coordinators, regulators, and technology	Department (SEAFDEC-AQD) and the University of the Philippines Visayas (UP Visayas): Functioned as knowledge producers and technology transfer partners by developing broodstock and hatchery technologies, conducting collaborative research, providing technical assistance, and supporting pilot implementation and	aquaculture enterprises: Commercialized hatchery technologies, adopted improved production practices, expanded aquaculture operations, and translated research outputs into market-oriented production systems, thereby facilitating the scaling of innovation.	Participated as technology adopters and beneficiaries by utilizing hatchery-bred fry, supporting the uptake of improved aquaculture practices, and contributing to the broader diffusion and socioeconomic impacts of innovation within local communities.	mechanisms, coordinated research partnerships, technology transfer arrangements, and structured capacity-building programs established a highly integrated innovation ecosystem linking government, universities, industry, and community stakeholders.	encompassing research and development, project funding, technology transfer, regulatory support, workforce training, commercialization, and large-scale aquaculture production. These coordinated activities strengthened innovation adoption while generating measurable economic and livelihood benefits.	partnerships among government agencies, research institutions, industry, and local aquaculture communities. Continuous knowledge exchange, technical assistance, training programs, technology transfer, and commercialization activities fostered institutionalized multisectoral relationships and supported the widespread diffusion of

		disseminatio n partners by financing the GAINEX project, coordinating research and commercializ ation activities, implementin g hatchery development programs, providing technical training, and generating statistical data to support planning and policy implementati on.	capacity-building initiatives.					aquaculture innovations.
3 (SID-b247)	Included	Provincial Environment and Natural Resources Office (PENRO)–Nueva Ecija,	Tarlac State University (TSU) and Central Luzon State University (CLSU):	Information and communicati ons technology (ICT) specialists:	Government personnel, biodiversity committee members, environment al	Strong. A clearly institutionaliz ed governance structure linked	Strong. Collaboration integrated digital technologies, environmenta l monitoring,	Strong. Sustained collaboration was maintained through continuous

Department of Environment and Natural Resources (DENR), and the Landscape and Wildlife Indicators (LAWIN) System: Served as system owners, governance coordinators, and operational implementers by managing biodiversity data, overseeing environmental monitoring, coordinating institutional activities, and	Functioned as knowledge partners by providing technical assistance, methodological support, system development expertise, and capacity-building activities that strengthened the implementation and evaluation of the biodiversity information system.	Contributed technical expertise by evaluating database architecture, system usability, security, maintainability, and user interface performance, supporting continuous system improvement without direct involvement in commercialization or system ownership.	practitioners, and community users: Participated as system users and evaluators by utilizing biodiversity information, validating system outputs, supporting environmental monitoring, and contributing feedback for system refinement and decision-making.	government agencies, universities, technical experts, and community users through formal operational responsibilities, integrated information systems, and coordinated environmental management, reflecting a well-established innovation ecosystem.	system development, technical evaluation, and evidence-based decision support into routine biodiversity management. The combination of ICT innovation, institutional coordination, and capacity building strengthened environmental governance and operational effectiveness.	interaction among government agencies, universities, ICT specialists, biodiversity experts, and community users. Regular system evaluation, knowledge exchange, institutional coordination, and iterative system improvement fostered stable multisectoral relationships and supported the long-term operation of the environment

		integrating the system into broader environmental governance and conservation initiatives.						al information system.
4 (SID-b694)	Included	Commission on Higher Education (CHED), Department of Science and Technology (DOST), Department of Trade and Industry (DTI), Intellectual Property Office of the Philippines (IPOPHL–Taguig), Land Bank of the Philippines (LBP),	Cagayan State University (CSU), Isabela State University (ISU), and Nueva Vizcaya State University (NVSU): Functioned as knowledge producers and innovation intermediaries by operating Technology Business	Start-ups, technopreneurs, incubatees, financial institutions, private enterprises, and commercialization partners (e.g., Kasama Company): Participated in technology commercialization, enterprise development, market	Students, graduates, cacao growers, local entrepreneurs, and community-based enterprises: Participated as innovation adopters, enterprise developers, and beneficiaries by engaging in incubation programs, entrepreneurship training,	Strong. A highly institutionalized innovation ecosystem was established through coordinated government policies, university-based incubators, financial support systems, intellectual property mechanisms, and active participation	Strong. Collaboration supported a comprehensive innovation pathway integrating entrepreneurship education, research and development, incubation, intellectual property protection, financing, technology commercialization, and enterprise development. These	Strong. Sustained and institutionalized collaboration was evident through continuous partnerships among government agencies, universities, industry partners, financial institutions, and community stakeholders. Long-term mentoring,

		Cooperative Banks, and Local Government Units (LGUs): Provided policy direction, funding, regulatory oversight, intellectual property support, financial services, and institutional coordination to strengthen university-based incubation, technopreneurship, and innovation development.	Incubators (CSU BIZNEST, ISU CVCDC, and NVSU Sabatan Hub), delivering entrepreneurship education, mentoring start-ups, supporting research commercialization, facilitating technology transfer, and implementing incubation programs.	expansion, financing, and innovation scaling, translating research outputs into commercially viable products, services, and businesses.	technology adoption, and community-based enterprise development that contributed to local innovation and economic growth.	from industry and community stakeholders. Clearly defined institutional roles and formal innovation infrastructures supported a mature Quadruple Helix configuration.	coordinated activities generated measurable innovation outputs, including start-up creation, commercialization opportunities, employment generation, and strengthened regional innovation capacity.	funding mechanisms, incubation services, intellectual property support, commercialization activities, and enterprise development fostered dense knowledge exchange, strong multisectoral relationships, and a well-established innovation ecosystem.
5 SID-b695	Included	Department of Science and	Benguet State University	Micro, Small, and Medium Enterprises	Community-based organization	Strong. A highly institutionaliz	Strong. Collaboration established	Strong. Sustained collaboration

Technology (DOST), Department of Social Welfare and Development–Sustainable Livelihood Program (DSWD-SLP), Local Government Units (LGUs), Cooperative Development Authority (CDA), Securities and Exchange Commission (SEC), Food and Drug Administration (FDA), Department of Labor and Employment (DOLE), Food and	(BSU), University of Baguio (UB), and the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA): Functioned as knowledge producers and technology transfer partners by delivering technical training, capacity-building programs, research support, equipment assistance, and	(MSMEs), social enterprises, and private-sector market partners: Managed production, product development, commercialization, marketing, employment generation, and enterprise operations while collaborating with government and academic institutions to expand market opportunities and strengthen	s, cooperatives, local associations, producers, and beneficiary groups: Participated as enterprise developers, technology adopters, and beneficiaries by managing community-based production, participating in capacity-building activities, generating local employment, and supporting the adoption and sustainability of science-	ed innovation ecosystem linked government agencies, universities, enterprises, and community organizations through coordinated funding mechanisms, regulatory systems, technology transfer programs, and structured enterprise development initiatives. Clearly defined institutional roles supported a mature Quadruple	an integrated innovation pathway connecting research funding, technology transfer, technical training, regulatory support, enterprise development, commercialization, and community livelihood generation. These coordinated activities strengthened science- and technology-based social enterprises while producing measurable economic and social	was evident through long-term partnerships among government agencies, universities, enterprises, cooperatives, and community organizations. Continuous funding, technology transfer, capacity-building activities, regulatory support, marketing assistance, and enterprise mentoring fostered dense knowledge exchange,

Nutrition Research Institute (FNRI), Philippine Textile Research Institute (PTRI), and other partner agencies: Provided research funding, enterprise development support, regulatory oversight, technology transfer, technical assistance, infrastructure, and market facilitation to strengthen science- and technology-based social enterprises.	innovation diffusion to strengthen enterprise development and community-based production systems.	business sustainability.	and technology-driven livelihood initiatives.	Helix configuration.	outcomes across multiple cases.	institutional learning, and enduring multisectoral relationships within the Philippine innovation ecosystem.

6 (SID-b110)	Conditionally Included	Department of Education (DepEd), Commission on Higher Education (CHED), school administrators, and partner educational institutions: Provided policy direction, institutional oversight, governance, and administrative supervision by establishing attendance requirements, monitoring compliance, and overseeing the	Researchers, teachers, and participating higher education institutions: Functioned as knowledge producers and system implementers by designing, developing, validating, and deploying the automated attendance monitoring system, while integrating its use into classroom management and educational	None explicitly identified. The study did not document the participation of private-sector organizations, technology firms, or commercial partners in the development, commercialization, or scaling of the attendance monitoring system.	Students and parents: Participated as primary users and beneficiaries of the system. Students engaged as end users whose attendance records were monitored, while parents received attendance-related information that supported communication and student monitoring within the educational environment.	Moderate. Institutional roles were clearly defined among government, universities, and community actors, with structured governance supporting system implementation within the education sector. However, the absence of private-sector participation limited broader cross-sector integration and the development of a fully realized	Moderate. The collaboration supported the development and implementation of an ICT-enabled attendance monitoring system that improved administrative efficiency, classroom management, and reporting processes. Nevertheless, innovation remained confined to educational administration, with limited evidence of broader technology commercialization, intersectoral	Weak. Interactions were primarily hierarchical and operational, with government providing oversight, universities leading system development and implementation, and community actors serving mainly as users and beneficiaries. Collaboration was largely system-mediated and characterized by one-

		implementation of the automated attendance monitoring system.	administration.			Quadruple Helix innovation ecosystem.	innovation, or knowledge co-production beyond the academic setting.	way information flows rather than sustained knowledge exchange, co-creation, or long-term multisectoral partnerships.
7 (SID-b209)	Conditionally Included	Department of Agriculture (DA), Agricultural Technologists (AT), Provincial Agriculturists (PA), and the Regional Crop Protection Center (RCPC): Served as regulators, coordinators, and operational implementers by	Cagayan State University–College of Information Technology (CIT-U) and agricultural scientists: Functioned as knowledge producers and technical support partners by developing the GIS-enabled mobile	None explicitly identified. The study did not document the participation of private-sector organizations, agribusiness firms, or commercial technology providers in the development, commercializ	Farmers: Participated as primary users and information providers by reporting pest and disease occurrences, contributing field-level observations, and supporting agricultural surveillance and local decision-making processes.	Moderate. Institutional roles were clearly defined among government agencies, universities, and farming communities within a government-led surveillance system. However, the absence of private-sector participation	Moderate. Collaboration supported the development and implementation of a GIS-enabled agricultural monitoring system that strengthened pest surveillance, data management, and evidence-based decision-making.	Weak. Interactions were predominantly hierarchical and information-driven, with farmers providing field data, universities contributing technical expertise, and government agencies leading surveillance

		overseeing pest surveillance, collecting and validating field data, consolidating reports, supporting evidence-based decision-making, and coordinating regional crop protection activities.	monitoring system, providing scientific interpretation of pest and disease data, and supporting decision-making through technical and analytical expertise.	ation, or implementation of the monitoring system.		and broader cross-sector governance limited the development of a fully integrated Quadruple Helix innovation ecosystem.	Nevertheless, innovation remained focused on operational monitoring and administrative support, with limited evidence of commercialization, technology diffusion, or broader multisectoral innovation.	and decision-making. Collaboration was largely linear and operational, with limited knowledge co-production, reciprocal learning, or sustained multisectoral partnerships characteristic of a mature innovation ecosystem.
8 (SID-b318)	Conditionally Included	Department of Science and Technology (DOST), DOST–Philippine Council for Industry, Energy and Emerging Technology	Bataan Peninsula State University (BPSU), Saint Louis University (SLU), Miriam College, Advanced Manufacturin	Micro, Small, and Medium Enterprises (MSMEs), SM Group, and other private-sector collaborators: Participated by supporting	Students, faculty members, aspiring entrepreneurs, innovators, and local technology users: Participated as primary	Moderate. Institutional roles were clearly defined among government agencies, universities, industry, and community stakeholders	Moderate. The collaboration successfully established makerspaces, fabrication laboratories, and technopreneurship hubs that	Weak. Interactions were primarily institutional and infrastructure-oriented, with government providing policy and

Research and Development (DOST-PCIEERD), Commission on Higher Education (CHED), Department of Trade and Industry (DTI), and the City Government of Balanga: Served as policy enablers, funding providers, and innovation ecosystem facilitators by supporting the establishment of makerspaces, fabrication laboratories,	g Research Laboratory (AMReL), MakerLab, and the SLU TechHub ecosystem: Functioned as knowledge producers and innovation intermediaries by establishing and managing makerspaces, fabrication laboratories, incubation centers, and innovation hubs that supported research, prototyping, entrepreneurship, and technology-	prototyping activities, providing infrastructure and resource assistance, and collaborating with universities to explore technology applications and entrepreneurial opportunities.	users and beneficiaries of makerspaces and innovation hubs by engaging in experiential learning, prototype development, entrepreneurship activities, and innovation capacity-building initiatives.	through structured funding mechanisms and innovation infrastructure. However, collaboration remained largely infrastructure- and institution-driven, with limited evidence of deeply integrated multisectoral innovation networks or sustained industry engagement.	strengthened research, prototyping, innovation education, and entrepreneurial capacity. Nevertheless, evidence of sustained technology commercialization, product co-development, innovation scaling, or continuous cross-sector innovation remained limited.	financial support, universities operating innovation facilities, industry contributing limited technical and infrastructure support, and community actors serving mainly as users and beneficiaries. Collaboration was characterized more by resource provision than by sustained knowledge co-production, iterative

		innovation hubs, and technopreneurship programs through funding, institutional policies, and infrastructure development.	oriented learning.					innovation, or long-term multisectoral partnerships.
9 (SID-b469)	Conditionally Included	Department of Science and Technology–Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (DOST-PCAARRD) and Local Government Units (LGUs): Served as	Central Mindanao University (CMU): Functioned as the primary knowledge producer and extension partner by delivering technical training, providing agricultural inputs, conducting technology	None explicitly identified. The study did not document the active participation of private-sector enterprises, agribusiness firms, processors, or commercial partners in technology commercialization, value-	Farmer-cooperators and local farming communities: Participated as technology adopters and project beneficiaries by establishing and managing cacao plantations, applying recommended production	Moderate. Institutional roles were clearly defined among government agencies, the university, and farming communities through coordinated funding, technical assistance, and agricultural extension	Moderate. Collaboration supported agricultural capacity building through technical training, technology transfer, input provision, field monitoring, and extension services that strengthened cacao production.	Weak. Interactions were predominantly hierarchical and program-driven, with government providing funding and coordination, the university delivering technical expertise, and farming communities

		funding providers, coordinators, and program enablers by financing the cacao development project, coordinating implementation, selecting beneficiaries, and supporting local agricultural extension activities.	transfer, monitoring plantation establishment, and offering continuous technical assistance to participating farmers.	chain development, or innovation scaling.	practices, and engaging in training and extension activities to improve agricultural productivity.	mechanisms. However, the absence of private-sector participation limited broader cross-sector integration and the development of a fully integrated Quadruple Helix innovation ecosystem.	Nevertheless, innovation remained primarily within a technology dissemination and agricultural extension model, with limited evidence of commercialization, value-chain integration, or collaborative innovation beyond project implementation.	adopting recommended practices. Collaboration was characterized by one-way knowledge transfer rather than sustained knowledge co-production, reciprocal learning, or long-term multisectoral partnerships.
10 (SID-b582)	Conditionally Included	Government of the Philippines (GOV_PH), Philippine Accreditation Board (PAB), Halal Certification	None explicitly identified. The study did not document the active participation of	Halal producers, exporters, suppliers, certification organizations, tourism enterprises, and other	Consumers and Muslim communities: Participated as end users and beneficiaries by creating demand for	Moderate. Institutional roles were clearly defined between government regulatory bodies and	Moderate. Collaboration effectively supported halal certification, accreditation, regulatory compliance,	Weak. Interactions were predominantly hierarchical and compliance-oriented,

Bodies (HCB), Islamic Da'wah Council of the Philippines (IDCP), and other national regulatory agencies: Served as regulators, accreditation authorities, and policy enablers by establishing halal governance frameworks under Republic Act No. 10817, developing certification standards, ensuring regulatory compliance, and	universities or research institutions in research, technology development, knowledge transfer, or capacity-building activities within the operational halal certification and export system.	private-sector stakeholders: Participated by producing halal-certified products and services, complying with accreditation standards, coordinating supply chains, supporting market development, and expanding domestic and international halal trade.	halal-certified products and services, contributing to market adoption, and reinforcing the social and cultural relevance of halal certification within the broader community.	industry actors through structured certification, accreditation, and compliance mechanisms. However, the absence of university participation limited knowledge-generation functions and constrained the development of a fully integrated Quadruple Helix innovation ecosystem.	quality assurance, and export facilitation across the halal value chain. Nevertheless, the system primarily functioned as a regulatory and commercial ecosystem, with limited evidence of collaborative research, technology development, or multisectoral innovation.	with government agencies establishing regulatory standards and industry actors implementing certification requirements. Community participation was largely demand-driven, while reciprocal knowledge exchange, co-creation, and sustained collaboration among the institutional spheres remained limited.

		supporting the institutionalization of the Philippine halal industry.						
11 (SID-b590)	Conditionally Included	Local Government Unit (LGU) of Valencia City, Local Government Leadership (LGULEAD), Government Agencies (GOVAG), and National Legislature (NATLEG): Served as policy makers, regulators, governance coordinators, and system implementers by establishing the legal	None explicitly identified. The study did not document the active participation of universities or research institutions in the design, implementation, governance, evaluation, or continuous improvement of the e-government system.	Businesses and ICT service providers: Participated by utilizing digital government services, supporting business transactions, and providing the technological infrastructure necessary for electronic service delivery. However, their involvement was primarily operational	Citizens and government employees: Participated as primary users and beneficiaries of the e-government system by accessing digital public services, engaging in electronic transactions, and supporting the implementation of ICT-enabled governance within the local	Moderate. Institutional roles were clearly established between government agencies, industry stakeholders, and community users through a structured digital governance framework. However, the absence of university participation limited knowledge-generation	Moderate. Collaboration strengthened digital public service delivery, administrative efficiency, inter-agency coordination, and ICT-enabled governance across multiple service domains. Nevertheless, the system primarily supported operational improvements in public administratio	Weak. Interactions were predominantly hierarchical and transactional, with government agencies directing service delivery, industry providing technological support, and citizens and government employees functioning primarily as service users.

framework, overseeing digital governance, coordinating inter-agency operations, and managing the delivery of electronic government (e-government) services across Government-to-Citizen (G2C), Government-to-Business (G2B), Government-to-Employee (G2E), and Government-to-Government (G2G) platforms.	rather than collaborative in innovation development.	government environment.	and research functions, resulting in a government-centered digital governance system rather than a fully integrated Quadruple Helix innovation ecosystem.	n, with limited evidence of collaborative research, technology co-development, or multisectoral innovation.	Collaboratio n was characterize d by one-way service provision rather than sustained knowledge exchange, co-creation, or long-term multisectoral partnerships.

Note: The 20 analytical cases from the 2013–2018 period and the 11 analytical cases from the 2020–2025 period were systematically selected based on the predefined inclusion criteria described in Chapter III. Within this dataset, Cases 1–4 (2013–2018) and Cases

1–5 (2020–2025) are classified as fully included because they document well-defined multisectoral interactions involving government, universities, industry, and, where applicable, community actors that collectively demonstrate integrated innovation processes consistent with the Triple Helix Innovation Model (THIM) and emerging Quadruple Helix configurations. In contrast, Cases 5–20 (2013–2018) and Cases 6–11 (2020–2025) are classified as conditionally included because they document only partial engagement of one or more helix actors or focus primarily on contextual, organizational, or process-oriented aspects of innovation, thereby providing complementary evidence for interpreting the Philippine innovation ecosystem rather than representing fully integrated innovation configurations. Across all analytical cases, the Structural, Functional, and Relational dimensions of multisectoral interaction were assessed qualitatively and classified as Strong, Moderate, or Weak based on the degree of institutional integration, collaborative functionality, and sustainability of actor relationships documented in the literature. A Strong classification indicates clearly defined and complementary roles among government, university, industry, and community actors, supported by formal governance mechanisms, institutionalized partnerships, adequate resources and infrastructure, sustained knowledge exchange, and demonstrable innovation, commercialization, or societal outcomes extending beyond short-term project implementation. A Moderate classification reflects meaningful collaboration with observable outputs and functional coordination but with limitations in actor integration, continuity, institutionalization, or long-term sustainability, often characterized by project-based initiatives, university-led extension activities, or limited participation of one or more helix actors. A Weak classification denotes fragmented, hierarchical, or predominantly transactional relationships characterized by limited coordination, minimal knowledge co-production, weak institutional integration, and little evidence of sustained multisectoral collaboration or broader innovation ecosystem development.

A. ANALYTICAL CASE STUDIES (2013–2018)

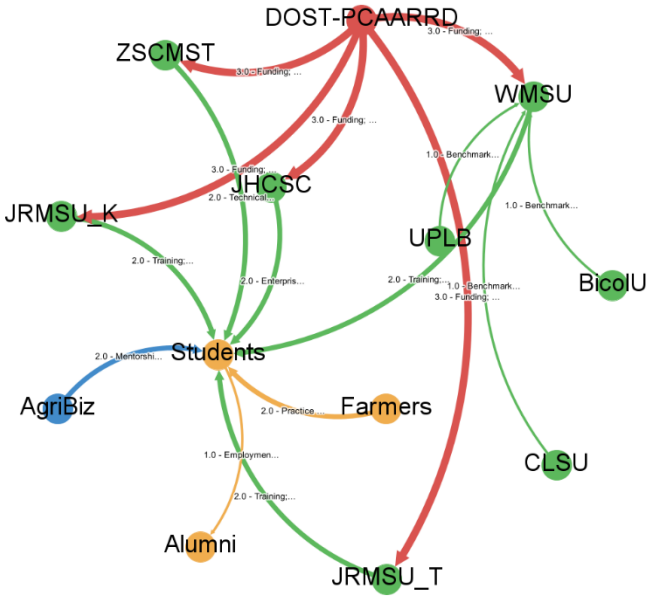
1. Studies that Fully Satisfied the Inclusion Criteria (2013–2018)

Case Study 1 (SID-a90): Enhancing AFNR Education and Regional Employability through Multisectoral Collaboration in the Zamboanga Peninsula

This analytical case examined a coordinated innovation initiative that strengthened multisectoral collaboration among government, universities, industry, and community actors within the agriculture, fisheries, and natural resources (AFNR) sector in the Zamboanga Peninsula (ZAMPEN) (Saavedra, 2018). Implemented across five State Universities and Colleges (SUCs); Western Mindanao State University (WMSU), Jose Rizal Memorial State University (JRMSU) Tampilisan and Katipunan campuses, Josefina H. Cerilles State College (JHCSC) Dumingag campus, and Zamboanga State College of Marine Sciences and Technology (ZSCMST), the initiative sought to strengthen technical education, entrepreneurship, and regional employability through coordinated institutional collaboration.

Consistent with the analytical framework adopted in this study, the case is interpreted using the structural, functional, and relational dimensions of the Quadruple Helix Framework. While the institutional collaboration reflects the core relationships described by the Triple Helix Innovation Model, the active participation of local farmers, cooperatives, alumni, and community stakeholders demonstrates the broader participation of the fourth helix within the Philippine innovation ecosystem. Figure 4.1 presents the documented network of interactions among participating actors.

Figure 4.1 Case Study 1 (SID-a90): Network visualization of actor interactions in the Philippine Agri-innovation system.



Note: Nodes represent Government, University, Industry, and Community actors involved in STI coordination, education, enterprise development, and field implementation. Directed edges indicate reported relationships including funding, policy oversight, training, mentorship, enterprise-based learning, benchmarking, practice hosting, and outcome feedback. Edge weights range from 1 to 3, where 3 denotes strategic funding, policy alignment, and system coordination (DOST-PCAARRD); 2 denotes operational collaboration such as curriculum enrichment, faculty training, mentorship, and enterprise facilitation led by universities; and 1 denotes benchmarking, exposure visits, and feedback-oriented linkages. Directionality reflects flows of resources and knowledge from Government to Universities and onward to Industry and Community actors, with reciprocal feedback from practice partners and end-users. DOST-PCAARRD functions as the central coordinator providing funding, infrastructure, equipment, and STI policy alignment. Universities serve as implementers and knowledge intermediaries through curriculum enrichment, faculty training, and enterprise-based learning. Industry and community actors provide mentorship, market feedback, and applied learning contexts. Students act as key linking actors, connecting universities, industry partners (AgriBiz), farmers, and alumni networks to support skills development and employment outcomes. Benchmarking institutions (UPLB, CLSU, Bicol University) provide supplementary exposure and comparative learning. Overall, the network reflects a coordinated government-led collaboration model supporting innovation, entrepreneurship, and applied learning across actors.

Government Actors

Government agencies served as strategic funders, policy enablers, and system coordinators throughout the initiative. The Department of Science and Technology–Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (DOST–PCAARRD) provided financial support, strategic oversight, and alignment with national Science, Technology, and Innovation (STI) priorities. A total project investment of ₱9,804,126 supported laboratory upgrading, procurement of specialized equipment, faculty and student training, enterprise development activities, and institutional capacity enhancement across the participating SUCs. Beyond funding, government agencies established an enabling policy environment that strengthened knowledge transfer, entrepreneurship, and regional innovation capacity.

University Actors

The participating universities functioned as knowledge producers, innovation intermediaries, and project implementers. Their responsibilities extended beyond conventional instruction to include curriculum enhancement, faculty development, technology transfer, entrepreneurship education, and experiential learning. Nine technical and entrepreneurial modules covering tissue culture, coco-sap sugar processing, rubber nursery management, seaweed production, feasibility studies, marketing, and accounting were integrated into AFNR programs. Faculty capacity was strengthened through Training of Trainers (TOT) programs involving 74 faculty members, enabling the effective delivery of both technical and entrepreneurial competencies. Universities also facilitated enterprise-based learning through income-generating projects, mentoring activities, benchmarking visits to leading higher

education institutions, and collaboration with local stakeholders, reinforcing their role as knowledge hubs within the regional innovation ecosystem.

Industry Actors

Industry actors participated primarily as enterprise partners, practice hosts, and market collaborators. Local agribusinesses provided practical training environments, technical mentoring, production sites, and market-oriented guidance that enabled students to apply classroom knowledge in real production settings. Industry participation strengthened university-industry linkages by supporting enterprise incubation, providing commercial feedback, and exposing students to production planning, marketing strategies, and agribusiness management practices. These interactions enhanced the practical relevance of the curricular innovations while facilitating the translation of knowledge into entrepreneurial activities.

Community Actors

Community actors, including farmers, cooperatives, alumni, and local stakeholders, participated as innovation adopters, collaborators, and beneficiaries. Farmers and community organizations provided field-based learning environments where students applied technical and entrepreneurial knowledge to locally relevant production systems. Community participation also facilitated knowledge exchange, contextual validation of innovations, and continuous feedback that strengthened the responsiveness of enterprise activities to local needs. Alumni engagement further supported graduate entrepreneurship and contributed to sustaining innovation-oriented practices beyond project implementation. These interactions illustrate the growing contribution of community actors to the Philippine innovation ecosystem.

Outcomes and Impacts

The initiative generated substantial institutional, educational, and innovation-related outcomes.

- Curriculum and Human Capital Development: Ten AFNR academic programs incorporated enhanced technical and entrepreneurial modules; additional short-term technical courses improved graduate employability; seventy-four faculty members completed specialized Training of Trainers programs; more than 1,200 students and alumni participated in technical and entrepreneurship training.
- Infrastructure and Institutional Capacity: Laboratories, training facilities, rubber nurseries, and seaweed production facilities were upgraded, while more than twenty specialized equipment units strengthened practical instruction and research capability.
- Employability and Entrepreneurship: A tracer study involving 111 graduates demonstrated measurable outcomes: 42% obtained employment; 10% established self-employment through agriculture-related enterprises; and 32% of unemployed graduates pursued entrepreneurial ventures. Collectively, these outcomes demonstrate improvements in human capital development, entrepreneurial capacity, and regional innovation performance.

Challenges and Sustainability Strategies

The initiative encountered several implementation challenges, including differences in faculty expertise, uneven laboratory readiness among participating campuses, coordination difficulties across institutions, limited financial resources for

enterprise activities, and mismatches between technical training and regional labor market requirements.

To strengthen long-term sustainability, the participating institutions implemented several strategies: continuous faculty development through recurring Training of Trainers programs; structured enterprise-based learning and mentoring activities; upgrading of laboratories, production facilities, and specialized equipment; alumni mentoring to support graduate entrepreneurship; sustained collaboration with local agribusinesses, cooperatives, and community stakeholders; and periodic curriculum refinement to maintain alignment with regional labor market needs. These interventions strengthened institutional capacity while supporting the continuity of innovation activities beyond the project's formal duration.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: This case demonstrates a strong structural configuration characterized by clearly defined and complementary institutional roles among government, universities, industry, and community actors. Formal funding mechanisms, coordinated governance, infrastructure investments, and institutional partnerships establish a well-organized innovation ecosystem that facilitated multisectoral collaboration.
- Functional Dimension: Functionally, the initiative integrates curriculum enhancement, faculty development, entrepreneurship education, enterprise incubation, and community engagement into a coherent innovation pathway. Government agencies supply strategic resources and policy direction, universities generate and transfer knowledge, industry provides commercialization and mentoring opportunities, while community actors

facilitate knowledge application and innovation adoption. These coordinated functions contributed directly to employability, entrepreneurship, and regional innovation.

- Relational Dimension: The relational dimension is likewise strong, reflecting sustained collaboration through mentoring, enterprise-based learning, networking, benchmarking, and continuous engagement among all participating actors. Trust, reciprocal learning, and long-term partnerships extend beyond the project's implementation period, strengthening institutional relationships and supporting ongoing innovation activities.

Case Summary

Overall, Case Study 1 represents a strong Quadruple Helix innovation configuration, demonstrating highly institutionalized collaboration among government, universities, industry, and community actors. Coordinated investments in education, infrastructure, entrepreneurship, and stakeholder engagement generate measurable improvements in employability, enterprise development, and regional innovation capacity. The case illustrates how sustained multisectoral collaboration can strengthen the Philippine innovation ecosystem by integrating policy support, knowledge production, market engagement, and community participation into a coherent and sustainable innovation system.

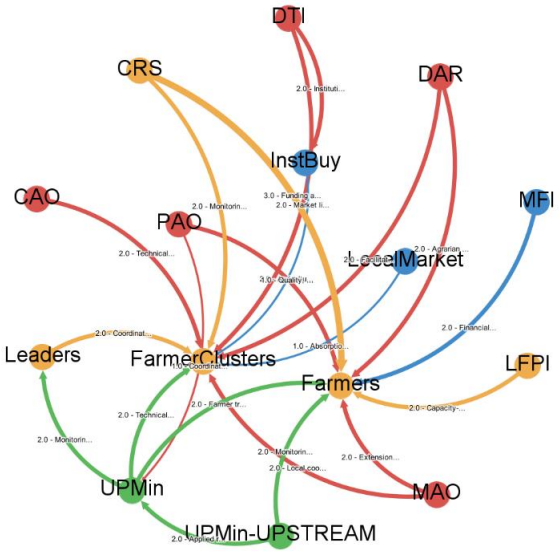
Case Study 2 (SID-a133): Strengthening Smallholder Vegetable Production Systems and Market Linkages through Multisectoral Collaboration in the Southern Philippines

This analytical case examined the implementation of a cluster-based collaborative marketing strategy designed to strengthen smallholder vegetable

production systems in the Southern Philippines (Real et al., 2013). The initiative was implemented across Bukidnon, Davao City, and South Cotabato, involving 353 farmers organized into 29 production clusters. Through coordinated participation among government agencies, universities, development organizations, industry partners, and farming communities, the intervention sought to improve agricultural productivity, organizational capacity, and market access for smallholder farmers.

Consistent with the analytical framework adopted in this study, the case was interpreted using the structural, functional, and relational dimensions of the Quadruple Helix Framework. While government and universities provided institutional and technical support, the participation of farmers, development organizations, institutional buyers, and local markets demonstrates the broader contribution of community actors within the Philippine innovation ecosystem. Figure 4.2 presents the documented network of interactions among participating actors.

Figure 4.2. Case Study 2 (SID-a133): Network visualization of actor interactions in a cluster-based agri-development system.



Note: Nodes represent Government, University, Industry, and Community actors involved in technical support, production coordination, capacity building, and market

facilitation. Directed edges indicate reported relationships including technical assistance, training, cluster coordination, financial support, and market linkages. Edge weights range from 1 to 3, where 3 denotes primary funding and technical guidance (notably CRS and key government agencies); 2 denotes extension services, capacity building, and coordination functions delivered by government offices, UPMin-UPSTREAM, and development partners; and 1 denotes market absorption, output specification, and downstream engagement through institutional buyers and local markets. Directionality reflects flows of support toward community-based production hubs, with government and development actors providing enabling resources and universities serving as technical facilitators. Government actors (e.g., CAO, DAR, DTI, MAO, PAO) provide institutional support, coordinate cluster activities, and provide access to inputs such as seeds and infrastructure (e.g., rain shelters), as well as linkages to development partners and markets. CRS functions as a key funder and technical guidance provider. UPMin and UPSTREAM act as knowledge intermediaries, delivering farmer training, advising on crop selection, pest management, production planning, quality control, and marketing. Community actors (Farmers, Farmer Clusters, Leaders) serve as central implementers, engaging in collective production, shared resource management, and joint marketing. Industry actors, including institutional buyers, local markets, and microfinance institutions, provide market access and financial support. Overall, the network reflects a centralized, community-centered collaboration model anchored in farmer clusters and reinforced through multi-actor technical, financial, and market support, enabling sustained collective learning and productivity gains.

Government Actors

Government agencies functioned as institutional facilitators, technical enablers, and coordinators throughout the intervention. Key agencies included the Local Government Units (LGUs), Provincial Agriculture Offices (PAOs), Municipal Agriculture Offices (MAOs), City Agriculture Offices (CAOs), the Department of Trade and Industry (DTI), and the Department of Agrarian Reform (DAR) These agencies coordinated cluster formation, facilitated meetings, provided technical guidance, distributed improved seed varieties, supported the construction of rain shelters for protected cropping, and connected farmer clusters with development organizations and institutional markets. Their involvement established an enabling environment that strengthened agricultural production, collective marketing, and access to production resources.

University Actors

The University of the Philippines Mindanao (UPMin), together with UPSTREAM, served as the primary knowledge intermediary and technical facilitator. Academic staff organized farmer training programs, delivered technical assistance on crop selection, integrated pest management, crop rotation, contour farming, intercropping, production planning, quality control, and market-oriented farming practices. Researchers also introduced sustainable and low-cost production technologies, monitored field performance, and continuously advised farmer clusters on improving productivity and meeting buyer specifications. Through these activities, the universities translated scientific knowledge into practical agricultural innovations while strengthening local capacity for sustainable vegetable production.

Industry Actors

Industry participation centered on institutional buyers, local markets, and microfinance institutions. Institutional buyers provided market specifications and purchasing arrangements that guided production planning, while local markets absorbed cluster outputs and strengthened commercialization opportunities. Microfinance institutions supported production by providing financial services that improved farmers' access to operating capital. These market-oriented relationships encouraged coordinated production scheduling, improved product quality, and strengthened the commercial viability of cluster-based farming systems.

Community Actors

Community actors played a central role in implementing and sustaining the intervention. Farmer clusters, cluster leaders, and producer organizations coordinated production activities, shared resources, participated in collective decision-making, and

implemented collaborative marketing strategies. Development organizations, including the Catholic Relief Services (CRS) and the Landcare Foundation of the Philippines, Inc. (LFPI), further strengthened community capacity through technical assistance, organizational development, monitoring, and project support. Their participation facilitated trust-building, collective learning, and continuous knowledge exchange among participating farmers.

Innovation Outcomes

The intervention generated significant improvements in agricultural production, organizational capacity, and economic performance.

- Agricultural Production: Adoption of improved vegetable varieties increased productivity and reduced disease incidence; integrated pest management and non-chemical production practices reduced production costs by up to 59% while maintaining or improving yields; protected cropping systems reduced pesticide application by more than 50% while stabilizing year-round production.
- Organizational Capacity: Farmer clusters implemented communal farming, crop diversification, crop rotation, and coordinated production scheduling, improving resource utilization and strengthening organizational governance.
- Market and Economic Performance: A 2011 survey reported that 71% of participating farmers experienced increased production following cluster formation. Collective marketing, improved product quality, and economies of scale enhanced market access, strengthened relationships with institutional buyers, and increased household income.

Challenges and Sustainability Strategies

The initiative encountered several implementation challenges, including differences in farmer technical capacity, inconsistent compliance with production protocols, coordination difficulties among cluster members, climatic variability, and limited access to production inputs and financial resources.

To strengthen long-term sustainability, several complementary strategies were implemented: continuous farmer training and cluster orientation activities; standardized production protocols and quality assessment procedures; protected cropping systems to minimize climate-related risks; communal farming and crop diversification to reduce production risk; provision of improved seed varieties, revolving funds, and production inputs; and continuous technical support, farmer-to-farmer learning, and mentoring facilitated by universities and development organizations.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: This case demonstrates a strong structural configuration characterized by clearly defined and complementary roles among government agencies, universities, industry actors, and community organizations. Formal institutional support, cluster governance mechanisms, development partnerships, and coordinated resource allocation established a well-organized collaborative structure for agricultural innovation.
- Functional Dimension: The initiative likewise demonstrates a strong functional configuration through the integration of technical training, sustainable production practices, collective marketing, organizational development, and market linkage mechanisms. Government agencies facilitated institutional

support, universities generated and transferred technical knowledge, industry actors strengthened commercialization pathways, while community organizations operationalized innovations through collective farming and shared governance.

- Relational Dimension: The relational dimension is also strong, reflecting sustained interaction among farmer clusters, universities, government agencies, development organizations, and market partners. Cluster formation, collaborative marketing, communal farming, continuous mentoring, and iterative knowledge exchange fostered trust, collective learning, and long-term cooperation beyond the formal project period.

Case Summary

Overall, Case Study 2 represents a strong Quadruple Helix innovation configuration, demonstrating highly coordinated collaboration among government, universities, industry, and community actors. Through the integration of technical assistance, institutional support, community organization, and market engagement, the initiative strengthens agricultural productivity, improves market access, enhances farmer livelihoods, and promotes sustainable innovation within the Philippine vegetable production sector.

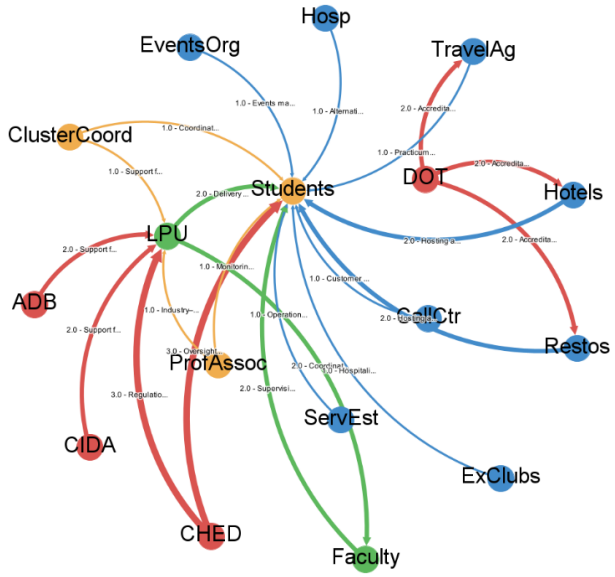
Case Study 3 (SID-a177): Strengthening Tourism and Hospitality Practicum Training through Multisectoral Collaboration in the Philippines

This analytical case examined the expectations, perceptions, and experiences of stakeholders involved in practicum training for tourism and hospitality programs in the Philippines (Aquino, 2014). The study focused on higher education institutions

(HEIs), students, government agencies, industry partners, and professional organizations, exploring how coordinated practicum arrangements strengthen experiential learning and workforce preparedness. Practicum training, commonly implemented as internships or on-the-job training, enabled students to translate classroom knowledge into workplace competencies through structured industry immersion.

Consistent with the analytical framework adopted in this study, the case was interpreted using the structural, functional, and relational dimensions of the Quadruple Helix Framework. While government agencies, universities, and industry partners constitute the core institutional actors, the participation of students, professional associations, and practicum coordinators reflects the broader contribution of community actors within the Philippine tourism and hospitality innovation ecosystem. Figure 4.3 presents the documented network of interactions among participating actors.

Figure 4.3. Case Study 3 (SID-a177): Network visualization of actor interactions in a practicum-based education and training system.



Note: Nodes represent Government, University, Industry, and Community actors involved in regulation, education delivery, practicum supervision, and skills

development. Directed edges indicate reported relationships including accreditation, regulatory oversight, training support, supervision, mentorship, industry exposure, and placement coordination. Edge weights range from 1 to 3, where 3 denotes regulatory authority and accreditation functions (CHED, DOT, and international partners such as ADB and CIDA); 2 denotes training, orientation, supervision, and skills development support provided by universities and government agencies; and 1 denotes operational placement coordination, monitoring, and practicum hosting by industry and community actors. Directionality reflects flows of regulatory standards, training support, and supervision toward central educational and practicum actors. Government actors (CHED, DOT, ADB, CIDA) provide accreditation standards, regulatory oversight, and technical guidance for practicum implementation. Universities (LPU and faculty) function as coordinators and educators, delivering pre-practicum orientation, supervising students, aligning academic preparation with industry requirements, and evaluating performance. Industry actors (e.g., travel agencies, service establishments, hotels, restaurants, call centers, and events organizations) provide experiential learning opportunities, structured mentorship, and practical workplace exposure. Community and professional groups (cluster coordinators and professional associations) support placement coordination, monitoring of practicum quality, and linkage facilitation. Students occupy central operational roles, receiving training and mentorship across university and industry settings. Overall, the network reflects a centralized, student-centered practicum system integrating regulatory oversight, academic coordination, and industry-based experiential learning to support skill development and employability.

Government Actors

Government agencies served as regulators, policy enablers, and quality assurance providers. The Commission on Higher Education (CHED) established minimum standards for practicum implementation through Commission on Higher Education Memorandum Orders (CMOs), defining practicum duration, training requirements, and institutional agreements with host establishments. The Department of Tourism (DOT) complemented these functions by providing accreditation, technical guidance, and monitoring to ensure compliance with national tourism standards. International development partners, including the Asian Development Bank (ADB) and the Canadian International Development Agency (CIDA), further supported workforce development initiatives aimed at strengthening tourism competencies and reducing

skills mismatches. Together, these organizations created the regulatory and institutional environment necessary for effective practicum implementation.

University Actors

Higher education institutions, represented primarily by the Lyceum of the Philippines University (LPU), functioned as knowledge providers, practicum coordinators, and academic supervisors. Universities prepared students through pre-practicum seminars covering workplace expectations, professional ethics, communication skills, résumé preparation, and mock interviews. Faculty members coordinated practicum placements, monitored student progress through site visits, evaluated student performance, and maintained communication with industry supervisors. Universities also explored alternative practicum arrangements, including school-based facilities and international internship programs, to address placement limitations while strengthening experiential learning opportunities.

Industry Actors

Industry actors, including hotels, restaurants, travel agencies, event organizations, call centers, and other hospitality establishments, served as practicum hosts and workplace mentors. These organizations provided structured experiential learning environments where students developed technical competencies, customer service skills, and professional work ethics under the supervision of experienced practitioners. Industry partners also supported student learning by providing uniforms, meals, transportation allowances, structured training plans, workplace supervision, and performance feedback. Their participation ensured that academic preparation remained aligned with current industry practices and workforce requirements.

Community Actors

Community actors included students, practicum coordinators, and professional associations involved in tourism and hospitality education. Students functioned as the primary beneficiaries and active participants in experiential learning, applying academic knowledge within real workplace settings. Professional associations and practicum coordinators supported placement coordination, monitored training quality, facilitated communication among stakeholders, and promoted continuous improvement of practicum programs. Their involvement strengthened institutional collaboration while supporting the quality and sustainability of experiential learning.

Innovation Outcomes

The practicum initiative generated important outcomes in workforce preparation, stakeholder coordination, and educational quality.

- Curriculum and Workforce Development: Standardized practicum requirements strengthened alignment between academic programs and industry expectations; pre-practicum orientation programs improved student preparedness, workplace awareness, and professional competencies; faculty supervision enhanced monitoring, assessment, and continuous improvement of student performance.
- Expansion of Experiential Learning: Universities diversified practicum opportunities by expanding placements beyond traditional hotels and restaurants to include hospitals, call centers, event organizations, and international internship programs.
- Institutional Coordination: Improved collaboration among government agencies, universities, industry partners, and professional organizations

strengthened practicum quality, regulatory compliance, and graduate employability.

Challenges and Sustainability Strategies

Several implementation challenges were identified, including limited industry placement capacity, increasing student demand, variability in training quality and duration, financial and logistical constraints, and extensive faculty supervision responsibilities.

To strengthen long-term sustainability, participating institutions implemented several complementary strategies: comprehensive pre-practicum orientation and student preparation programs; expansion of practicum placements through non-traditional and international training sites; standardization of practicum hours, training requirements, and supervision procedures; strengthened collaboration with industry partners to provide student support services and structured mentoring; and assignment of dedicated faculty coordinators to improve monitoring, evaluation, and stakeholder communication. These strategies enhanced institutional coordination while improving the consistency and quality of experiential learning.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: This case demonstrates a strong structural configuration characterized by clearly defined institutional roles among government agencies, universities, industry partners, and community actors. Government agencies established regulatory standards, universities coordinated academic preparation, industry organizations delivered workplace training, and professional associations supported placement coordination and quality assurance.

- Functional Dimension: The initiative also demonstrates a strong functional configuration through the integration of academic instruction, industry-based experiential learning, regulatory oversight, and professional development. Universities translate theoretical knowledge into workplace competencies, government agencies ensure regulatory compliance, industry partners provide practical training, and community actors facilitate continuous coordination and program improvement.
- Relational Dimension: The relational dimension is strong, reflecting sustained collaboration through pre-practicum orientation, faculty supervision, workplace mentoring, continuous feedback, and institutional coordination. These interactions foster trust, reciprocal learning, and long-term partnerships among educational institutions, government agencies, industry organizations, and professional networks, thereby strengthening the overall practicum ecosystem.

Case Summary

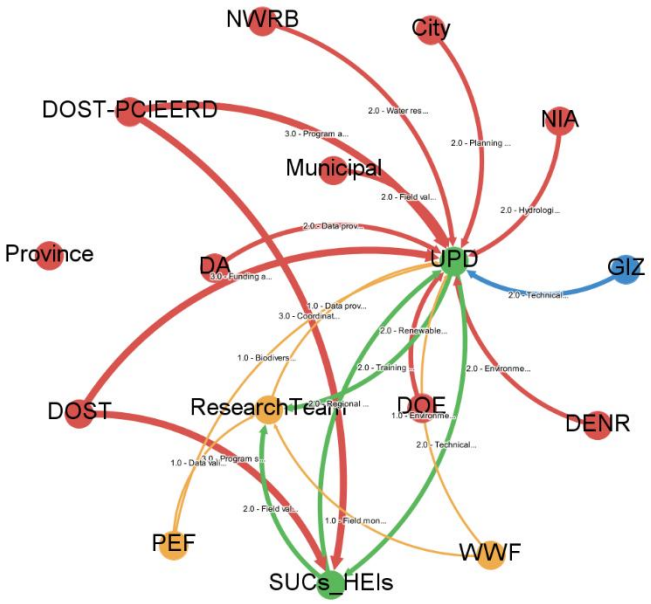
Overall, Case Study 3 represents a strong Quadruple Helix innovation configuration, demonstrating highly institutionalized collaboration among government, universities, industry, and community actors in tourism and hospitality education. Through coordinated regulation, academic preparation, workplace mentoring, and professional engagement, the practicum system strengthened workforce readiness and enhanced graduate employability. It improves the quality of experiential learning within the Philippine tourism and hospitality sector.

Case Study 4 (SID-a180): Strengthening National Resource Mapping through Multisectoral Collaboration Using LiDAR Technologies in the Philippines

This analytical case examined the Phil-LiDAR 2 Program, a nationwide initiative that utilized Light Detection and Ranging (LiDAR) and other remote sensing technologies, to develop high-resolution resource maps for agriculture, forestry, coastal resources, hydrology, and renewable energy in the Philippines (Blanco et al., 2016). Implemented over three years, the program involved 15 universities and higher education institutions (HEIs) distributed across Luzon, Visayas, and Mindanao, working in partnership with national government agencies, local government units (LGUs), non-government organizations (NGOs), and development partners.

Consistent with the analytical framework adopted in this study, the case was interpreted using the structural, functional, and relational dimensions of the Quadruple Helix Framework. While government agencies and universities provided institutional leadership and technical expertise, the participation of LGUs, NGOs, development organizations, and local stakeholders illustrated the broader contribution of community actors in strengthening geospatial innovation and evidence-based governance. Figure 4.4 presents the documented network of interactions among participating actors.

Figure 4.4. Case Study 4 (SID-a180): Network visualization of actor interactions in a LiDAR-based geospatial mapping and governance system.



Note: Nodes represent Government, University, Industry, and Community actors engaged in funding, data production, technical implementation, validation, and decision-support integration. Directed edges indicate reported relationships including funding, program oversight, data provision, workflow implementation, training, field validation, monitoring, and sectoral collaboration. Edge weights range from 1 to 3, where 3 denotes primary funding, administrative oversight, and coordination authority (e.g., DOST-PCIEERD and related government agencies); 2 denotes technical implementation, training, LiDAR/GIS processing, and collaborative mapping conducted by universities; and 1 denotes supplementary validation, monitoring, and feedback contributions from community and partner organizations. Directionality reflects flows of funding, technical expertise, and data governance from government toward university-led implementation and onward to validation and application by community and sectoral actors. Government agencies (e.g., DA, DENR, DOE, NIA, NWRB, and provincial offices) provide funding, program administration, logistical support, and data validation for national and local planning integration. DOST and DOST-PCIEERD function as central coordinating bodies for geospatial innovation programs. Universities (UPD and SUCs/HEIs) act as primary knowledge producers and technical implementers, responsible for LiDAR/GIS processing, workflow development, staff training, field validation, and workshop facilitation. Industry and development partners (e.g., GIZ) provide technical support and monitoring frameworks. Community actors (e.g., LGUs, NGOs such as PEF and WWF, and research collaborators) serve as end-users and validators, contributing environmental monitoring, feedback, and adoption of geospatial outputs. Overall, the network reflects a centralized, government- and university-led geospatial innovation system supported by multi-actor collaboration that enables data-driven governance, capacity building, and sustained knowledge transfer.

<u>Government Actors</u>

Government agencies served as strategic funders, policy enablers, and program coordinators. The Department of Science and Technology (DOST), through the Philippine Council for Industry, Energy and Emerging Technology Research and Development (PCIEERD), provided overall program funding, administrative oversight, and strategic direction. Several national government agencies, including the Department of Agriculture (DA), Department of Environment and Natural Resources (DENR), Department of Energy (DOE), National Irrigation Administration (NIA), and National Water Resources Board (NWRB), supported the initiative by providing datasets, validating mapping outputs, and integrating generated resource maps into national and local planning processes. Local Government Units (LGUs) further facilitated field implementation and promoted the utilization of geospatial outputs for evidence-based planning and resource management.

University Actors

The University of the Philippines Diliman (UPD) served as the lead implementing institution and principal knowledge producer. UPD developed standardized workflows, technical protocols, and operational procedures for LiDAR processing, Geographic Information Systems (GIS), and remote sensing applications, which were subsequently transferred to participating State Universities and Colleges (SUCs) and HEIs. University teams conducted field validation, processed spatial datasets, generated resource maps, and implemented technical training, workshops, and mentoring activities to strengthen institutional capacity in geospatial technologies. These activities established a nationwide network of researchers and technical specialists capable of sustaining future geospatial innovation initiatives.

Industry Actors

Industry participation was primarily represented by development organizations and technical partners that provided specialized expertise and implementation support. Organizations such as the German Agency for International Cooperation (GIZ) contributed technical assistance, while other collaborating institutions supported monitoring activities and the application of geospatial technologies across multiple resource sectors. Although private-sector commercialization was limited, these organizations strengthened technical implementation and facilitated broader adoption of geospatial innovations.

Community Actors

Community actors included Local Government Units (LGUs), non-government organizations (NGOs), environmental organizations such as the World Wide Fund for Nature (WWF) and the Philippine Eagle Foundation (PEF), and local stakeholders involved in field validation and environmental planning. These actors participated in orientation programs, technical training, data validation, environmental monitoring, and the application of generated resource maps for local planning and resource management. Their involvement strengthened the practical relevance of the program while facilitating knowledge exchange between technical experts and end users.

Innovation Outcomes

The Phil-LiDAR 2 Program generated substantial advances in geospatial innovation, institutional collaboration, and human-capital development.

- Geospatial Innovation: Standardized workflows for agricultural, coastal, forest, hydrological, and renewable energy resource mapping were successfully developed; the program produced 107 agricultural resource maps, 34 coastal

resource maps, six forest assessment maps, 41 watershed hydrologic datasets, and three provincial hydropower assessments.

- Human Capital Development: A total of 769 researchers and project personnel received specialized training in LiDAR processing, GIS, and remote sensing, significantly strengthening national expertise in geospatial technologies.
- Research and Technological Development: The initiative generated numerous conference presentations and scientific publications while developing mobile applications for field data collection and geospatial analysis, improving the accessibility and operational use of spatial information.
- Institutional Collaboration: Strong partnerships among universities, government agencies, LGUs, NGOs, and development organizations facilitated technical coordination, quality assurance, and the widespread dissemination of geospatial products for environmental planning and resource management.

Challenges and Sustainability Strategies

Several implementation challenges were identified, including rapid personnel recruitment and training, variations in LiDAR data quality, demanding project timelines, and the need to institutionalize geospatial expertise beyond the project period.

To strengthen long-term sustainability, participating institutions implemented several complementary strategies: continuous technical training and capacity-building programs; sustained collaboration with LGUs and national government agencies to support updating and utilization of resource maps; expansion of research into crop suitability assessment, vulnerability mapping, and GIS-based decision-support systems; and establishment of university-based geoinformatics centers to support research, instruction, extension services, and long-term technical capability. These

initiatives strengthened institutional capacity while promoting the continued application of geospatial technologies in environmental governance and resource management.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: This case demonstrates a strong structural configuration characterized by clearly defined and complementary roles among government agencies, universities, industry partners, and community organizations. Formal funding mechanisms, nationwide institutional coordination, standardized workflows, and multi-level governance establish a robust organizational structure for geospatial innovation.
- Functional Dimension: The initiative likewise demonstrates a strong functional configuration through the integration of advanced geospatial technologies, technical training, collaborative mapping, environmental monitoring, and evidence-based planning. Government agencies provide policy support and funding, universities generate technical knowledge, industry partners contribute specialized expertise, and community actors validate and apply the resulting geospatial information.
- Relational Dimension: The relational dimension is strong, reflecting sustained collaboration through technical workshops, mentoring activities, field validation, data sharing, and continuous stakeholder engagement. Long-term partnerships among universities, government agencies, LGUs, NGOs, and development organizations strengthened trust, knowledge exchange, and institutional learning, supporting the sustainability of the national geospatial innovation system.

Case Summary

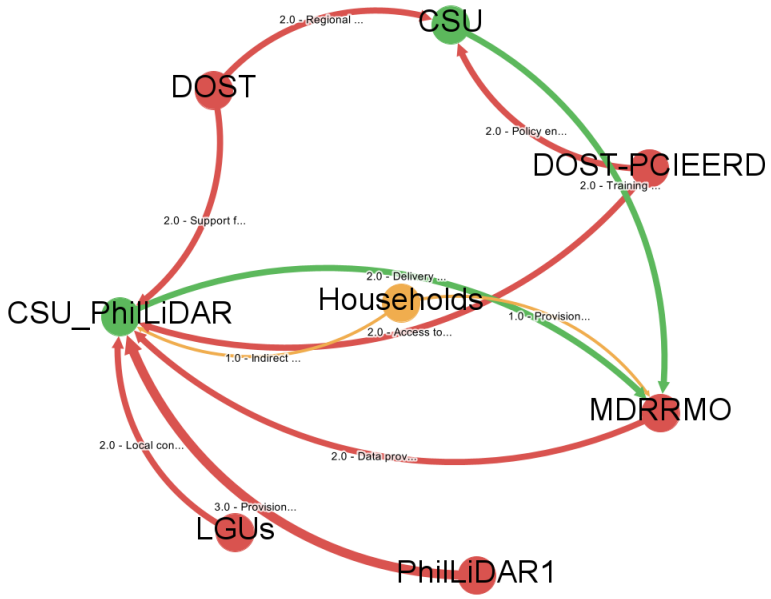
Overall, Case Study 4 represents a strong Quadruple Helix innovation configuration, demonstrating highly institutionalized collaboration among government, universities, industry, and community actors. Through coordinated investments in geospatial technologies, technical capacity development, and multisectoral partnerships, the Phil-LiDAR 2 Program strengthened evidence-based governance, environmental planning, and national resource management while establishing a sustainable foundation for future geospatial innovation in the Philippines.

2. Studies that conditionally satisfied the inclusion criteria (2013-2018)

Case Study 5 (SID-a12): Strengthening Local Flood Disaster Management through Government–University Collaboration in the Philippines.

This analytical case examined the collaboration between the Caraga State University (CSU) Phil-LiDAR 1 Project and the Municipality of Jabonga, Agusan del Norte, in developing a LiDAR-based flood hazard assessment and decision-support system for local disaster risk reduction and management (Makinano-Santillan et al., 2016). The initiative integrated high-resolution geospatial datasets, hydrological models, and a web-based application (Flood EViDEns) to support near-real-time flood visualization and damage estimation. The case demonstrated a functional partnership between government and academia in applying geospatial technologies to strengthen municipal disaster preparedness. However, it was conditionally included because the study primarily focuses on technological implementation rather than broader Triple Helix dynamics. Industry participation, community co-production, and evidence of wider innovation diffusion remain limited. Figure 4.5 presents the documented network of interactions among participating actors.

Figure 4.5. Case Study 5 (SID-a12): Network visualization of actor interactions in a LiDAR-enabled local disaster risk reduction system.



Note: Nodes represent Government, University, and Community actors involved in data provision, geospatial analysis, system development, and local disaster preparedness. Directed edges indicate reported relationships including access to LiDAR datasets, program facilitation, technical training, system implementation, hazard mapping, and socio-economic data provision. Edge weights range from 1 to 3, where 3 denotes provision of national LiDAR datasets and core enabling infrastructure (e.g., DOST, DOST-PCIEERD, Phil-LiDAR programs); 2 denotes program support, coordination, training, and operational implementation; and 1 denotes indirect data provision and beneficiary engagement from households and local stakeholders. Directionality reflects flows of data access, technical support, and program facilitation from national government toward university implementers and local government units. Government actors (DOST, DOST-PCIEERD, Phil-LiDAR1, and MDRRMO) provide LiDAR data access, program facilitation, local coordination, and operational guidance for disaster risk reduction activities. The university (CSU and CSU_PhilLiDAR) serves as the primary knowledge producer and technical implementer, responsible for generating digital terrain and surface models, producing flood hazard maps, developing the Flood EViDEns decision-support tool, and conducting training for MDRRMO personnel. Local government units (including MDRRMO) act as operational partners, receiving training, datasets, and hazard outputs for local disaster preparedness and response. Community actors (households) provide socio-economic data and function as indirect beneficiaries of hazard mapping outputs. Overall, the network reflects a centralized, university-led disaster risk management system supported by national government data infrastructure and local government implementation, with limited but targeted community data integration focused on decision-support outputs.

Government Actors

Government agencies functioned primarily as operational partners and enabling institutions. The Municipal Disaster Risk Reduction and Management Office (MDRRMO) of Jabonga provided local datasets, operational coordination, and technical guidance necessary for hazard mapping and system implementation. The Department of Science and Technology (DOST), through the Caraga Regional Office and the Phil-LiDAR Program, facilitated the collaboration by providing access to national LiDAR datasets, technical support, and capacity-building activities. Government agencies also integrated the resulting hazard maps into municipal disaster risk reduction and management planning.

University Actors

Caraga State University (CSU), through the Phil-LiDAR 1 Project, served as the principal knowledge producer and technical implementer. The university generated Digital Terrain Models (DTMs), Digital Surface Models (DSMs), hydrological simulations, and calibrated flood hazard maps for the Mainit–Tubay River Basin.CSU also developed Flood EViDEns, a web-based decision-support platform integrating LiDAR data, hydrological modeling, socio-economic datasets, and flood simulations to support early warning, evacuation planning, and post-disaster assessment. In addition, the university conducted technical training for MDRRMO personnel to strengthen local capacity in operating and maintaining the system.

Industry Actors

Industry participation was minimal. The study did not document significant involvement of private-sector organizations in system development,

commercialization, technology transfer, or long-term operational support. Consequently, industry actors played only a limited role within the innovation process.

Community Actors

Community participation was largely indirect. Households contributed socio-economic information that supported flood vulnerability analysis, while residents served primarily as beneficiaries of the hazard maps and decision-support system. Although the project enhanced community disaster preparedness through improved access to hazard information, there was little evidence of active community involvement in system design, validation, or collaborative decision-making.

Innovation Outcomes

The project generated several important technical and institutional outputs.

- Geospatial Innovation: Development of high-resolution flood hazard maps identifying vulnerable barangays, infrastructure, and evacuation areas; validation of hazard maps achieved mapping accuracies of approximately 68–72%.
- Decision-Support System: Development of the Flood EViDEns web-based platform for near-real-time flood visualization, water-level estimation, and damage assessment.
- Capacity Development: Training of MDRRMO personnel in LiDAR interpretation, geospatial analysis, and operational use of the Flood EViDEns system, strengthening municipal disaster management capabilities.

Despite these achievements, the study provides limited evidence regarding wider adoption, commercialization, regional replication, or long-term policy integration beyond the municipality of Jabonga.

Challenges and Sustainability Strategies

Implementation challenges included incomplete household datasets, limited municipal ICT infrastructure, and continuing technical support requirements. Long-term sustainability also depended on maintaining updated geospatial datasets and ensuring continued institutional use of the system.

To address these challenges, the project implemented several sustainability measures: continuous technical training for MDRRMO personnel; periodic calibration of hydrological models using updated monitoring data; development of a lightweight web-based interface compatible with existing municipal ICT infrastructure; establishment of data updating and technical coordination protocols between CSU and the LGU; and integration of flood hazard maps into municipal disaster risk reduction and emergency planning.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: The case demonstrates moderate structural configuration. Government agencies and CSU maintained clearly defined collaborative roles, with DOST providing technical support and the LGU serving as the primary operational partner. However, limited participation from industry and broader community actors constrained the development of a fully integrated innovation ecosystem.
- Functional Dimension: The initiative demonstrates a moderate functional configuration through the successful integration of LiDAR technology, hydrological modeling, geospatial analysis, and local governance. These innovations strengthened municipal disaster preparedness but remained

narrowly focused on hazard mapping and decision-support rather than broader technological diffusion or innovation commercialization.

- Relational Dimension: The relational dimension is moderate, reflecting sustained collaboration between CSU and the local government through technical coordination, capacity building, and operational support. Nevertheless, weak industry engagement and limited community participation restricted broader cross-sector collaboration and knowledge co-production.

Case Summary

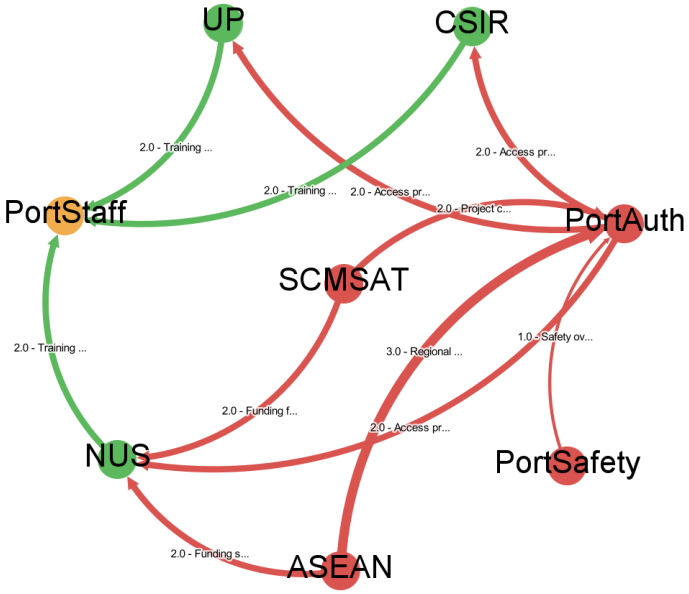
Overall, Case Study 5 illustrates how government–university collaboration can effectively apply advanced geospatial technologies to strengthen local disaster risk reduction and management. Although the initiative demonstrates strong technical implementation and institutional coordination, its limited engagement with industry and community actors constrains its representation of a fully integrated Quadruple Helix innovation system, supporting its classification as a conditionally included analytical case.

Case Study 6 (SID-a23): Coordinating Regional Marine Biofouling Monitoring through Government–University Collaboration in Southeast Asia and India

This analytical case examined the ASEAN–India Cooperation Project on the Extent of Transfer of Alien Invasive Organisms in South and Southeast Asia, which established a coordinated regional monitoring program to document marine biofouling communities across ten major ports in Southeast Asia and India (Lim et al., 2018). Standardized PVC settlement panels were deployed over a 12-month period to monitor sessile marine organisms, detect invasive species, and establish baseline

ecological data to support future port biosecurity initiatives. The case demonstrated a coordinated collaboration between government agencies and research institutions in conducting regional ecological monitoring. However, it was conditionally included because the study primarily focuses on baseline ecological assessment rather than innovation, technology development, or broader Triple Helix interactions. Industry participation was minimal, community engagement was absent, and there was limited translation of research outputs into operational policy or technological innovation. Figure 4.6 presents the documented network of interactions among participating actors.

Figure 4.6 Case Study 6 (SID-a23): Network visualization of actor interactions in a regional port biofouling monitoring system.



Note: Nodes represent Government, University, and Community actors involved in regional coordination, logistical support, field research, training, and ecological monitoring. Directed edges indicate reported relationships including access provision, regional coordination, logistical support, field deployment, training, technical supervision, and monitoring activities. Edge weights range from 1 to 3, where 3 denotes primary regional coordination and oversight (e.g., ASEAN Secretariat and port authorities); 2 denotes project facilitation, access provision, training, and field implementation; and 1 denotes regulatory authorization and operational safety oversight. Directionality reflects flows of coordination, logistical access, and research support from regional and government bodies toward university-led implementation and port-based operational actors. Government and regional actors (ASEAN Secretariat and port authorities) provide regional coordination, logistical support,

facility access, and regulatory facilitation for monitoring activities. Research institutions (National University of Singapore, CSIR-NIO India, and University of the Philippines) function as knowledge producers, designing field protocols, conducting experiments, identifying marine species, and delivering technical training and supervision. Port personnel serve as operational participants, receiving training and supporting field monitoring and data collection. Industry and broader civil society involvement is minimal, with shipping companies largely absent from the collaboration structure. Overall, the network reflects a centralized, university-centered ecological monitoring system supported by government and port authority facilitation, focused on descriptive baseline data generation and personnel capacity building rather than broader innovation or industry integration.

Government Actors

Government agencies and port authorities functioned primarily as facilitators and operational partners. The ASEAN Secretariat and the Scientific Committee on Marine Science and Technology (SCMSAT) coordinated regional implementation, while participating port authorities provided logistical support, access to monitoring sites, and regulatory authorization for field activities. Government participation focused on facilitating research implementation, coordinating access to port facilities, and ensuring compliance with operational and safety requirements. However, government involvement remained largely administrative, with limited participation in technology development, policy formulation, or long-term biosecurity governance.

University Actors

Research institutions, including the National University of Singapore, CSIR–National Institute of Oceanography (India), and the University of the Philippines, served as the primary knowledge producers and technical implementers. The universities designed standardized monitoring protocols, deployed PVC settlement panels, conducted ecological surveys, identified fouling organisms, and analyzed biofouling communities using internationally recognized assessment methods. They also documented invasive species, including *Mytilopsis sallei*, and provided technical training for participating port personnel. Despite these scientific contributions,

methodological limitations, including staggered deployment schedules, loss of monitoring panels, incomplete datasets, and inconsistent monitoring periods, reduced comparability among study sites and limited the long-term applicability of the findings.

Industry Actors

Industry participation was minimal. Shipping companies and other maritime industry stakeholders were not actively involved in project design, ecological monitoring, technology development, or decision-making processes. Consequently, opportunities for technology transfer, commercialization, and industry-led innovation remained largely unexplored.

Community Actors

Community participation was limited to operational personnel working within participating ports. Port staff received training in biofouling monitoring, species identification, and ecological data collection, supporting routine monitoring activities. Broader civil society organizations and local communities were not actively engaged in project implementation, limiting opportunities for wider stakeholder participation and collaborative environmental governance.

Innovation Outcomes

The initiative generated several important scientific and institutional outputs.

- Baseline Ecological Information: Established baseline datasets describing marine biofouling communities across ten major ports; documented the occurrence of invasive marine species, including *Mytilopsis sallei*.

- Capacity Development: Strengthened technical capacity among port personnel through training in ecological monitoring, species identification, and standardized data collection procedures.
- Regional Collaboration: Established collaborative networks among research institutions, government agencies, and port authorities that provide a foundation for future regional monitoring initiatives.

Despite these achievements, the study generated limited evidence of technological innovation, policy implementation, commercialization, or long-term operational biosecurity systems.

Challenges and Sustainability Strategies

Implementation challenges included inconsistent access to monitoring sites, loss of settlement panels due to adverse weather conditions, limited taxonomic expertise, incomplete monitoring datasets, and insufficient long-term monitoring infrastructure.

To improve sustainability, the project introduced several strategies: standardized monitoring protocols across participating ports; technical training for port personnel to strengthen ecological monitoring capacity; promotion of regional data-sharing mechanisms to improve long-term monitoring consistency; and recommendations for establishing permanent monitoring facilities and regional biosecurity databases to support future invasive species surveillance.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: The case demonstrates moderate structural configuration. Universities served as the principal knowledge producers, while government agencies and port authorities provided coordination, logistical

support, and access to monitoring facilities. However, minimal participation from industry and community actors limited the development of a more integrated innovation ecosystem.

- Functional Dimension: The initiative exhibits a moderate functional configuration through successful regional ecological monitoring, baseline data generation, and technical capacity building. Nevertheless, the collaboration remained focused on descriptive environmental monitoring, with limited evidence of technological innovation, policy implementation, or commercialization.
- Relational Dimension: The relational dimension is moderate, reflecting sustained collaboration between research institutions and government port authorities through coordinated monitoring activities, technical training, and information sharing. However, weak engagement of maritime industries and broader community stakeholders constrained long-term cross-sector collaboration and knowledge co-production.

Case Summary

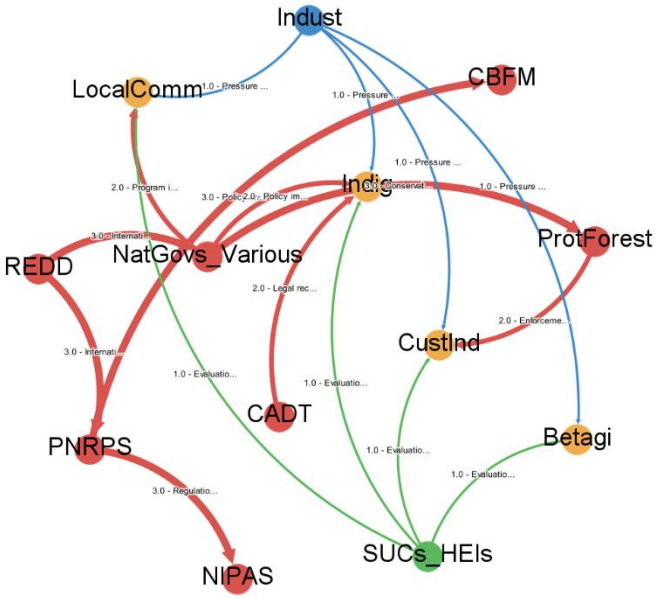
Overall, Case Study 6 demonstrates how regional government–university collaboration can strengthen marine ecological monitoring and invasive species surveillance through coordinated scientific research and capacity building. Although the initiative successfully established baseline ecological information and regional monitoring networks, limited industry participation, minimal community engagement, and the absence of broader innovation outcomes constrain its representation of a fully integrated Quadruple Helix innovation system, supporting its classification as a conditionally included analytical case.

Case Study 7 (SID-a24): Strengthening REDD+ Forest Governance through Government–Community Collaboration in South and Southeast Asia

This analytical case examined the implementation of Reducing Emissions from Deforestation and Forest Degradation (REDD+) programs across six South and Southeast Asian countries, Indonesia, the Philippines, Bangladesh, Sri Lanka, Thailand, and India, to evaluate their effectiveness in achieving carbon emissions reduction, biodiversity conservation, and poverty alleviation (Mohammed et al., 2016). The study compared 37 forest governance programs employing different institutional arrangements, ranging from centralized government management to community-based and co-managed forest systems.

The case demonstrated how government institutions and local communities collaborate in environmental governance under the REDD+ framework. However, it was conditionally included because its primary emphasis is on environmental governance and policy implementation rather than innovation-oriented Triple Helix interactions. Universities served mainly as evaluators, while industry participation remained limited. Figure 4.7 presents the documented network of interactions among participating actors.

Figure 4.7. Case Study 7 (SID-a24): Network visualization of actor interactions in a multi-level REDD+ forest governance system.



Note: Nodes represent Government, University, Community, and Industry actors engaged in policy design, regulation, implementation, evaluation, and forest management. Directed edges indicate reported relationships including international policy guidance, national coordination, legal recognition, enforcement, program implementation, evaluation, and external influence. Edge weights range from 1 to 3, where 3 denotes primary policy leadership and national program coordination (e.g., REDD+ and national government agencies); 2 denotes regulatory enforcement, legal recognition, and program implementation support; and 1 denotes evaluation, analytical assessment, or indirect influence from external or industry actors. Directionality reflects flows of governance authority and policy implementation from national and international institutions toward community-based forest management systems. Government actors at national and local levels design, regulate, and implement REDD+ and related forest conservation programs, providing legal frameworks, enforcement, and institutional support (including instruments such as NIPAS and CBFM). Community actors (indigenous groups and local communities) occupy central implementation roles through community-based forest management and customary systems. Universities (SUCs/HEIs) function primarily as evaluators and analysts, supporting carbon stock measurement, biodiversity assessment, and policy evaluation, with limited operational involvement. Industry actors are minimally involved, with occasional or indirect influence. Overall, the network reflects a centralized, state–community dominated governance model, supported by analytical input from academia, characterized by strong policy–implementation alignment but limited cross-sector innovation and industry integration.

Government Actors

Government agencies served as the principal policymakers, regulators, and program implementers across the participating countries. They established legal

frameworks, enforced forest protection policies, implemented REDD+ strategies, and coordinated conservation programs such as the Philippine National REDD+ Strategy (PNRPS), National Integrated Protected Areas System (NIPAS), and Community-Based Forest Management (CBFM). Government institutions also provided regulatory oversight, land-use planning, monitoring, and capacity-building activities. Although these interventions generated positive environmental outcomes, highly centralized governance sometimes reduced local participation and limited adaptive management, particularly where strict conservation policies restricted community access to forest resources.

University Actors

Universities and research institutions served primarily as knowledge providers and evaluators. Their contributions focused on carbon stock assessment, biodiversity monitoring, environmental analysis, and policy evaluation rather than direct implementation or innovation management. Although scientific findings informed policy development and environmental assessment, universities played only a peripheral operational role. Consequently, knowledge transfer, technology diffusion, and innovation intermediation, core functions of the Triple Helix framework, were only weakly represented.

Industry Actors

Industry participation was limited and generally indirect. Private-sector actors occasionally influenced forest governance through commercial activities and resource extraction, but they were not actively involved in collaborative innovation, technology development, or sustainable forest management initiatives. Consequently,

opportunities for industry-driven innovation and public–private collaboration remained largely absent throughout the evaluated REDD+ programs.

Community Actors

Local communities were the primary implementers of participatory forest management programs. Community-Based Forest Management (CBFM), customary forest governance systems, and agroforestry initiatives enabled communities to participate in forest restoration, biodiversity conservation, and livelihood development. Community participation generally produced stronger poverty alleviation outcomes and improved implementation feasibility by combining environmental conservation with income-generating activities. However, governance capacity, funding instability, and external economic pressures continued to constrain long-term sustainability.

Innovation Outcomes

The comparative assessment generated several important governance and sustainability outcomes.

- Environmental Management: Protected and conservation forests achieved the greatest reductions in carbon emissions; community-managed forests and agroforestry systems also contributed to carbon sequestration while supporting local livelihoods.
- Biodiversity Conservation: Biodiversity conservation was strongest in protected areas and customary forest systems with effective conservation measures.
- Livelihood Development: Community-based forest management and agroforestry programs generated the most positive socio-economic outcomes through diversified livelihood opportunities and improved household income.

Despite these achievements, the study provides limited evidence of technological innovation, commercialization, knowledge transfer, or broader innovation ecosystem development.

Challenges and Sustainability Strategies

Major implementation challenges included governance rigidity, limited institutional capacity, unstable funding, biodiversity trade-offs within production forests, and conflicts between conservation policies and traditional livelihood practices.

To strengthen long-term sustainability, several strategies were implemented: promotion of agroforestry and diversified forest management systems; introduction of economic incentives to encourage community participation; capacity-building programs to strengthen local governance; and collaborative forest management involving government agencies, communities, donor organizations, and selected private stakeholders. Although these measures improved environmental governance, the absence of systematic university-led innovation and stronger industry participation limited broader innovation system development.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: The case demonstrates moderate structural configuration. Government agencies and local communities formed the core governance structure, while universities contributed mainly through environmental assessment and policy evaluation. Industry participation remained limited, preventing the emergence of a fully integrated innovation ecosystem.
- Functional Dimension: The initiative exhibits a moderate functional configuration by successfully integrating environmental regulation, community

participation, and conservation strategies to improve forest governance. However, technological innovation, commercialization, entrepreneurship, and structured knowledge transfer remained largely absent.

- Relational Dimension: The relational dimension is moderate, reflecting sustained collaboration between government institutions and local communities through participatory forest management and livelihood programs. Nevertheless, weak engagement of universities in operational activities and limited industry participation constrained broader knowledge co-production and cross-sector innovation.

Case Summary

Overall, Case Study 7 demonstrated how government–community collaboration can strengthen forest governance, biodiversity conservation, and sustainable livelihood development under the REDD+ framework. Although the initiative illustrates effective environmental governance and participatory resource management, limited university engagement and minimal industry participation constrain its representation of a fully integrated Quadruple Helix innovation system, supporting its classification as a conditionally included analytical case.

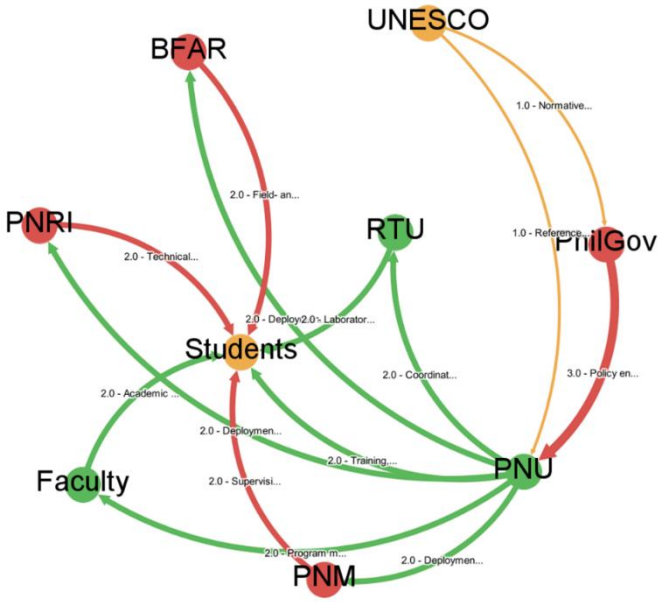
Case Study 8 (SID-a29): Strengthening Research- and Laboratory-Based Teacher Training through Government–University Collaboration in the Philippines

This analytical case examined the Bachelor of Science in Biology for Teachers (BSBT) On-the-Job Training (OJT) Program of the Philippine Normal University (PNU), which integrated research- and laboratory-based training through formal partnerships with government research institutions, including the Philippine National Museum

(PNM), Philippine Nuclear Research Institute (PNRI), Bureau of Fisheries and Aquatic Resources (BFAR), and Rizal Technological University (RTU) (Evangelista & Morales, 2015). Using the Context–Input–Process–Product (CIPP) evaluation model, the study assessed the effectiveness of the practicum program in preparing competent and work-ready pre-service biology teachers.

The case demonstrated structured collaboration between government agencies and a higher education institution in supporting professional training and human capital development. However, it was conditionally included because its primary emphasis is on educational program evaluation rather than innovation, technology transfer, or broader Triple Helix interactions. Industry participation was absent, while community engagement remained limited. Figure 4.8 presents the documented network of interactions among participating actors.

Figure 4.8. Case Study 8 (SID-a29): Network visualization of actor interactions in a government–university practicum training system.



Note: Nodes represent Government, University, and Community actors involved in policy support, laboratory access, field supervision, and OJT implementation. Directed edges indicate reported relationships including policy enabling, program deployment, coordination, laboratory and field supervision, training, practicum facilitation, and normative guidance. Edge weights range from 1 to 3, where 3 denotes primary policy

enabling and oversight (e.g., national government research agencies); 2 denotes program coordination, supervision, training, and practicum implementation led by universities and government institutions; and 1 denotes normative or reference guidance from external organizations. Directionality reflects flows of policy support, supervision, and program implementation toward central university-led training activities. Government research agencies provide laboratories, equipment, field sites, professional supervision, and policy-mandated support for training and research activities. The university (PNU) serves as the central coordinator, designing, deploying, and evaluating on-the-job training (OJT) programs that integrate theory and practice with a strong pedagogical focus. Government institutions (e.g., BFAR, PNM, PNRI, and related agencies) contribute technical supervision, laboratory access, and program support. Students occupy central operational roles as trainees within the practicum system. Community and external organizations play minimal or normative roles, with limited engagement and no substantive industry participation. Overall, the network reflects a centralized, government–university training model focused on workforce preparation and pedagogical development, with strong institutional linkages but limited cross-sector collaboration, innovation, or industry integration.

Government Actors

Government agencies served as institutional partners by providing laboratories, scientific equipment, field sites, and professional supervision for student trainees. These agencies supported the university in delivering practical research experiences that complemented classroom instruction and aligned with national teacher education objectives. Government support enabled students to access authentic research environments unavailable within the university, contributing to improved professional preparedness and stronger alignment between academic training and workplace expectations. Despite these contributions, collaboration relied primarily on operational coordination rather than formal innovation partnerships or long-term institutional governance mechanisms.

University Actors

The Philippine Normal University functioned as the central coordinator, knowledge provider, and program evaluator. It designed the OJT curriculum, coordinated student deployment, supervised implementation, and evaluated program

effectiveness using the CIPP framework. The university successfully integrated theoretical instruction with laboratory-based learning, resulting in positive student evaluations and improved perceptions of professional preparedness. However, its role remained primarily pedagogical rather than innovation-oriented, with limited involvement in collaborative research, technology transfer, or knowledge commercialization with partner institutions.

Industry Actors

Industry participation was absent. Training placements were limited to government research institutions and public laboratories, providing valuable professional experience but little exposure to private-sector innovation, research commercialization, or entrepreneurial practice. Consequently, the program did not demonstrate meaningful university–industry collaboration characteristic of mature innovation ecosystems.

Community Actors

Community engagement was limited. Students served as the principal beneficiaries of the practicum program, while external organizations contributed mainly through normative guidance and educational support rather than active participation in collaborative learning or innovation activities.

Innovation Outcomes

The program generated several positive educational and workforce development outcomes.

- Professional Development: Improved program implementation and practicum delivery across successive cohorts; increased student confidence in applying

theoretical knowledge within professional research environments; strengthened workforce preparedness and perceived employability.

- Institutional Capacity: Expanded student access to government laboratories, scientific equipment, and field-based learning environments; enhanced integration of classroom instruction with practical scientific experience.

Despite these achievements, the study provides limited evidence of innovation outputs, collaborative research, technology transfer, or broader contributions to the national innovation ecosystem.

Challenges and Sustainability Strategies

Implementation challenges included limited faculty supervision, inconsistent orientation activities, unequal trainee workloads, restricted access to specialized laboratory facilities, and the geographical dispersion of partner institutions.

To strengthen long-term sustainability, the study recommended: improving faculty supervision and monitoring systems; strengthening student orientation and practicum guidelines; expanding the diversity of placement institutions; increasing access to laboratory facilities and specialized equipment; and formalizing institutional coordination mechanisms between universities and partner agencies. These measures would improve workforce preparation while creating opportunities for more integrated institutional collaboration.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: The case demonstrates moderate structural configuration. Government agencies and the university maintained clearly defined institutional roles that supported professional training. However, the

absence of industry participation and minimal community engagement limited the development of a more comprehensive innovation ecosystem.

- Functional Dimension: The initiative exhibits a moderate functional configuration through effective integration of academic instruction and government-based laboratory training, producing positive educational and employability outcomes. Nevertheless, the collaboration remained focused on workforce preparation rather than innovation, technology transfer, or entrepreneurship.
- Relational Dimension: The relational dimension is moderate, reflecting sustained operational collaboration between the university and government research institutions through supervision, laboratory access, and practicum coordination. However, limited co-creation, weak cross-sector engagement, and the absence of industry partnerships constrained broader knowledge exchange and innovation.

Case Summary

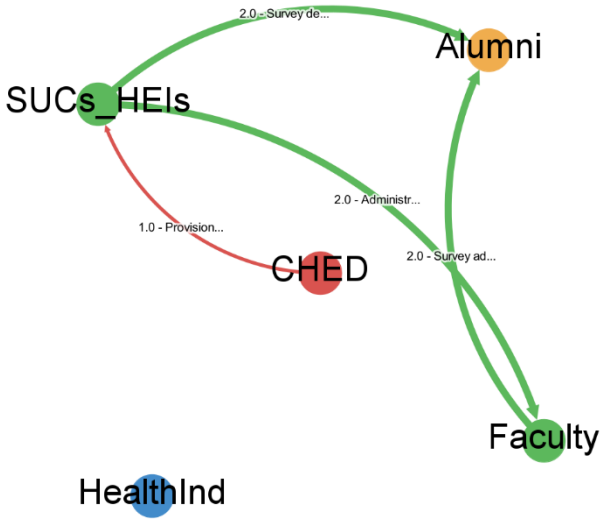
Overall, Case Study 8 demonstrates how government–university collaboration can strengthen professional teacher education through structured research- and laboratory-based practicum experiences. While the initiative effectively enhanced student competencies and workforce preparedness, limited industry participation, minimal community engagement, and the absence of innovation-oriented collaboration constrain its representation of a fully integrated Quadruple Helix innovation system, supporting its classification as a conditionally included analytical case.

Case Study 9 (SID-a33): Evaluating Nursing Education and Professional Practice Alignment through University-Led Graduate Tracer Studies in the Philippines.

This analytical case examined the relationship between nursing education and professional practice through a graduate tracer study conducted among 112 alumni of a nursing college in Manila (Gatbonton, 2018). Using the Commission on Higher Education (CHED) graduate tracer study instrument, the study evaluated graduates' perceptions of curriculum quality, instructional effectiveness, educational resources, and workplace relevance to determine how well nursing education prepared graduates for professional practice.

The case demonstrated how universities utilize graduate tracer studies to assess curriculum effectiveness and workforce preparedness. However, it was conditionally included because the study focused primarily on educational evaluation rather than innovation, technology transfer, or broader Triple Helix interactions. Government participation was limited to standardized evaluation tools, while industry and community engagement remained minimal. Figure 4.9 presents the documented network of interactions among participating actors.

Figure 4.9 Case Study 9 (SID-a33): Network visualization of actor interactions in a tracer study–based curriculum evaluation system.



Note: Nodes represent Government, University, Industry, and Community actors involved in policy support, survey implementation, data collection, and curriculum assessment. Directed edges indicate reported relationships including provision of standardized tracer study instruments, survey administration, data analysis, and feedback provision. Edge weights range from 1 to 2, where 2 denotes survey administration, data collection, and evaluation processes led by universities, and 1 denotes policy guidance and instrument provision from government agencies. Directionality reflects flows of policy instruments and evaluation feedback toward university-led assessment activities. Government (CHED) provides standardized tracer study tools and limited policy guidance, without active involvement in program design or implementation. The university (nursing college) leads the study design, survey administration, data analysis, and curriculum evaluation to identify strengths and gaps in training programs. Alumni serve as primary community respondents, providing feedback on program outcomes and employability. Industry and healthcare employers are minimally represented and not actively engaged in the tracer study process. Overall, the network reflects a university-centered evaluation system supported by standardized government instruments, with limited multi-sector engagement and a primarily internal feedback loop for curriculum improvement.

Government Actors

Government participation was limited to providing institutional guidance for educational assessment. The Commission on Higher Education (CHED) supplied the standardized graduate tracer study instrument used to evaluate alumni perceptions of curriculum quality, instructional effectiveness, and professional outcomes. Although CHED established national evaluation standards, government agencies were not actively involved in curriculum co-development, workforce planning, policy

implementation, or collaborative institutional improvement. Consequently, government participation remained supportive rather than operational.

University Actors

The nursing college served as the principal knowledge producer and evaluator. It designed and implemented the tracer study, analyzed alumni responses, and identified strengths and weaknesses within the nursing curriculum. The university demonstrated strong analytical capability through the use of validated survey instruments and statistical analyses, revealing significant positive relationships between educational experiences and graduate employability, career development, and professional competence. The findings also informed institutional improvements in curriculum delivery, instructional quality, and student support services. However, the university's role remained primarily evaluative and pedagogical, with limited evidence of collaborative research, technology transfer, or innovation partnerships with healthcare institutions.

Industry Actors

Industry participation was minimal. Hospitals, healthcare employers, and professional organizations were not directly involved in curriculum evaluation, graduate assessment, or collaborative decision-making. As a result, opportunities for curriculum co-development, workforce planning, and innovation-oriented university–industry partnerships were largely absent.

Community Actors

Alumni served as the primary community participants by providing retrospective evaluations of their educational experiences and professional development. Their feedback contributed valuable information regarding curriculum relevance,

employability, and workplace preparedness. However, alumni participation remained consultative rather than collaborative, with limited involvement in curriculum planning or institutional governance.

Innovation Outcomes

The study generated several important educational and institutional outcomes.

- Curriculum Evaluation: Graduates reported high levels of satisfaction with curriculum quality, instructional delivery, grading systems, and work-related learning experiences.
- Professional Alignment: Significant positive relationships were identified between educational experiences and employability, career development, and professional competence, indicating strong alignment between nursing education and workplace requirements.
- Institutional Improvement: The study identified opportunities to strengthen ICT infrastructure, research participation, scholarship support, extracurricular activities, and student participation in institutional governance.

Despite these contributions, the study provides limited evidence of technological innovation, knowledge transfer, collaborative research, or broader innovation ecosystem development.

Challenges and Sustainability Strategies

The study identified several institutional challenges, including limited ICT resources, inadequate research opportunities, restricted scholarship support, and inconsistent student participation in institutional decision-making.

To strengthen long-term program quality, several strategies were recommended: establishing curriculum committees with healthcare stakeholder participation; strengthening partnerships with hospitals and clinical institutions; enhancing faculty development to incorporate emerging healthcare practices; expanding practical training opportunities through additional clinical placements; and securing greater government support for educational infrastructure and curriculum improvement. These recommendations aim to strengthen curriculum responsiveness while promoting closer alignment between higher education and professional practice.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: The case demonstrates a weak structural configuration. The university functioned as the central institutional actor, supported by CHED through standardized evaluation instruments. However, limited participation from healthcare employers and community stakeholders constrained broader institutional integration.
- Functional Dimension: The initiative exhibits a moderate functional configuration by generating valuable evidence for curriculum improvement and demonstrating alignment between nursing education and professional practice. Nevertheless, the collaboration remained focused on educational evaluation rather than innovation, technology development, or knowledge commercialization.
- Relational Dimension: The relational dimension is weak, reflecting interactions primarily between the university and its alumni through the tracer study process. Limited engagement with government agencies, healthcare employers, and professional organizations restricted sustained cross-sector collaboration and knowledge exchange.

Case Summary

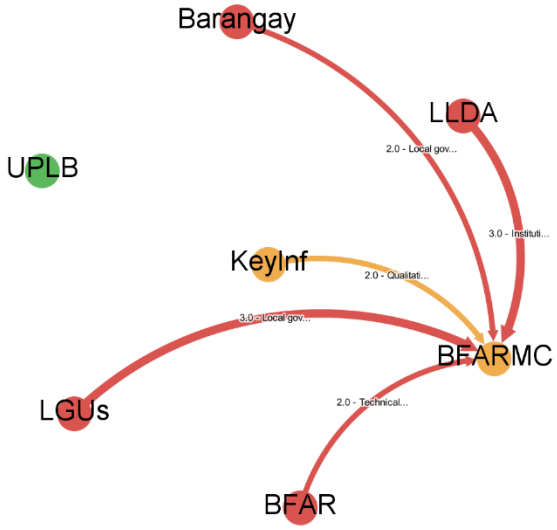
Overall, Case Study 9 demonstrates how university-led graduate tracer studies can support curriculum evaluation and strengthen alignment between nursing education and professional practice. Although the study provides important evidence for educational quality improvement, limited government participation, minimal industry engagement, and the absence of innovation-oriented collaboration constrain its representation of a fully integrated Quadruple Helix innovation system, supporting its classification as a conditionally included analytical case.

Case Study 10 (SID-a34): Strengthening Community-Based Fisheries Governance through Government–Community Collaboration in Los Baños, Laguna

This analytical case examined the empowerment of the Barangay Fisheries and Aquatic Resources Management Council (BFARMC) in Tadlac, Los Baños, Laguna (Almazan & Vargas, 2016). The study evaluated leadership, governance capacity, participation, communication, coordination, and organizational performance using interviews with BFARMC members and key informants.

The case illustrated how decentralized fisheries governance supports community participation in environmental stewardship. However, it was conditionally included because it focuses primarily on government–community governance rather than innovation-driven collaboration. University participation was minimal, private-sector actors were absent, and there was little evidence of knowledge co-production, technology transfer, or innovation. Figure 4.10 presents the documented network of interactions among participating actors.

Figure 4.10. Case Study 10 (SID-a34): Network visualization of actor interactions in a community-based fisheries governance system.



Note: Nodes represent Government, University, and Community actors involved in funding, technical training, operational support, governance coordination, and monitoring. Directed edges indicate reported relationships including institutional funding, technical and paralegal training, fingerling provision, operational assistance, governance oversight, and qualitative monitoring. Edge weights range from 2 to 3, where 3 denotes primary institutional support and funding (e.g., BFAR, LLDA, and municipal government agencies), and 2 denotes operational support, training, governance coordination, and monitoring functions. Directionality reflects flows of institutional support, regulatory oversight, and technical assistance toward community-based governance structures. Government agencies (BFAR, LLDA, and municipal offices) provide formal funding, technical training, operational legitimacy, and governance coordination for fisheries management activities. Community actors (BFARMC and local stakeholders) occupy central operational roles, engaging in resource management, monitoring, and local governance functions, supported by qualitative input from key informants and barangay-level administration. The university (UPLB) is geographically proximate but only weakly engaged, with potential but unrealized advisory and educational contributions. Industry and private sector actors are absent from the network. Overall, the system reflects a government-led, community-centered governance model focused on stewardship and operational management, with limited institutional integration of academia and no meaningful industry participation.

Government Actors

Government agencies, including the Laguna Lake Development Authority (LLDA), Bureau of Fisheries and Aquatic Resources (BFAR), and the Municipal Government of Los Baños, served as the principal institutional enablers. They

provided regulatory oversight, technical assistance, operational funding, fish fingerlings, environmental training, and support for fisheries management activities. Despite these interventions, respondents reported insufficient financial resources, limited enforcement capacity, and weak coordination between BFARMC and local government units, constraining long-term organizational effectiveness.

University Actors

Although the University of the Philippines Los Baños (UPLB) is located near the study area, its involvement was minimal and largely informal. The study identified opportunities for universities to contribute through environmental education, fisheries research, technical assistance, and community extension. However, these functions were not systematically integrated into BFARMC operations, limiting the university's role as a knowledge intermediary or innovation partner.

Industry Actors

No private-sector or industry actors were directly involved in BFARMC governance or fisheries management activities. Consequently, there was no evidence of market partnerships, technology transfer, commercialization, or private-sector investment within the local fisheries governance system.

Community Actors

BFARMC members served as the primary community actors responsible for fisheries management, environmental monitoring, and local governance. Although community participation was formally institutionalized, active engagement in planning, decision-making, and organizational activities remained inconsistent. Leadership challenges, limited communication, and weak participatory mechanisms reduced organizational effectiveness and community empowerment.

Innovation Outcomes

The initiative generated several governance and community development outcomes.

- Fisheries Governance: Strengthened local participation in fisheries management and environmental stewardship through the BFARMC structure.
- Resource Management: Members retained legal access to fisheries resources and participated in conservation and monitoring activities.
- Organizational Development: The study identified institutional weaknesses affecting leadership, communication, coordination, and member participation that constrained long-term organizational performance.

However, there was little evidence of technological innovation, entrepreneurship, policy experimentation, or broader innovation ecosystem development.

Challenges and Sustainability Strategies

The study identified several implementation challenges, including limited funding, weak organizational leadership, inconsistent member participation, inadequate regulatory enforcement, and environmental pressures affecting Laguna Lake.

To improve long-term sustainability, the study recommended the following: strengthening leadership development and livelihood training; expanding community awareness and governance orientation programs; establishing stronger partnerships with LGUs, NGOs, and other BFARMCs; institutionalizing monitoring and evaluation systems; and increasing UPLB involvement through research, environmental

education, and technical extension. These strategies aimed to strengthen institutional capacity and improve collaborative fisheries governance.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: The case demonstrates a weak structural configuration. Government agencies provided formal institutional support, while universities remained peripheral and industry actors were absent. Community participation existed but lacked broader cross-sector integration.
- Functional Dimension: The initiative exhibits a weak functional configuration. Activities focused primarily on fisheries governance, environmental stewardship, and community participation, with limited evidence of innovation, knowledge transfer, entrepreneurship, or technological development.
- Relational Dimension: The relational dimension is weak, characterized by limited collaboration between government and community actors: weak communication, inconsistent participation, and minimal university engagement constrained long-term institutional learning and collaborative governance.

Case Summary

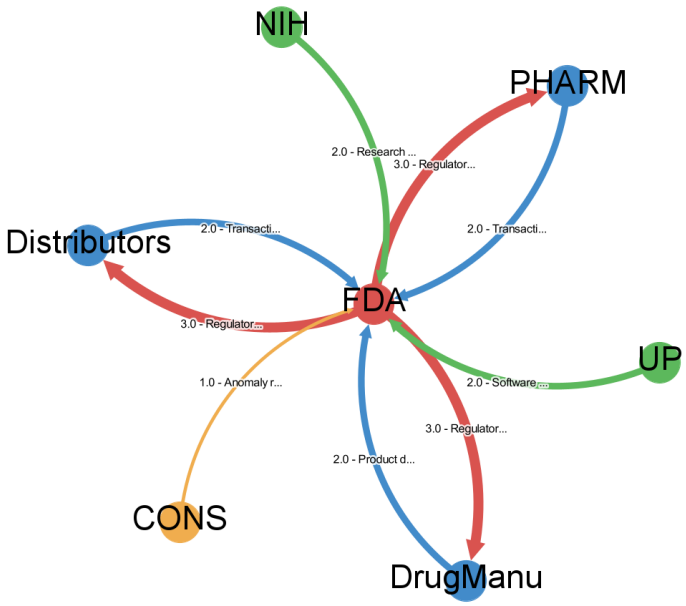
Overall, Case Study 10 demonstrates the importance of decentralized community-based fisheries governance in promoting local environmental stewardship. While government support enabled BFARMC operations, limited university participation, the absence of industry collaboration, and weak institutional integration restricted the initiative's contribution to a fully developed Quadruple Helix innovation system, supporting its classification as a conditionally included analytical case.

Case Study 11 (SID-a47): Blockchain-Based Pharmacosurveillance for Detecting Falsified and Substandard Drugs in the Philippine Supply Chain

This analytical case examined the development and simulation of a blockchain-based pharmacosurveillance system designed to improve pharmaceutical traceability, counterfeit drug detection, and consumer participation in the Philippines (Sylim et al., 2018). The prototype integrated blockchain technology, smart contracts, GS1 pedigree standards, RFID, and a distributed file system (DFS) to enable secure tracking of pharmaceutical products across manufacturers, wholesalers, retailers, regulators, and consumers.

The case was conditionally included because, although it demonstrates strong technological innovation and meaningful interaction among government, academia, industry, and consumers, the system was evaluated only through simulation rather than real-world implementation. Consequently, evidence of sustained institutional collaboration and operational innovation remains limited. Figure 4.11 presents the documented network of interactions among participating actors.

Figure 4.11 Case Study 11 (SID-a47): Network visualization of actor interactions in a blockchain-enabled pharmacosurveillance system.



Note: Nodes represent Government, University, Industry, and Community actors involved in regulatory oversight, system development, supply chain verification, and consumer authentication. Directed edges indicate reported relationships including regulatory supervision, transaction verification, product data submission, software development, GS1 integration, anomaly reporting, and consumer feedback. Edge weights range from 1 to 3, where 3 denotes primary regulatory oversight and verification authority (e.g., FDA); 2 denotes operational data submission, system integration, and technical implementation across industry and university actors; and 1 denotes consumer-level verification feedback and anomaly reporting. Directionality reflects flows of regulatory control, technical inputs, and transaction data toward centralized verification and monitoring functions. Government (FDA) provides regulatory legitimacy through supervision, transaction verification, registry maintenance, credential issuance, and anomaly monitoring. University actors (UP and NIH) contribute system design, blockchain architecture development, GS1 standard integration, and simulation testing, supporting the technical foundation of the platform. Industry actors (manufacturers, wholesalers, retailers, and pharmaceutical entities) implement supply chain participation through product data submission, transaction verification, and compliance with traceability protocols. Community actors (consumers) engage through product authentication and anomaly reporting via scanning mechanisms. Overall, the network reflects a centralized, technology-mediated regulatory system integrating government oversight, industry compliance, academic technical support, and consumer participation through a blockchain-based verification platform.

Government Actors

The Food and Drug Administration (FDA) served as the central regulatory authority responsible for supervising the blockchain network. The FDA verified supply chain transactions, maintained participant registries, issued user credentials, monitored anomaly reports, and ensured regulatory oversight of pharmaceutical traceability. While the system demonstrated the potential to strengthen pharmaceutical regulation, successful implementation would require supportive legislation, institutional capacity, and legal recognition of blockchain-based records.

University Actors

Academic institutions, particularly the University of the Philippines (UP) and the National Institutes of Health (NIH), contributed to the design and development of the blockchain platform. Their roles included developing the blockchain architecture, integrating GS1 pedigree standards, designing verification protocols, and conducting simulation testing. Although these contributions demonstrated knowledge generation and technological innovation, universities were not directly involved in system governance or operational implementation.

Industry Actors

Manufacturers, wholesalers, and retailers functioned as the primary operational actors within the blockchain network. Industry participants uploaded product information, validated transactions, complied with smart contract protocols, and maintained traceability records throughout the pharmaceutical supply chain. Their participation formed the operational foundation of the proposed pharmacosurveillance system.

Community Actors

Consumers participated as decentralized verification agents by scanning pharmaceutical products, confirming authenticity, accessing distribution histories, and reporting suspected counterfeit products to the FDA. Although consumer participation strengthened transparency and accountability, the system's effectiveness depended heavily on widespread public awareness and consistent user engagement.

Innovation Outcomes

The blockchain prototype demonstrated several important technological and regulatory innovations.

- Supply Chain Traceability: Enabled end-to-end tracking of pharmaceutical products using blockchain-based distributed ledgers.
- Automated Verification: Smart contracts and GS1 standards supported automated verification of product authenticity and transaction records.
- Consumer Participation: Consumers could verify medicines and report anomalies, strengthening transparency and public engagement in pharmacosurveillance.

Despite these promising results, all findings were generated under simulated conditions, and real-world effectiveness has yet to be demonstrated.

Challenges and Sustainability Strategies

Several challenges may affect large-scale implementation, including limited consumer participation, regulatory uncertainty, infrastructure requirements, technical capacity, and industry adoption.

To improve long-term sustainability, the study proposed strengthening FDA technical capacity and institutional readiness; providing training for pharmaceutical supply chain participants; conducting consumer awareness campaigns to encourage verification and reporting; developing legal frameworks that recognize blockchain records; and gradually integrating blockchain technologies into existing pharmaceutical distribution systems. These measures are intended to support future operational deployment and institutional adoption.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: The case demonstrates moderate structural configuration. Government provides regulatory leadership, industry manages supply chain operations, universities contribute technical expertise, and consumers participate in product verification. However, the interaction remains largely simulation-based rather than institutionally embedded.
- Functional Dimension: The case exhibits a strong functional configuration through the integration of blockchain technology, smart contracts, RFID, supply chain traceability, automated verification, and consumer authentication into pharmaceutical regulation.
- Relational Dimension: The relational dimension is moderate, with interactions mediated through the blockchain platform connecting regulators, academic developers, industry participants, and consumers. However, sustained collaboration and institutional integration have not yet been demonstrated under real-world conditions.

Case Summary

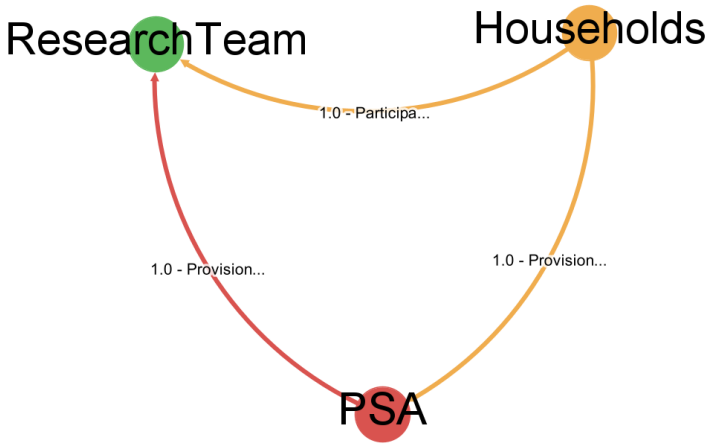
Overall, Case Study 11 demonstrates the potential of blockchain technology to strengthen pharmaceutical regulation, supply chain transparency, and consumer protection. While the prototype illustrates promising government–university–industry–community collaboration, its reliance on simulated implementation limits evidence of sustained institutional interaction, supporting its classification as a conditionally included analytical case.

Case Study 12 (SID-a55): Household and Socioeconomic Determinants of Poverty Recurrence in the Philippines

This analytical case examined the household and socioeconomic factors associated with poverty recurrence in the Philippines using data from the Annual Poverty Indicators Survey (APIS) and the Family Income and Expenditure Survey (FIES) (Bayudan-Dacuycuy & Lim, 2014). Employing descriptive statistics, multinomial logit, and probit regression analyses, the study investigated how household characteristics, education, occupation, geographic location, and exposure to economic shocks influence repeated poverty episodes.

The case was conditionally included because it focuses primarily on statistical analysis of poverty determinants rather than innovation, policy implementation, or cross-sector collaboration. Although the findings provide important evidence for poverty reduction policies, the study did not examine collaborative intervention development or innovation-driven interactions among government, universities, industry, and communities. Figure 4.12 presents the documented network of interactions among participating actors.

Figure 4.12 Case Study 12 (SID-a55): Network visualization of actor interactions in a socio-economic data analysis system.



Note: Nodes represent Government, University, and Community actors involved in survey data provision, statistical processing, and poverty analysis. Directed edges indicate reported relationships including survey administration, standardized dataset provision, socio-economic data collection, and analytical processing. Edge weights are 1, reflecting data provision and analytical input without operational intervention or program implementation. Directionality reflects flows of standardized survey data from households and government statistical agencies toward research-based analytical actors. Government (Philippine Statistics Authority) provides national survey datasets (e.g., APIS and FIES), standardized statistical guidance, and indirect support through survey administration. The university/research team conducts data analysis, including descriptive and regression modeling, to identify socio-economic and shock-related determinants of poverty. Community actors (households) serve as primary data providers through survey participation but are not involved in intervention design or implementation. No structured engagement exists with NGOs, private sector, or local government units. Overall, the network reflects a centralized data-to-knowledge system characterized by government-provided statistical inputs, university-led analysis, and household-level data provision, with limited cross-sector collaboration or applied intervention pathways.

Government Actors

The Philippine Statistics Authority (PSA) provided the primary institutional support through the administration of the APIS and FIES datasets. Government involvement was limited to providing standardized national survey data and statistical infrastructure. The study did not involve government participation in designing, implementing, or evaluating poverty reduction programs or collaborative policy interventions.

University Actors

The research team served as the primary knowledge producer and analytical actor. Using nationally representative household datasets, researchers identified key determinants of poverty recurrence through descriptive and econometric analyses. The study demonstrated that low educational attainment, rural residence, larger household size, and exposure to adverse economic shocks significantly increased the likelihood of repeated poverty. In contrast, education, health insurance, and urban residence reduced vulnerability. Although the study generated important policy-relevant evidence, universities functioned primarily as analytical institutions rather than as innovation intermediaries or partners in intervention development.

Industry Actors

No private-sector actors participated in the study. There was no evidence of industry involvement in poverty reduction initiatives, program implementation, or collaborative intervention development.

Community Actors

Households participated as survey respondents through the APIS and FIES data collection process. Their role was limited to providing socioeconomic information used in statistical analyses. Communities did not participate in policy formulation, intervention design, or implementation.

Innovation Outcomes

The study generated several important analytical contributions.

- Poverty Profiling: Identified regional and rural–urban disparities in chronic poverty across the Philippines.

- Risk Factor Identification: Demonstrated that education, household composition, employment shocks, natural disasters, and geographic location significantly influence poverty recurrence.
- Policy Evidence: Generated evidence supporting future poverty reduction strategies, including investments in education, social protection, and shock-responsive interventions.

However, the study did not develop or evaluate policy interventions, technological innovations, or collaborative implementation mechanisms.

Challenges and Sustainability Strategies

The study identified persistent structural challenges, including rural poverty, geographic inequality, household vulnerability, and limited resilience to economic and environmental shocks.

Based on the findings, the authors recommended the following: expanding access to education, particularly in disadvantaged communities; strengthening social protection and health insurance programs; providing targeted assistance to vulnerable households; developing shock-responsive policies addressing employment instability, food price volatility, and natural disasters. These recommendations highlight opportunities for future evidence-based poverty reduction initiatives but were not implemented or evaluated within the study.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: The case demonstrates a weak structural configuration. Government provided statistical data, universities conducted the analysis, while industry and civil society actors were absent from the research process.

- Functional Dimension: The case exhibits a moderate functional configuration through the generation of robust empirical evidence on poverty dynamics and household vulnerability. However, these findings were not translated into implemented interventions, technological innovation, or collaborative policy development.
- Relational Dimension: The relational dimension is weak, consisting primarily of interactions between researchers and survey respondents through government-administered datasets. There was little engagement with policymakers, local governments, NGOs, or the private sector.

Case Summary

Overall, Case Study 12 provides important evidence on the socioeconomic determinants of poverty recurrence in the Philippines and offers valuable insights for future social protection policies. Nevertheless, the absence of cross-sector collaboration, intervention development, and innovation-oriented implementation limits its contribution to a fully developed Quadruple Helix innovation system, supporting its classification as a conditionally included analytical case.

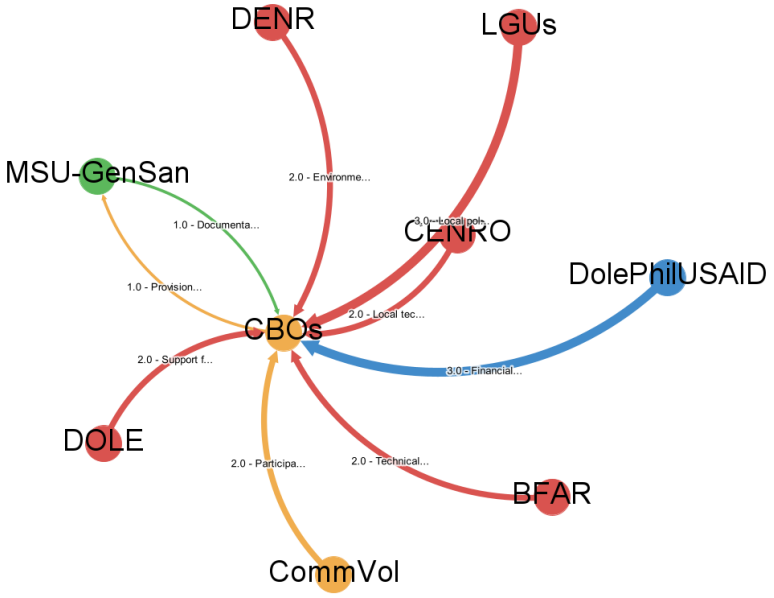
Case Study 13 (SID-a58): Community-Based Organizations in Coastal Resource Management in Sarangani Bay, Philippines

This analytical case examined the role of community-based organizations (CBOs) in coastal resource management (CRM) in Sarangani Bay, Philippines (Calva, 2018). Using key informant interviews and archival analysis, the study documented community initiatives related to marine protected areas, Bantay-Dagat operations, coastal clean-up activities, solid waste management, mangrove rehabilitation, and

alternative livelihood programs. The research evaluated the organizational factors that facilitated or constrained community participation in coastal resource management.

The case was conditionally included because it focuses primarily on community-based environmental governance rather than innovation-driven collaboration. Although it demonstrates strong partnerships among communities and government agencies, university involvement was largely limited to documentation, while technological innovation and private-sector participation were minimal. Figure 4.13 presents the documented network of interactions among participating actors.

Figure 4.13 Case Study 13 (SID-a58): Network visualization of actor interactions in a community-based coastal resource management system.



Note: Nodes represent Government, University, Community, and Industry actors engaged in conservation activities, livelihood support, monitoring, documentation, and technical assistance. Directed edges indicate reported relationships including legal and technical guidance, funding support, environmental monitoring, program facilitation, participation in conservation activities, and documentation of community initiatives. Edge weights range from 1 to 3, where 3 denotes primary financial support and program facilitation (e.g., government agencies and development partners), 2 denotes technical, legal, environmental, and operational support, and 1 denotes documentation and knowledge provision. Directionality reflects flows of financial, technical, and institutional support toward community-based implementation hubs. Government actors (BFAR, DENR, DOLE, CENRO, and LGUs) provide funding, technical assistance, legal and environmental guidance, and monitoring support for

coastal resource management initiatives. Community-based organizations (CBOs) and volunteers (CommVol) serve as central operational actors, implementing marine sanctuary management, Bantay-Dagat activities, coastal clean-ups, and alternative livelihood programs. The university (MSU-GSC) functions as a knowledge producer, documenting and analyzing community initiatives through interviews, archival research, and case categorization. Industry and development partners provide financial and technical support to selected initiatives. Overall, the network reflects a community-centered coastal governance system supported by government facilitation and university documentation, with strong horizontal community engagement but limited formalized co-production across government, academia, and industry.

Government Actors

Government agencies, including the Bureau of Fisheries and Aquatic Resources (BFAR), Department of Environment and Natural Resources (DENR), Department of Labor and Employment (DOLE), Community Environment and Natural Resources Office (CENRO), and local government units (LGUs), served as institutional facilitators. They provided financial assistance, technical support, legal guidance, environmental monitoring, and capacity-building activities that supported marine protected areas, Bantay-Dagat operations, mangrove rehabilitation, and community livelihood programs. Their role was primarily supportive and regulatory rather than innovation-oriented.

University Actors

Mindanao State University–General Santos City (MSU-GSC) served as the principal knowledge producer. The university documented community initiatives through interviews and archival research, identified factors influencing organizational performance, and analyzed successful coastal resource management practices. Although the study generated valuable knowledge on community-based conservation, the university's role remained descriptive and evaluative, with little evidence of technology development, knowledge commercialization, or innovation transfer.

Industry Actors

Industry participation was limited. Private foundations and development organizations provided financial and technical assistance to selected projects. Still, there was little evidence of sustained private-sector involvement in innovation, technology development, or commercialization of coastal resource management initiatives.

Community Actors

Community-based organizations (CBOs) were the primary operational actors. They implemented marine protected areas, mangrove rehabilitation, Bantay-Dagat patrols, coastal clean-up campaigns, solid waste management programs, and alternative livelihood projects. Successful organizations such as CAFIFAMCO and MCMFO demonstrated strong organizational commitment, effective stakeholder collaboration, and sustained community participation in environmental conservation.

Innovation Outcomes

The study documented several important environmental and organizational outcomes.

- Coastal Resource Management: Community organizations established and managed marine sanctuaries, mangrove rehabilitation projects, and coastal monitoring programs.
- Environmental Stewardship: Bantay-Dagat operations strengthened fisheries enforcement, while community-led clean-up activities improved coastal environmental management.

- Livelihood Development: Alternative livelihood programs reduced dependence on marine resource extraction and supported community participation in conservation.

Although these initiatives generated important local benefits, the study documented limited evidence of technological innovation, policy experimentation, or broader innovation system development.

Challenges and Sustainability Strategies

Several factors constrained the long-term sustainability of community-based coastal management, including limited financial resources, weak organizational capacity, leadership challenges, illegal fishing activities, and environmental degradation.

The study recommended the strengthening of partnerships with LGUs, national agencies, NGOs, and private organizations; improving organizational governance and leadership capacity; expanding alternative livelihood opportunities; replicating successful practices demonstrated by high-performing CBOs; and increasing institutional support through funding, technical assistance, and capacity-building programs. These measures aim to improve long-term organizational resilience and environmental sustainability.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: The case demonstrates moderate structural configuration. Community organizations served as the primary implementers, government agencies provided institutional support, and universities contributed documentation and analysis. Industry participation remained limited, preventing full Quadruple Helix integration.

- Functional Dimension: The case exhibits a moderate functional configuration. The initiative generated practical outcomes in marine conservation, environmental stewardship, and livelihood development but showed limited evidence of technological innovation, knowledge commercialization, or integrated policy development.
- Relational Dimension: The relational dimension is moderate, characterized by strong collaboration among community organizations, government agencies, and supporting institutions. However, interactions with universities were primarily research-oriented, while sustained partnerships with industry remained weak.

Case Summary

Overall, Case Study 13 demonstrates the value of community-based organizations in strengthening coastal resource management and environmental stewardship in Sarangani Bay. While the initiative achieved meaningful conservation and livelihood outcomes through strong community participation and government support, limited university integration and weak industry participation constrained its contribution to a fully developed Quadruple Helix innovation system, supporting its classification as a conditionally included analytical case.

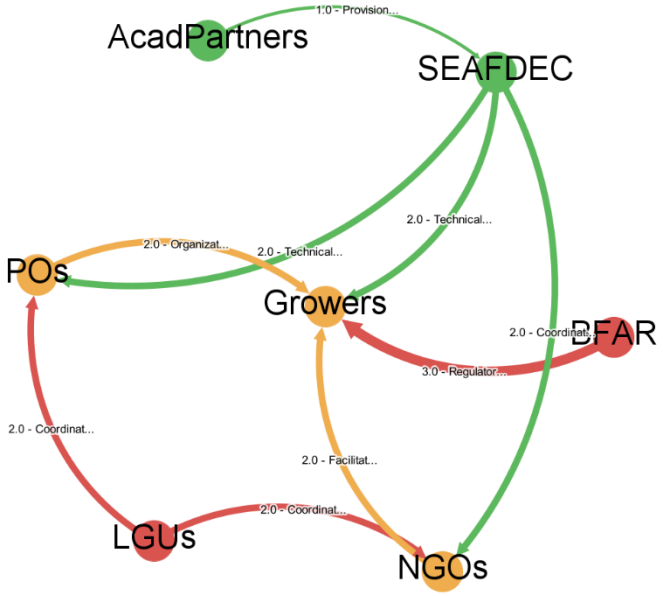
Case Study 14 (SID-a59): Community-Based Technology Transfer of Mudcrab (Scylla serrata) Nursery in Northern Samar, Philippines

This analytical case examined a community-based technology transfer initiative for smallholder mudcrab (Scylla serrata) aquaculture in Northern Samar, Philippines (Baticados et al., 2014). Implemented under the SEAFDEC/AQD Institutional Capacity

Development for Sustainable Aquaculture (ICDSA) Program with support from ACIAR, the project introduced pond-based mudcrab nursery technologies through season-long training, field demonstrations, and participatory learning across four municipalities. The initiative sought to improve rural livelihoods, reduce pressure on wild crab populations, and promote environmentally sustainable aquaculture practices.

The case was conditionally included because it primarily focused on technology adoption, livelihood improvement, and community capacity building rather than broader innovation system development. Although government agencies, research institutions, NGOs, and local communities collaborated effectively, industry participation and long-term technology commercialization remained limited. Figure 4.14 presents the documented network of interactions among participating actors.

Figure 4.14. Case Study 14 (SID-a59): Network visualization of actor interactions in a smallholder mudcrab aquaculture system.



Note: Nodes represent Government, University, and Community actors involved in regulatory facilitation, technical training, livelihood organization, and production monitoring. Directed edges indicate reported relationships including permit issuance, access facilitation to mangrove areas, coordination of nurseries and pond systems, training delivery, loan mediation, and socioeconomic assessment. Edge weights range

from 1 to 3, where 3 denotes primary regulatory oversight and access authorization (e.g., BFAR and LGUs), 2 denotes operational support, technical guidance, training, and coordination activities, and 1 denotes provision of technical expertise and socioeconomic analysis. Directionality reflects flows of regulatory access, technical support, and facilitation toward community-based production organizations. Government actors (BFAR and LGUs) provide regulatory oversight, legal permits, coordination support, and access to mangrove areas for aquaculture development. Research institutions (SEAFDEC/AQD and academic partners) serve as technical knowledge producers, leading pond and nursery system design, season-long training, production monitoring, and financial viability assessment. Community actors (smallholder mudcrab growers organized in people's organizations) function as central implementers of aquaculture activities, while NGOs facilitate participation through training support, loan access, and operational assistance. Industry and broader market actors are minimally engaged. Overall, the network reflects a community-centered aquaculture system supported by government regulation and research-led technical guidance, with moderate collaboration across actors but limited market integration and scalable multi-sector co-development.

Government Actors

Government agencies, particularly the Bureau of Fisheries and Aquatic Resources (BFAR) and local government units (LGUs), served as regulatory and facilitating actors. They provided permits for aquaculture activities, coordinated project implementation, facilitated access to mangrove areas, and supported institutional coordination among NGOs and community organizations. Their involvement enabled project implementation but remained largely administrative, with limited participation in technology development or long-term innovation management.

University Actors

SEAFDEC/AQD and its academic collaborators served as the principal knowledge producers and technical implementers. They developed and demonstrated mudcrab nursery technologies, conducted season-long training programs, monitored production performance, and evaluated the technical and financial viability of nursery systems. Research findings showed that mangrove-based nurseries achieved higher survival rates than non-mangrove systems, demonstrating the ecological and economic advantages of environmentally compatible aquaculture practices. Despite

these contributions, technology diffusion remained dependent on external funding, technical assistance, and continued institutional support.

Industry Actors

Industry participation was minimal. NGOs supported participant mobilization, facilitated access to loans, and assisted community organizations during implementation. However, private-sector actors, traders, and commercial aquaculture enterprises had limited involvement in technology commercialization, market development, or long-term scaling of the innovation.

Community Actors

Community participation centered on approximately 60 smallholder mudcrab growers organized into four people's organizations (POs). Participants adopted nursery technologies through hands-on training, demonstration farms, and participatory learning activities. Community members managed pond operations, applied improved nursery practices, and monitored production performance, making them the primary implementers of the technology transfer initiative.

Innovation Outcomes

The project generated several measurable technical, socio-economic, and environmental outcomes.

- Livelihood Development: Smallholder mudcrab nursery operations generated additional household income and strengthened livelihood opportunities for participating families.
- Capacity Building: Participants acquired practical skills in pond preparation, nursery management, feed formulation, water quality management, and financial record-keeping.

- Sustainable Aquaculture: Mangrove-based nursery systems achieved higher survival rates while promoting environmentally compatible aquaculture and reducing pressure on wild crab stocks.

Although the project demonstrated successful technology adoption, broader commercialization, institutional scaling, and long-term innovation diffusion remained limited.

Challenges and Sustainability Strategies

Major implementation challenges included limited culture areas, insufficient capital, dependence on externally supplied crablets, climate variability, poaching, and organizational weaknesses within cooperative ventures.

To strengthen long-term sustainability, the project emphasized the continued participatory training and farm demonstrations; support from LGUs and NGOs for land access, financing, and coordination; promotion of mangrove-compatible nursery systems; integration of cost-benefit analysis and financial monitoring into production management; and strengthening local organizational capacity to improve long-term adoption and governance. These strategies aimed to improve both livelihood sustainability and environmentally responsible aquaculture.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: The case demonstrates moderate structural configuration. Research institutions led technology development, government agencies facilitated implementation, and community organizations served as primary adopters. Industry participation remained limited, preventing full Quadruple Helix integration.

- Functional Dimension: The case exhibits a moderate functional configuration. The initiative successfully transferred aquaculture technology, strengthened community capacity, and generated livelihood benefits but showed limited evidence of commercialization, entrepreneurial development, or innovation system expansion.
- Relational Dimension: The relational dimension is moderate, characterized by sustained collaboration among researchers, government agencies, NGOs, and local communities through training, demonstration activities, and technical support. However, weak engagement with commercial market actors limited broader innovation diffusion and long-term cross-sector collaboration.

Case Summary

Overall, Case Study 14 demonstrates that participatory technology transfer can strengthen smallholder aquaculture, improve rural livelihoods, and promote environmentally sustainable production systems. While the initiative achieved meaningful technical and socio-economic outcomes through strong collaboration among research institutions, government agencies, NGOs, and communities, limited industry participation and constrained technology commercialization prevented the development of a fully integrated Quadruple Helix innovation system, supporting its classification as a conditionally included analytical case.

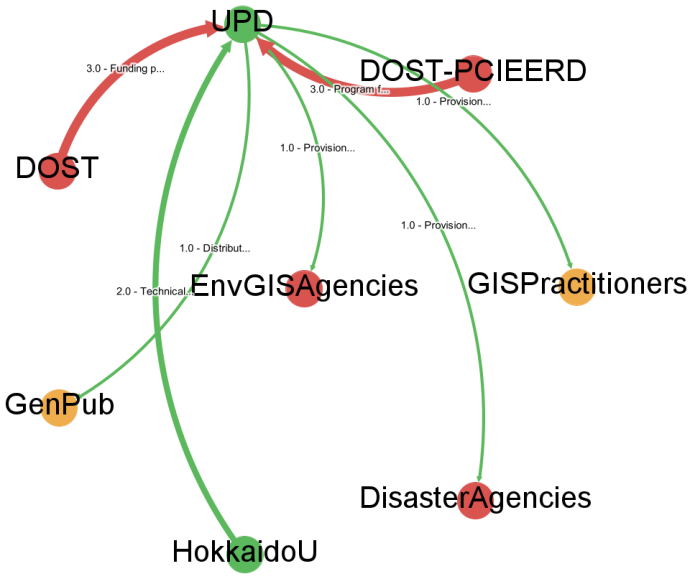
Case Study 15 (SID-a69): Free and Open-Source Data Processing, Archiving, and Distribution Subsystem for the Philippine Scientific Earth Observation Microsatellite

This analytical case examined the development of a free and open-source software (FOSS)-based Data Processing, Archiving, and Distribution (DPAD)

subsystem for the Philippine Scientific Earth Observation Microsatellite (PHL-Microsat/DIWATA) Program (Aranas et al., 2016). As part of the national microsatellite initiative, the project established domestic capability for satellite data ingestion, processing, archiving, and web-based distribution using open-source technologies. The subsystem was designed to support disaster risk reduction, environmental monitoring, and geospatial applications while reducing dependence on proprietary software.

The case was conditionally included because it primarily presents a technical infrastructure and system design initiative rather than a fully operational innovation ecosystem. Although strong government–university collaboration supported system development and national capacity building, evidence of downstream socio-economic impacts, industry participation, and sustained multi-sector innovation remained limited. Figure 4.15 presents the documented network of interactions among participating actors.

Figure 4.15 Case Study 15 (SID-a69): Network visualization of actor interactions in a satellite-based Earth observation and geospatial data system.



Note: Nodes represent Government, University, and Community actors involved in funding, system development, data processing, capacity building, and data

dissemination. Directed edges indicate reported relationships including funding provision, program supervision, strategic oversight, system architecture design, technical collaboration, and satellite data distribution to end-users. Edge weights range from 1 to 3, where 3 denotes primary funding, strategic direction, and program supervision (e.g., DOST and DOST-PCIEERD), 2 denotes technical collaboration, system development, and knowledge support, and 1 denotes data provision and distribution to end-users and practitioner groups. Directionality reflects flows of funding, technical expertise, and processed geospatial data toward central system development and downstream users. Government actors (DOST and DOST-PCIEERD) provide funding, strategic oversight, capacity-building support, and program supervision for the development of geospatial data systems. The University of the Philippines Diliman, in collaboration with Hokkaido University, serves as the primary knowledge producer, designing system architecture, developing data processing pipelines, integrating open-source software frameworks, and providing technical capacity building. Community and user groups (GIS practitioners, government agencies, disaster and environmental GIS users, and the general public) function primarily as end-users receiving processed satellite and geospatial data for operational and research purposes, with minimal co-development involvement. Industry participation is absent. Overall, the network reflects a centralized, university-led geospatial infrastructure system supported by government funding and oversight, with strong technical development but limited downstream co-creation and applied sectoral integration.

Government Actors

The Department of Science and Technology (DOST), through DOST-PCIEERD, served as the principal funder, policy enabler, and strategic coordinator. Government support included funding system development, establishing national space technology capability, strengthening technical human resources, and promoting satellite data as a public resource for disaster management, environmental monitoring, and resource planning. However, collaboration remained largely focused on institutional capacity building, with limited evidence of inter-agency co-development or operational integration into government decision-making systems.

University Actors

The University of the Philippines Diliman (UPD), in collaboration with Hokkaido University, functioned as the principal knowledge producer, system architect, and technical implementer. The research team designed the DPAD architecture,

developed automated satellite data processing workflows, integrated open-source software platforms, and established technical expertise in remote sensing and geospatial data management. The project also strengthened national capability in satellite operations while reducing reliance on proprietary software systems. Despite these achievements, technology transfer beyond academic and government institutions remained limited, and operational adoption had not yet been fully demonstrated.

Industry Actors

Industry participation was absent. Potential users, including GIS practitioners, government agencies, and environmental organizations, were identified primarily as future end-users of satellite products rather than active collaborators. The study provided no evidence of participation by commercial geospatial firms, private technology developers, or industry partners in system design, implementation, or commercialization.

Community Actors

Community engagement was indirect. Government agencies, GIS practitioners, disaster management organizations, and the general public were expected to access processed satellite products through the planned web-based distribution platform. However, these stakeholders did not participate in system development, requirements definition, or collaborative implementation.

Innovation Outcomes

The project generated several important technical and institutional outputs.

- Geospatial Infrastructure Development: Developed complete open-source architecture for satellite data processing, archiving, and distribution.

- National Capacity Building: Strengthened domestic expertise in satellite operations, remote sensing, and geospatial data processing while reducing dependence on proprietary software.
- Scalable Open-Source Platform: Established a modular and cost-efficient system capable of supporting future satellite missions and expanded geospatial applications.

Although the subsystem demonstrated significant technical advancement, operational impacts on disaster management, environmental governance, and public service delivery had not yet been empirically evaluated.

Challenges and Sustainability Strategies

Major challenges included adapting open-source platforms to mission-specific requirements, ensuring long-term system reliability and scalability, and sustaining technical expertise beyond the project period.

To strengthen sustainability, the project emphasized: continued government funding and institutional support; open sharing of source code and technical documentation; modular system architecture to facilitate future expansion; and ongoing technical capacity development in satellite data processing and geospatial technologies. These measures were intended to ensure long-term operational sustainability and future system enhancement.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: The case demonstrates moderate structural configuration. Government agencies provided funding and strategic oversight, while universities led technical development. However, industry participation

and community involvement remained minimal, limiting broader Quadruple Helix integration.

- Functional Dimension: The case exhibits a moderate functional configuration. It successfully developed national geospatial infrastructure and technical capability but provided limited evidence of operational adoption, commercialization, or broader innovation outcomes beyond system development.
- Relational Dimension: The relational dimension is weak, characterized by strong government–university collaboration but limited interaction with industry, operational government users, local communities, or other external stakeholders. Knowledge exchange remained largely confined to academic and government institutions.

Case Summary

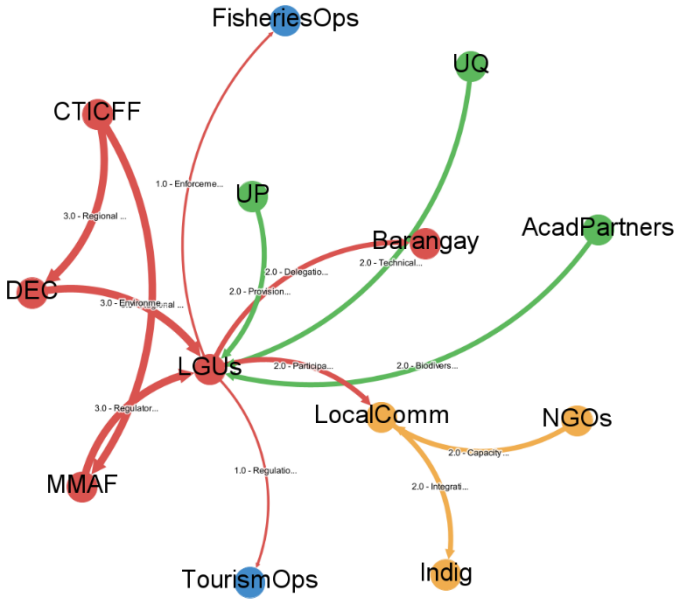
Overall, Case Study 15 demonstrates how coordinated government investment and university expertise can establish national capability in satellite data processing and Earth observation using open-source technologies. While the initiative produced significant technical infrastructure and strengthened national scientific capacity, limited stakeholder participation, absent industry engagement, and the lack of demonstrated operational impacts constrained the development of a fully integrated Quadruple Helix innovation system, supporting its classification as a conditionally included analytical case.

Case Study 16 (SID-a71): Multi-Country Marine Protected Area Networks in the Coral Triangle

This analytical case synthesized six sub-national Marine Protected Area (MPA) network initiatives implemented across the Coral Triangle region under the Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security (CTI-CFF) (Weeks et al., 2014). Covering Indonesia, Malaysia, Papua New Guinea, the Philippines, Solomon Islands, and Timor-Leste, the study examines governance approaches that integrate scientific knowledge, community participation, capacity building, and multiple-use zoning to strengthen marine conservation and resource management.

The case was conditionally included because it primarily provides a comparative synthesis of governance practices rather than an empirical evaluation of innovation outcomes. Although the study demonstrated extensive collaboration among governments, academic institutions, NGOs, and communities, evidence of technological innovation, private-sector engagement, and measurable socio-economic impacts remains limited. Figure 4.16 presents the documented network of interactions among participating actors.

Figure 4.16. Case Study 16 (SID-a71): Network visualization of actor interactions in a multi-level marine protected area (MPA) governance system.



Note: Nodes represent Government, University, Industry, and Community actors involved in policy coordination, ecological assessment, participatory governance, regulatory enforcement, and conservation planning. Directed edges indicate reported relationships including regional policy coordination, zoning and regulatory approval, environmental oversight, ecological modeling, biodiversity assessment, capacity building, and participatory monitoring and enforcement. Edge weights range from 1 to 3, where 3 denotes primary regional policy coordination and regulatory authority (e.g., national and local government agencies), 2 denotes technical support, participatory governance, ecological modeling, and capacity-building activities, and 1 denotes regulatory compliance and operational enforcement by regulated stakeholders. Directionality reflects flows of governance authority, technical expertise, and participatory inputs toward central decision-making and conservation management processes. Government actors at national, provincial, and local levels provide regulatory legitimacy through MPA declarations, zoning approvals, biodiversity strategy integration, and environmental oversight, often in coordination with NGOs and academic partners for technical support. Universities and research institutions (e.g., UP, UQ, and other academic partners) contribute ecological modeling, systematic conservation planning (e.g., Marxan-based approaches), biodiversity surveys, and capacity building, primarily in advisory and technical support roles. Community actors, including local communities and indigenous groups, participate actively in consultation, zoning, monitoring, and enforcement activities, forming a central component of governance implementation. Industry actors, including fisheries and tourism operators, function mainly as regulated stakeholders complying with conservation and zoning policies rather than co-creators in governance design. Overall, the network reflects a centralized, multi-level governance system anchored in government–community interaction, supported by academic and NGO technical input, with strong participatory planning but limited market-driven or innovation-oriented integration.

Government Actors

Government institutions at national, provincial, and local levels served as the principal policy makers, regulators, and coordinators of marine protected area (MPA) governance. Their responsibilities included establishing MPAs, approving zoning plans, integrating conservation initiatives into national biodiversity strategies, and coordinating intergovernmental management networks. Government agencies also provided an institutional and regulatory framework supporting conservation planning across participating countries. Despite these contributions, implementation frequently depended on technical support from universities, NGOs, and international partners, with limited evidence of long-term institutionalization or policy innovation beyond conservation governance.

University Actors

Universities and research institutions function as the primary knowledge producers and technical advisors. Their contributions included ecological surveys, biodiversity assessments, larval dispersal modeling, systematic conservation planning using tools such as Marxan, and scientific validation of zoning plans. Academic institutions also supported technical capacity building for conservation planning and ecosystem management. Although these activities strengthened the scientific basis of MPA network design, academic involvement remained largely advisory, with limited evidence of technology transfer, commercialization, or sustained innovation beyond conservation planning.

Industry Actors

Industry participation was limited. Fisheries operators and tourism stakeholders primarily functioned as regulated resource users expected to comply with conservation

measures and zoning regulations. The study provided little evidence of private-sector involvement in conservation planning, innovation development, or collaborative governance.

Community Actors

Community participation represented one of the strongest components of the initiative. Local communities and Indigenous groups actively participated in consultation, participatory mapping, zoning, environmental monitoring, enforcement, and community-based resource management. Traditional ecological knowledge was incorporated into conservation planning, particularly in areas governed by customary marine tenure systems. These participatory approaches strengthened local ownership, improved compliance, and enhanced the legitimacy of marine conservation initiatives.

Innovation Outcomes

The initiative generated several governance and institutional outcomes.

- Expansion of Marine Protected Areas: Supported the establishment and expansion of interconnected MPA networks across the Coral Triangle region.
- Strengthened Governance: Improved coordination among national and local government agencies through collaborative conservation planning and cross-jurisdictional management.
- Capacity Building: Enhanced local institutional capacity for conservation planning, environmental monitoring, and resource management.
- Participatory Conservation: Increased stakeholder participation and strengthened compliance through community-based governance and integration of scientific and local ecological knowledge.

While these achievements strengthened conservation governance, the study presented limited evidence of measurable ecological recovery, socio-economic improvement, or broader innovation outcomes.

Challenges and Sustainability Strategies

Major implementation challenges included mismatches between ecological and political boundaries, uneven institutional capacity, dependence on external NGOs and donors, and balancing conservation objectives with local livelihood needs.

To strengthen long-term sustainability, the initiative emphasized: development of regional learning networks and knowledge-sharing platforms; continued capacity building for local conservation institutions; implementation of multiple-use zoning to balance conservation and livelihoods; and gradual transfer of governance responsibilities to local institutions and communities. Although these strategies provide a strong governance framework, their long-term effectiveness and scalability were not empirically evaluated.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: The case demonstrates moderate structural configuration. Government agencies, universities, NGOs, and communities maintained well-defined governance roles, while industry participation remained limited to regulatory compliance rather than innovation collaboration.
- Functional Dimension: The case exhibits a moderate functional configuration. It successfully integrated scientific knowledge, participatory planning, and conservation governance but showed limited evidence of technological innovation, commercialization, or broader economic transformation.

- Relational Dimension: The relational dimension is moderate, characterized by sustained collaboration among governments, academic institutions, NGOs, and local communities through participatory planning, knowledge sharing, and conservation management. However, interaction with industry remained relatively weak, limiting broader innovation ecosystem development.

Case Summary

Overall, Case Study 16 demonstrates how multi-level collaboration can strengthen marine protected area governance through coordinated conservation planning, scientific support, and active community participation. While the initiative successfully fostered institutional coordination, participatory governance, and knowledge integration across the Coral Triangle, limited industry engagement, technological innovation, and demonstrated socio-economic impacts prevented the development of a fully integrated Quadruple Helix innovation system, supporting its classification as a conditionally included analytical case.

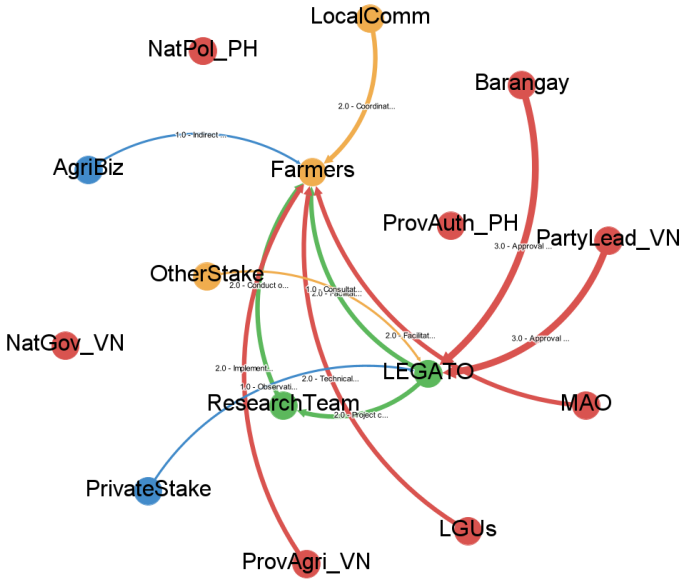
Case Study 17 (SID-a76): Stakeholder Engagement in a Transdisciplinary Rice Agroecosystem Project in Southeast Asia

This analytical case examined stakeholder engagement within the LEGATO (Land-use Intensity and Ecological Engineering–Assessment Tools for Risks and Opportunities in Irrigated Rice-Based Production Systems) project, a five-year transdisciplinary research initiative implemented in the Philippines and Vietnam (Spangenberg et al., 2018). The project involved an international consortium of research institutions, government agencies, farmers, agribusiness actors, and civil

society organizations to promote ecological engineering in irrigated rice systems through participatory research and stakeholder collaboration.

The case was conditionally included because it primarily documents stakeholder engagement processes and participatory governance rather than evaluating innovation outcomes or long-term socio-economic impacts. Although the project demonstrates extensive collaboration among universities, governments, and communities, evidence of technological innovation, commercialization, and sustained institutional transformation remains limited. Figure 4.17 presents the documented network of interactions among participating actors.

Figure 4.17. Case Study 17 (SID-a76): Network visualization of actor interactions in a participatory ecological engineering and agricultural governance system.



Note: Nodes represent Government, University, Industry, and Community actors involved in project approval, participatory research, ecological engineering, training, field implementation, and consultation processes. Directed edges indicate reported relationships including project approval, local coordination, technical advisory, training, ecological engineering design, stakeholder consultation, field implementation support, and feedback collection. Edge weights range from 1 to 3, where 3 denotes primary project approval and alignment with local and provincial priorities, 2 denotes operational facilitation, training, and participatory research support, and 1 denotes minimal engagement such as observation or consultation. Directionality reflects flows of approval, facilitation, and knowledge exchange toward central research and implementation actors. Government actors at municipal, provincial, and national levels provide project approval, coordination, and facilitative support, acting as gatekeepers

and enablers of local implementation. However, engagement is uneven across jurisdictions and limited in terms of enforcement and policy innovation. University and research institutions (e.g., LEGATO and associated research teams) coordinate the project, develop ecological engineering concepts, conduct stakeholder analysis, and facilitate knowledge co-production and capacity building. Community actors, including farmers, farm workers, barangay units, and local communities, are centrally involved through interviews, group discussions, training activities, citizen science, and field-level implementation. Industry and private-sector actors are largely peripheral, contributing minimal engagement. Overall, the network reflects a participatory, university-led ecological governance system anchored in strong community involvement and local government facilitation, with limited integration of private-sector actors and constrained linkages to higher-level national governance and agribusiness systems.

Government Actors

Government agencies at municipal, provincial, and national levels served as facilitators, coordinators, and institutional gatekeepers. Local governments supported project implementation by facilitating field activities, coordinating extension services, and engaging farming communities. In Vietnam, provincial authorities demonstrated stronger institutional support by aligning ecological engineering practices with regional agricultural priorities. In contrast, participation by higher-level government actors remained inconsistent and was often driven by political visibility rather than sustained policy engagement. Although government institutions enabled project implementation, the study provided limited evidence of long-term policy integration, institutional reform, or sustained governance innovation.

University Actors

Universities and research institutions function as the principal knowledge producers, project coordinators, and facilitators of transdisciplinary research. Academic partners designed stakeholder engagement methodologies, coordinated ecological engineering research, conducted interviews and participatory workshops, and integrated local knowledge into scientific investigations. They also facilitated training activities, citizen science initiatives, collaborative field experiments, and

adaptive refinement of research priorities based on stakeholder feedback. While these activities strengthened knowledge co-production and participatory learning, academic contributions remained focused on research implementation rather than commercialization or long-term innovation system development.

Industry Actors

Industry participation was limited. Agribusiness actors and private-sector stakeholders were identified as relevant stakeholders but participated only marginally throughout the project. Their involvement was generally limited to consultation or observation rather than active collaboration in ecological innovation, technology development, or market-oriented implementation.

Community Actors

Community participation represented one of the strongest components of the project. Farmers, farm workers, barangay officials, and local communities actively participated in interviews, focus group discussions, participatory research, field demonstrations, ecological monitoring, and citizen science activities. Continuous stakeholder engagement strengthened trust, social learning, and local ownership while allowing community knowledge to shape project implementation and research priorities.

Innovation Outcomes

The project generated several important governance and learning outcomes.

- Stakeholder Mapping: Established a systematic process for identifying and classifying stakeholders across multiple governance levels.
- Knowledge Co-Production: Integrated scientific and local knowledge to refine ecological engineering practices and research priorities.

- Capacity Building: Improved stakeholder understanding of ecological farming, pesticide reduction, and sustainable rice production through participatory training and learning activities.
- Behavioral Change: Increased ecological awareness and reduced insecticide use were observed in selected project sites, particularly in Vietnam.

Although these outcomes strengthened participatory governance and adaptive learning, the study provided limited evidence of measurable ecological, economic, or institutional impacts beyond the project period.

Challenges and Sustainability Strategies

Major challenges included inconsistent participation by high-level government and private-sector actors, stakeholder conflicts, dependence on short-term research funding, and differences in political and institutional contexts between participating countries.

To strengthen long-term sustainability, the project emphasized: continuous stakeholder analysis throughout implementation; adaptive communication and conflict management strategies; repeated face-to-face engagement with stakeholders; flexible engagement approaches responsive to local contexts; and development of project exit strategies to encourage continuity beyond the research period. Although these strategies strengthened participatory governance, their long-term effectiveness and scalability were not empirically assessed.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: The case demonstrates moderate structural configuration. Universities, government agencies, and communities maintained

strong collaborative roles throughout project implementation, while industry participation remained limited.

- Functional Dimension: The case exhibits a moderate functional configuration. The project successfully supported knowledge co-production, participatory research, and ecological learning but showed limited evidence of technological innovation, commercialization, or broader economic transformation.
- Relational Dimension: The relational dimension is moderate, characterized by sustained interaction, trust-building, and collaborative learning among researchers, local governments, and farming communities. However, engagement with national policymakers and private-sector stakeholders remained relatively weak, limiting broader innovation ecosystem development.

Case Summary

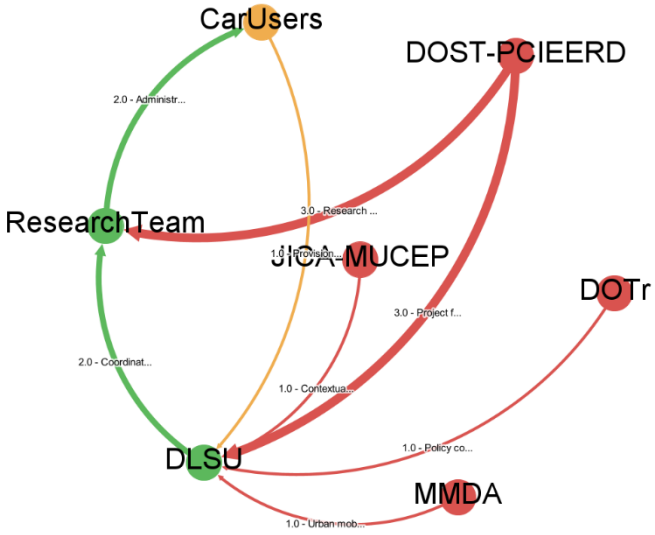
Overall, Case Study 17 demonstrates how participatory stakeholder engagement can strengthen transdisciplinary environmental research through collaborative learning, adaptive governance, and knowledge co-production. While the LEGATO project successfully fostered strong relationships among universities, governments, and local communities, limited industry participation, technological innovation, commercialization, and long-term institutional integration prevented the development of a fully integrated Quadruple Helix innovation system, supporting its classification as a conditionally included analytical case.

Case Study 18 (SID-a93): Modeling Environmental and Traffic Impacts of Car-to-Public Transport Shifts in Metro Manila

This analytical case examined the PUBFix project, a government-funded transport modeling initiative that assessed the potential impacts of shifting private vehicle users to high-capacity public transportation along Epifanio Delos Santos Avenue (EDSA), Metro Manila's primary urban transport corridor (Roxas et al., 2018). Using stated preference (SP) surveys, binary logit modeling, and network simulation through EMME4, the study estimated commuter responses to improved public transport services, particularly Bus Rapid Transit (BRT), and quantified the resulting traffic, economic, and environmental impacts.

The case was conditionally included because it primarily demonstrates evidence-based transport planning through simulation rather than implementation or innovation deployment. Although the study illustrates strong government–university collaboration in policy-oriented research, it provides limited evidence of operational implementation, institutional experimentation, or sustained multi-sector collaboration. Figure 4.18 presents the documented network of interactions among participating actors.

Figure 4.18. Case Study 18 (SID-a93): Network visualization of actor interactions in an urban transport modeling and policy analysis system.



Note: Nodes represent Government, University, and Community actors involved in funding, data provision, survey administration, transport modeling, and policy support. Directed edges indicate reported relationships including research funding, methodological coordination, project supervision, survey deployment, data provision, policy input, and analytical framework support. Edge weights range from 1 to 3, where 3 denotes primary funding and strategic oversight (e.g., DOST-PCIEERD, DOTr, MMDA, and related agencies), 2 denotes operational coordination, survey administration, and research facilitation, and 1 denotes provision of behavioral data and contextual inputs from end-users. Directionality reflects flows of funding, data, and policy inputs toward university-led analytical and modeling processes. Government actors (DOST-PCIEERD, DOTr, MMDA, and related agencies) provide funding, policy alignment, project supervision, and transport system data inputs to support research activities. The university/research team (DLSU and associated researchers) serves as the central analytical actor, designing surveys, estimating logit models, and integrating outputs into transport simulation systems (e.g., EMME4) for policy analysis and decision support. Community actors (private car users) function primarily as survey respondents, contributing behavioral data but not participating in co-design or implementation processes. Industry and civil society actors are not substantively engaged. Overall, the network reflects a centralized, university-led transport modeling system characterized by strong government-funded research production and limited downstream implementation, co-creation, or multi-stakeholder integration.

Government Actors

Government agencies provided funding, policy alignment, transport datasets, and strategic oversight. The Department of Science and Technology–Philippine Council for Industry, Energy, and Emerging Technology Research and Development (DOST-PCIEERD) funded the PUBFix project, while the Department of Transportation

(DOTr), the Metro Manila Development Authority (MMDA), and transport planning initiatives supported by the Japan International Cooperation Agency (JICA) supplied transportation data, origin–destination matrices, and policy context for the simulations. Government participation enabled the analytical evaluation of alternative transport scenarios but remained largely supportive. The study did not demonstrate direct government involvement in transport system co-design, implementation, policy institutionalization, or infrastructure deployment beyond the provision of research support and planning data.

University Actors

The university served as the principal knowledge producer and technical implementer. Researchers from De La Salle University designed stated preference surveys, estimated commuter choice models using binary logit analysis, and integrated behavioral outputs into the EMME4 transportation simulation platform. The research team developed analytical models capable of estimating changes in travel behavior, traffic conditions, economic efficiency, and environmental impacts under improved public transportation scenarios. These activities generated robust decision-support evidence for transport planning. However, the study remained focused on analytical modeling and did not demonstrate technology transfer, operational deployment of planning tools, or institutional integration of simulation systems into long-term transport governance.

Industry Actors

Industry participation was absent. Public transportation operators, private mobility providers, transport companies, and other private-sector organizations were not directly involved in project design, implementation, or evaluation. Consequently,

the study provided little evidence of private-sector collaboration, innovation co-development, or commercialization pathways within the transportation planning process.

Community Actors

Community participation was limited to behavioral data provision. Private car users participated as survey respondents by providing stated preference data regarding their willingness to shift from private vehicles to improved public transportation services. Their involvement supported behavioral modeling but did not extend to participatory planning, transport system design, policy deliberation, or implementation.

Innovation Outcomes

The study generated several simulation-based findings relevant to sustainable urban transportation.

- Mode Shift Potential: Behavioral modeling predicted that approximately 12% of private car users would shift to improved public transportation under the proposed scenarios.
- Traffic Performance: Average peak-hour travel speed along EDSA was projected to increase from 18.39 km/h to 21.32 km/h.
- Economic Benefits: Simulations indicated reductions in travel time and vehicle operating costs associated with increased public transport use.
- Environmental Benefits: Environmental costs were projected to decrease by approximately 36% through reductions in carbon dioxide (CO_2), nitrogen oxides (NO_x), and suspended particulate matter (SPM) emissions.

Although these results demonstrate the potential benefits of public transport improvements, all outcomes remained simulation-based and were not validated through pilot implementation or operational deployment.

Challenges and Sustainability Strategies

The study identified several methodological and institutional limitations. Major challenges included reliance on stated preference surveys, assumptions regarding constant travel costs despite improved service quality, exclusion of existing public transport users and lower-income commuters, and the absence of financial, political, and institutional feasibility analyses for Bus Rapid Transit implementation.

To strengthen future implementation, the study recommends the following: sustained investment in reliable, comfortable, and accessible public transportation; stronger policy support for modal shift and traffic management; continued integration of environmental sustainability into transport planning; and incorporation of transport modeling into long-term urban mobility planning. These recommendations provide strategic guidance but were not empirically evaluated within the study.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: The case demonstrates moderate structural configuration. Government agencies and the university maintained strong collaborative roles through research funding, policy alignment, and technical analysis, while community participation was limited to survey data provision. Industry actors were not substantively engaged.
- Functional Dimension: The case exhibits a moderate functional configuration. The study generated sophisticated analytical models supporting transport

planning and environmental assessment but did not progress to implementation, technology transfer, or institutional innovation.

- Relational Dimension: The relational dimension is low to moderate. Relationships primarily involved one-way flows of funding, transport data, and behavioral information toward university-led modeling activities. Collaborative planning, co-design, and long-term institutional partnerships among government, industry, and community actors were largely absent.

Case Summary

Overall, Case Study 18 demonstrates how government-supported academic research can provide rigorous analytical evidence for sustainable transportation planning through behavioral modeling and network simulation. The study illustrates strong university–government collaboration in producing decision-support tools for urban mobility and environmental management. However, the absence of implementation, institutional transformation, industry participation, and sustained multi-stakeholder collaboration limits the case to a conditionally included analytical study rather than a fully operationalized Quadruple Helix innovation system.

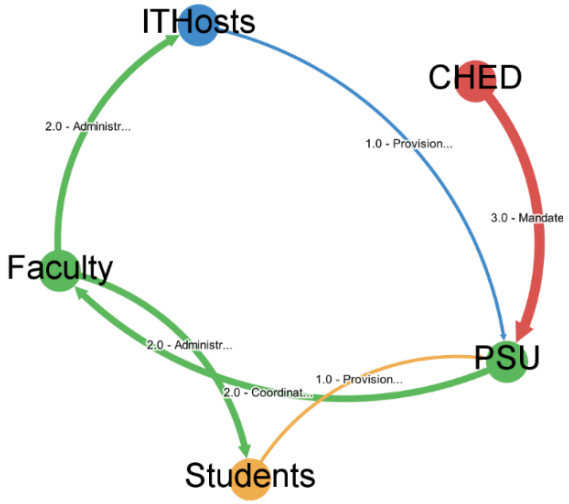
Case Study 19 (SID-a99): University–Industry Skills Alignment through IT Internships in the Philippines

This case examined a descriptive skills gap analysis that investigated the perceived importance of soft and hard skills among Information Technology (IT) internship students and their industry supervisors in the Philippines (Patacsil & Tablatin, 2017). Anchored in internship-based experiential learning, the study surveyed fourth-year Bachelor of Science in Information Technology (BSIT) students

and their corresponding workplace supervisors to identify differences between academic preparation and industry expectations. The findings were intended to inform curriculum enhancement and improve graduate employability.

The case was conditionally included because it provides empirically grounded evidence on university–industry alignment through internship-based learning but remains limited to descriptive educational evaluation. Although the study demonstrates structured interaction between universities and industry partners, it provides limited evidence of innovation co-production, policy implementation, or long-term institutional transformation. Figure 4.19 presents the documented network of interactions among participating actors.

Figure 4.19 Case Study 19 (SID-a99): Network visualization of actor interactions in a CHED-mandated internship and skills assessment system.



Note: Nodes represent Government, University, Industry, and Community actors involved in regulatory oversight, internship implementation, survey administration, and curriculum evaluation. Directed edges indicate reported relationships including regulatory enabling, methodological coordination, survey deployment, data provision, internship supervision, and curriculum recommendation development. Edge weights range from 1 to 3, where 3 denotes primary regulatory mandate and policy oversight (e.g., CHED), 2 denotes survey administration, research coordination, and internship facilitation, and 1 denotes provision of survey responses and skill assessment data. Directionality reflects flows of regulatory guidance, methodological input, and empirical data toward university-led evaluation processes. Government actors (CHED) provide regulatory mandates and structural frameworks for internship programs but are not directly involved in research, curriculum design, or evaluation activities. The university

(PSU and faculty) serves as the central knowledge producer, designing and implementing surveys, analyzing student–industry skill perceptions, and generating curriculum improvement recommendations. Industry partners act as internship supervisors and survey respondents, contributing skill feedback and hosting students in workplace settings. Students function as primary data providers through survey participation but are not engaged in co-creation processes. Community and broader civil society actors are absent. Overall, the network reflects a centralized, university-led evaluation system supported by regulatory internship structures and industry participation, characterized by largely transactional interactions and limited co-design, institutional integration, or long-term collaborative development.

Government Actors

Government participation was primarily regulatory and enabling. The Commission on Higher Education (CHED) established the policy framework requiring internship or On-the-Job Training (OJT) programs for Bachelor of Science in Information Technology (BSIT) and Bachelor of Science in Information Systems (BSIS) programs. These policies provided the institutional basis for university–industry internship partnerships examined in the study. Government support therefore consisted primarily of regulatory oversight through internship requirements and higher education standards. No government agency directly participated in the research design, survey implementation, curriculum evaluation, or development of curriculum improvement strategies. Likewise, the study presented no evidence that its findings informed national policy reforms or workforce development initiatives.

University Actors

The university served as the principal knowledge producer and analytical actor. Researchers from Pangasinan State University designed and validated the survey instrument, achieving Cronbach's alpha reliability coefficient of 0.833, administered questionnaires to IT interns and industry supervisors, and analyzed the resulting data using weighted mean analysis, skills-gap computation, ranking procedures, and one-way ANOVA. The study identified differences between student and employer

perceptions of workplace competencies and translated these findings into recommendations for curriculum enhancement and employability improvement. Nevertheless, the university's contribution remained primarily evaluative. The study did not demonstrate implementation of curriculum reforms, replication across multiple institutions, or institutionalization of the proposed recommendations beyond the host university.

Industry Actors

Industry partners participated primarily as internship supervisors and evaluative stakeholders. Workplace supervisors provided assessments of the importance of technical and soft skills required in professional environments while hosting student interns during their practical training. Their participation supplied practical workplace perspectives that complemented students' perceptions of employability competencies. However, industry involvement remained largely consultative. Employers did not participate in curriculum co-design, collaborative decision-making, joint educational planning, or long-term partnership mechanisms beyond internship supervision and survey participation.

Community Actors

Students functioned as the primary community participants. Fourth-year IT students contributed survey responses regarding their perceptions of workplace competencies and internship experiences. Their participation provided the empirical basis for comparison with industry supervisors but remained limited to data provision rather than active participation in curriculum development or institutional decision-making. Broader community organizations, professional associations, and civil society groups were not involved in the study.

Innovation Outcomes

The study generated several findings related to employability and curriculum alignment.

- Soft Skills Alignment: Students and industry supervisors demonstrated strong agreement regarding the importance of communication, teamwork, and interpersonal skills.
- Hard Skills Differences: Significant differences emerged between student and industry perceptions of technical competencies, with students assigning greater importance to hard technical skills than their workplace supervisors.
- Curriculum Feedback: The findings provided evidence supporting curriculum review and greater integration of workplace-relevant competencies within Information Technology programs.

Although these outcomes contribute to educational improvement, they remained advisory and perception-based. The study did not evaluate curriculum implementation, graduate performance, or long-term employability outcomes.

Challenges and Sustainability Strategies

The study identified several methodological and institutional limitations. Major challenges included the relatively small sample of 46 matched student–industry responses, concentration within a limited geographic area, reliance on self-reported perceptions, and the absence of longitudinal assessment of graduate outcomes or curriculum effectiveness.

To strengthen future university–industry collaboration, the study recommended: greater integration of soft skills throughout Information Technology curricula; stronger industry participation in curriculum planning and educational review; continued

enhancement of entry-level technical competencies aligned with workplace requirements; and broader assessment of employability outcomes across multiple institutions and industry sectors. These recommendations provide practical guidance but were not empirically evaluated within the study.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: The case demonstrates moderate structural configuration. Universities and industry partners interacted through internship programs and workplace supervision, while government participation was limited to regulatory oversight through CHED internship policies. Community participation consisted primarily of student respondents, and broader civil society involvement was absent.
- Functional Dimension: The case exhibits a moderate functional configuration. The study generated evidence supporting curriculum enhancement and employability assessment but did not demonstrate innovation development, technology transfer, policy implementation, or institutional transformation.
- Relational Dimension: The relational dimension is low to moderate. Relationships were primarily transactional, involving internship supervision and survey-based feedback. The study provided limited evidence of collaborative curriculum co-design, sustained partnership mechanisms, or long-term institutional learning among government, universities, industry, and community actors.

Case Summary

Overall, Case Study 19 demonstrates how internship-based collaboration can strengthen alignment between higher education and industry expectations through

systematic skills assessment. The study provides useful evidence for curriculum enhancement and employability planning by identifying differences between student and employer perceptions of workplace competencies. However, because collaboration remained primarily evaluative and advisory, with limited policy integration, innovation development, and long-term institutional collaboration, the case is conditionally included rather than representing a fully operationalized Quadruple Helix innovation system.

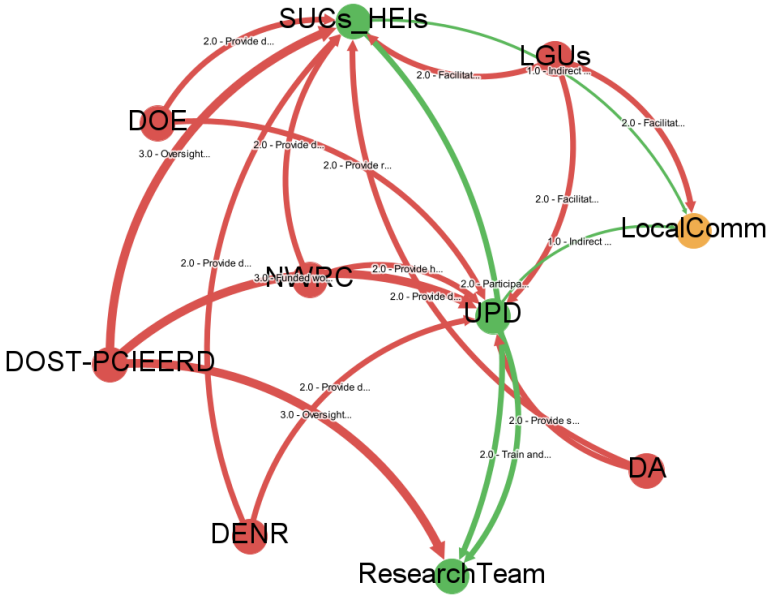
Case Study 20 (SID-a276): University–Government Collaboration for National Natural Resource Mapping Using LiDAR in the Philippines

This case examined a nationwide geospatial mapping initiative that integrated LiDAR and other remotely sensed data to produce high-resolution inventories of agricultural, coastal, forest, hydrological, and renewable energy resources in the Philippines (Blanco et al., 2015). Led by the University of the Philippines Diliman (UPD) in collaboration with 14 State Universities and Colleges (SUCs) and Higher Education Institutions (HEIs), the program aimed to address national gaps in environmental information, strengthen disaster risk reduction, and support evidence-based planning and resource management.

The case was conditionally included because it demonstrates strong university-led technological innovation, multi-institutional collaboration, and national capacity building but focuses primarily on methodological development and data production. While government–university collaboration was extensive, the study provides limited evidence of private-sector participation, commercialization, or direct community co-

production. Figure 4.20 presents the documented network of interactions among participating actors.

Figure 4.20. Case Study 20 (SID-a276): Network visualization of actor interactions in a national environmental and geospatial workflow development system.



Note: Nodes represent Government, University, and Community actors involved in funding, methodological standardization, workflow development, training, field data collection, and dataset dissemination. Directed edges indicate reported relationships including funding provision, strategic guidance, dataset sharing, workflow implementation, mentoring, and indirect community facilitation. Edge weights range from 1 to 3, where 3 denotes primary funding, strategic oversight, and national coordination (e.g., DOST-PCIEERD and related agencies), 2 denotes operational support, training, workflow implementation, and data provision, and 1 denotes indirect facilitation and downstream benefits to communities. Directionality reflects flows of funding, methodological direction, and data toward central university-led system development and implementation nodes. Government actors (DOST-PCIEERD and other NGAs such as DA, DENR, DOE, NWRC, and LGUs) provide funding, strategic guidance, datasets, and operational support for national-scale mapping initiatives. The University of the Philippines Diliman serves as the central knowledge producer, designing and standardizing geospatial workflows, developing high-resolution national mapping methodologies, training over 200 research assistants, and disseminating best practices across multiple universities. Other university actors and research teams support workflow implementation, field data collection, and capacity building. Community engagement is indirect, primarily mediated through LGUs and trained research assistants, with limited participatory or co-creative involvement. Industry participation is minimal. Overall, the network reflects a centralized, university-led national geospatial capacity-building system supported by strong multi-level government collaboration, emphasizing methodological innovation and workforce development but limited private-sector integration and direct community co-production.

Government Actors

Government agencies played central funding, coordination, and implementation support roles throughout the program. The Department of Science and Technology–Philippine Council for Industry, Energy, and Emerging Technology Research and Development (DOST-PCIEERD) provided primary funding, strategic oversight, and national program coordination. National government agencies, including the Department of Agriculture (DA), Department of Environment and Natural Resources (DENR), Department of Energy (DOE), National Water Resources Council (NWRC), and regional government offices, contributed secondary datasets, technical coordination, and institutional support for workflow implementation. Local government units (LGUs) supported field validation, local coordination, and implementation activities during data collection and verification. Government participation extended beyond regulatory oversight by providing financial resources, institutional coordination, technical datasets, and long-term support for national geospatial capability development. However, the study presented limited evidence of downstream policy implementation or institutional adoption beyond technical workflow integration.

University Actors

The University of the Philippines Diliman served as the principal knowledge producer, technical innovator, and national coordinating institution. UPD developed standardized methodologies for Agricultural Resource Mapping (PARMap), Coastal Resource Assessment (CoastMap), Forest Resource Extraction and Land Cover Systems (FRExLS), Philippine Hydrologic Dataset Development (PHD), and Renewable Energy Resource Mapping (REMaps). These workflows integrated LiDAR point clouds, orthophotographs, satellite imagery, Geographic Information Systems

(GIS), object-based image analysis, and Support Vector Machine (SVM) classification techniques. UPD also coordinated technical implementation across 14 partner universities through mentoring, workflow validation, technical supervision, biannual colloquia, and standardized training programs. More than 200 research assistants were trained in remote sensing, LiDAR processing, and geospatial analysis, strengthening national expertise in environmental mapping and spatial technologies.

These activities established a nationwide academic network supporting geospatial innovation and methodological harmonization. However, the study focused primarily on technical development and institutional capacity building rather than technology commercialization or large-scale knowledge transfer beyond government and academic institutions.

Industry Actors

Industry participation was minimal. Private-sector organizations did not play significant roles in workflow development, technical implementation, commercialization, or application of the mapping technologies. Consequently, the initiative demonstrated limited collaboration with commercial geospatial firms or private environmental service providers.

Community Actors

Community engagement occurred primarily through indirect institutional participation. Local government units facilitated field validation, local coordination, and implementation activities, while trained research assistants served as regional knowledge multipliers supporting data collection and institutional capacity development within participating universities and local implementation sites. Although communities benefited indirectly through improved environmental planning, disaster

risk reduction, and resource management, they did not participate directly in methodological development, workflow design, or collaborative decision-making.

Innovation Outcomes

The program generated several important technical and institutional outcomes.

- National Geospatial Datasets: High-resolution inventories of agricultural resources, coastal ecosystems, forests, hydrological systems, and renewable energy resources were produced for multiple regions across the Philippines.
- Methodological Innovation: Standardized LiDAR-based workflows integrating remote sensing, GIS, satellite imagery, and machine learning significantly strengthened national geospatial capability.
- Human Capital Development: More than 200 researchers received specialized training in LiDAR processing, remote sensing, and environmental mapping, expanding national technical expertise.
- Institutional Network Development: The initiative established a coordinated university–government network involving 15 higher education institutions that supported workflow standardization, collaborative implementation, and national knowledge sharing.

These outputs strengthened disaster risk reduction, environmental planning, and evidence-based governance while providing a foundation for future geospatial innovation. However, commercialization and broader industry utilization remained limited.

Challenges and Sustainability Strategies

The program encountered several technical and organizational challenges. Major challenges included varying levels of geospatial expertise across participating

universities, coordination of activities among 15 institutions distributed throughout the country, and maintaining methodological consistency during workflow implementation and validation.

To strengthen long-term sustainability, the program implemented: extensive mentoring and train-the-trainer programs; technical workshops and cluster-based colloquia for workflow harmonization; continuous collaboration among universities and government agencies; and institutional integration of datasets and standardized methodologies within participating organizations. These strategies emphasized institutional learning, workforce development, and technical sustainability rather than commercialization or market expansion.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: The case demonstrates a strong structural configuration. Universities and government agencies formed an extensive national collaboration network involving funding, technical implementation, dataset sharing, and workforce development. Community participation occurred indirectly through LGUs and trained research personnel, while industry participation remained minimal.
- Functional Dimension: The case exhibits strong functional configuration. The initiative generated standardized geospatial workflows, national environmental datasets, technological capability, and substantial human capital development supporting disaster risk reduction and environmental management. Nevertheless, evidence of commercialization, entrepreneurial activity, or large-scale policy innovation remained limited.
- Relational Dimension: The relational dimension is moderate to strong. Intensive collaboration occurred among universities, government agencies, research

assistants, and regional implementation teams through mentoring, technical supervision, workflow standardization, and knowledge-sharing activities. However, direct collaboration with private-sector organizations and community co-production remained relatively limited.

Case Summary

Overall, Case Study 20 demonstrates a highly coordinated university–government collaboration that significantly strengthened national geospatial capability through LiDAR-based environmental mapping, methodological innovation, and workforce development. The initiative established a nationwide research network supporting standardized resource assessment and evidence-based planning. However, because collaboration remained concentrated within government and academic institutions, with limited private-sector participation, commercialization, and direct community co-production, the case is conditionally included rather than representing a fully operationalized Quadruple Helix innovation system.

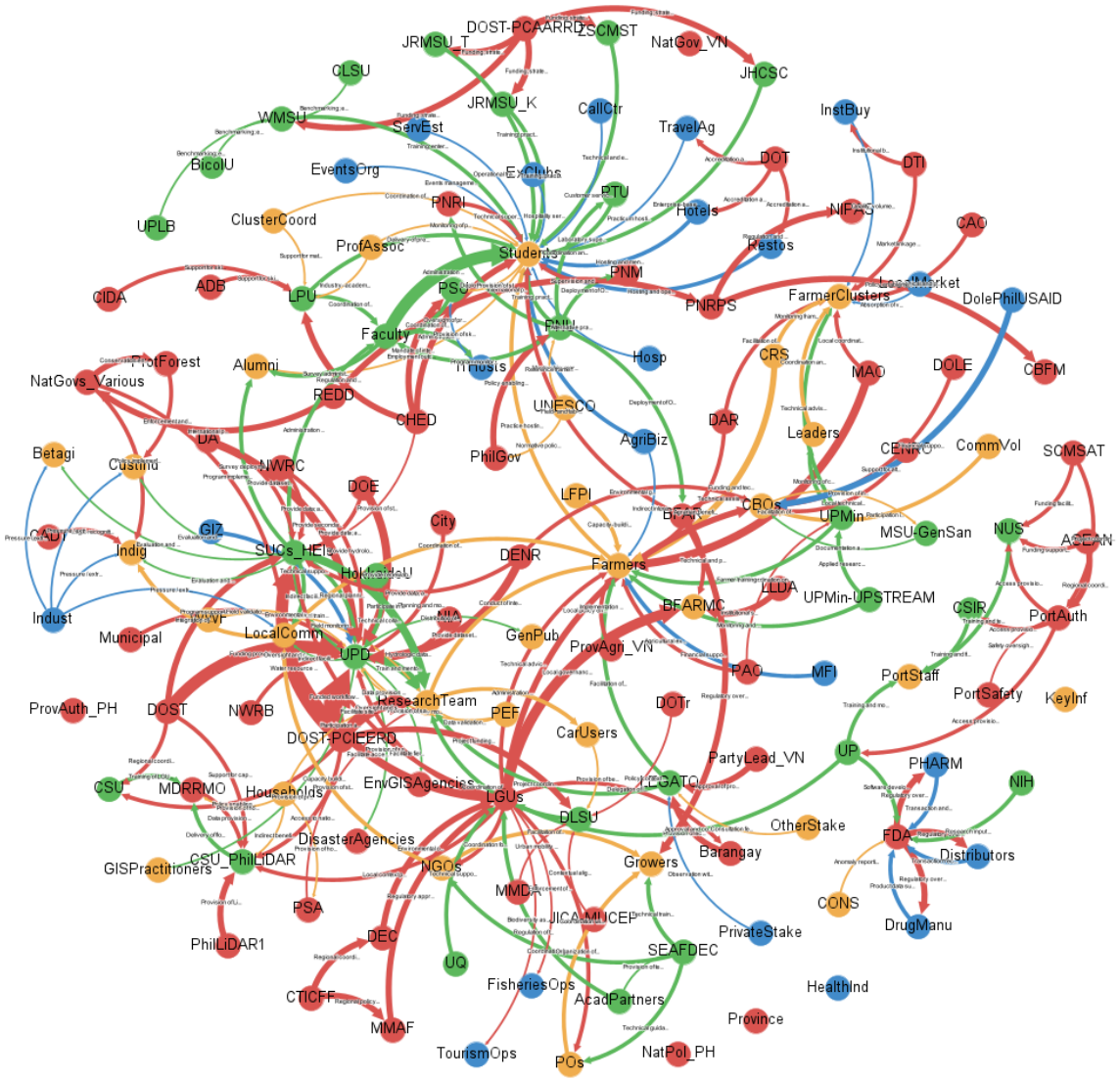
3. System-Level Interpretation of the Philippine Innovation Ecosystem (2013–2018): A Program-Driven, Semi-Operational Quadruple Helix Innovation System

The synthesis of the fully included cases (Cases 1–5) and the conditionally included cases (Cases 6–20) provides a comprehensive understanding of how the Quadruple Helix Innovation Model (QHIM) was manifested within the Philippine innovation ecosystem between 2013 and 2018, prior to the enactment of the Philippine Innovation Act (Republic Act No. 11293) and related national innovation policies. Collectively, the cases demonstrate that innovation during this period was driven primarily by interactions among government agencies, universities, industry actors, and, to varying degrees, community stakeholders. However, the strength, depth,

continuity, and institutionalization of these interactions varied substantially across sectors and innovation initiatives.

Figure 4.21 consolidates the twenty analytical cases and illustrates the distribution, intensity, and diversity of Quadruple Helix configurations identified across the meta-synthesis. This highlights considerable variation in the participation of government, universities, industry, and community actors across different innovation contexts. While all four helices were represented throughout the dataset, their relative influence and interaction patterns differed according to sectoral priorities, institutional arrangements, governance structures, and innovation objectives.

Figure 4.21. Case Studies 1–20 (2013–2018): Network visualization of actor interactions.



Note: This figure visualizes documented interactions among Government, University, Industry, and Community actors across Cases 1–20. Nodes represent institutional actors and their roles in coordination, knowledge production, regulation, implementation, commercialization, service delivery, and community participation. Directed edges represent reported relationships, including funding, policy and regulatory oversight, technical training, technology transfer, data sharing, capacity building, implementation support, and market linkage. Edge weights range from 1 to 3, where 3 indicates strategic coordination, primary funding authority, or regulatory leadership; 2 denotes structured operational collaboration such as implementation, training, and technology transfer; and 1 represents supporting interactions including consultation, data provision, documentation, or indirect facilitation. Edge direction indicates the flow of authority, resources, technical expertise, or information, with feedback loops shown where reported. Cases 1–5 exhibit the strongest Quadruple Helix Innovation Model (QHIM) configurations, characterized by institutionalized collaboration among government, universities, industry, and community actors through coordinated funding, knowledge generation, commercialization, implementation, and

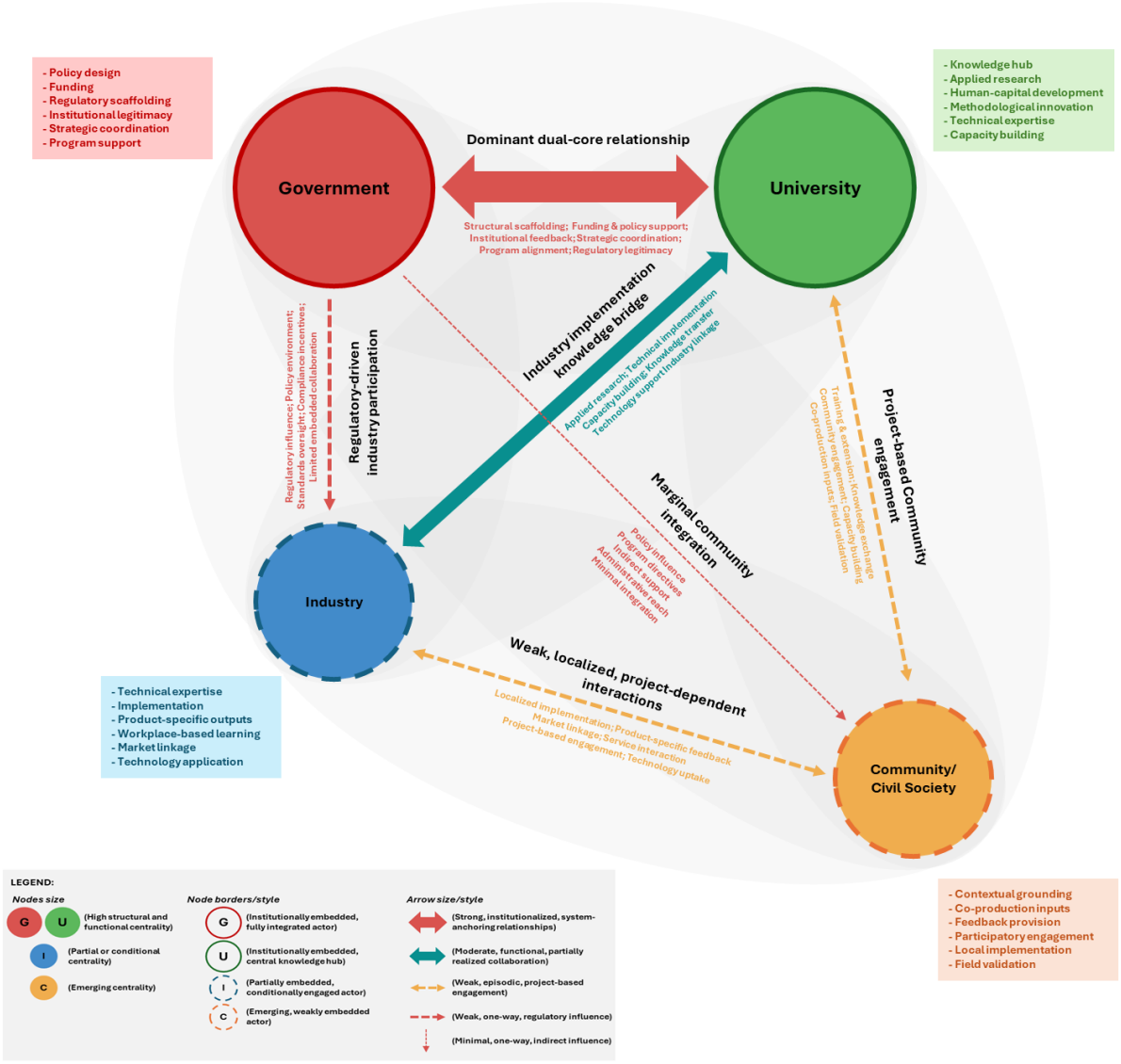
community participation. Cases 6–20 extend these interactions across multiple sectors but generally reflect more centralized, government- and university-led configurations in which industry participation is largely sector-specific and community involvement is primarily implementation-, validation-, or data-oriented. Overall, this shows that the Philippine innovation ecosystem during 2013–2018 was predominantly program-driven and institutionally anchored, with government and universities serving as the principal drivers of innovation, while industry and community participation varied across sectors and initiatives. Collectively, the cases depict a pre-policy, semi-operational Quadruple Helix innovation system characterized by strong public–academic coordination, uneven industry engagement, and emerging but variably institutionalized community participation. For detailed descriptions and complete network visualizations, refer to the individual case studies.

Building upon these empirical patterns, Figure 4.22 synthesizes the overall system configuration emerging from the twenty analytical cases. It presents a conceptual representation of the Philippine innovation ecosystem before the implementation of formal national innovation policies. Together, Figures 4.21 and 4.22 move from case-level evidence toward a system-level interpretation of the structural, functional, and relational characteristics of the Philippine Quadruple Helix during the pre-policy period.

Viewed through the Quadruple Helix perspective, the Philippine innovation ecosystem during 2013–2018 exhibited the essential structural components of an innovation system but had not yet achieved the institutional integration characteristic of a mature Quadruple Helix ecosystem. Government agencies, universities, industry actors, and community participants were identifiable across the cases; however, their interactions varied considerably in terms of intensity, reciprocity, continuity, and institutional embeddedness. In many initiatives, collaboration remained focused on technology transfer, technical assistance, administrative coordination, or project implementation rather than sustained co-creation, shared governance, or institutionalized innovation partnerships. Consequently, knowledge generation, innovation diffusion, and capacity-building frequently remained sector-specific,

geographically localized, or project-dependent rather than becoming systematically embedded within a coherent national innovation ecosystem.

Figure 4.22 System-Level Interpretation of the Philippine Innovation Ecosystem (2013–2018): A Program-Driven, Semi-Operational Quadruple Helix Innovation System.



Note: This diagram presents a system-level interpretation of the Philippine innovation ecosystem prior to the enactment of the Philippine Innovation Act (Republic Act No. 11293) and related national innovation policies. Four primary actors are represented as color-coded nodes: Government (red), Universities (green), Industry (blue), and Communities/Civil Society (orange). Node size indicates relative structural and functional centrality, while solid borders represent strongly embedded actors and dashed borders indicate comparatively weaker or emerging institutional participation.

Arrows represent the intensity and direction of interactions among the four helices. Thick solid arrows indicate strong institutionalized collaboration involving policy, funding, knowledge production, and implementation; medium solid arrows denote sustained operational collaboration such as applied research, technology transfer, commercialization, and capacity building; thin dashed arrows represent project-based or context-dependent interactions including technology adoption, consultation, implementation, and user feedback; and very thin dashed arrows indicate indirect or limited influence. Arrow colors correspond to the actor providing the primary source of authority, knowledge, funding, or technical resources. Overall, this illustrates a pre-policy, semi-operational Quadruple Helix innovation system characterized by strong government–university coordination, moderate industry engagement, and uneven but emerging community participation. Innovation was primarily program-driven and institutionally coordinated, with collaboration occurring through formal projects and organizational arrangements rather than fully integrated, co-creative innovation ecosystems.

This pattern reflects broader observations that Quadruple Helix systems evolve according to their institutional context rather than following a universal organizational model. Administrative traditions, governance arrangements, regulatory environments, organizational capacities, and sectoral priorities shape how actors perform their innovation roles and interact within the broader system (Cai, 2015). Across the Philippine cases, government agencies and universities consistently occupied dominant coordinating and knowledge-producing positions, whereas industry participation varied according to commercialization opportunities and sectoral demand. Community participation similarly ranged from active co-production and local implementation to passive service utilization or consultation. Although community engagement was increasingly recognized as important for innovation, it remained unevenly institutionalized across the cases.

Experiences from other emerging economies reinforce this interpretation. The Quadruple Helix assumes institutional capacities that enable sustained collaboration among government, academia, industry, and society. However, where innovation intermediaries, commercialization mechanisms, participatory governance structures, and collaborative networks remain underdeveloped, innovation interactions often

become policy-driven, administratively coordinated, or project-based rather than continuously embedded within self-sustaining innovation ecosystems (Wongwanich, 2022). The Philippine cases between 2013 and 2018 largely reflect this developmental stage. Institutional structures were already evident, innovation activities occurred across multiple sectors, and cross-sector collaboration was emerging; however, collaborative relationships had not yet consistently matured into enduring innovation networks capable of sustaining system-wide transformation.

The fully included analytical cases (Cases 1–5) demonstrate the strongest manifestation of the Quadruple Helix Innovation Model. Across these initiatives, government agencies provided strategic leadership through policy direction, funding, regulatory support, and implementation coordination. Universities functioned as principal knowledge producers, technology developers, innovation intermediaries, and human capital developers. Industry actors translated research outputs into commercialization, production systems, technological deployment, and enterprise development, while community actors actively participated through co-production, livelihood development, technology adoption, service delivery, user feedback, and market utilization.

Within these mature cases, the structural, functional, and relational dimensions of the Quadruple Helix were closely aligned. Institutional roles were clearly differentiated yet mutually reinforcing. Government created enabling environments; universities generated scientific knowledge and technological innovation; industry facilitated commercialization and operational scaling; while community actors strengthened contextual relevance, technology adoption, societal value creation, and continuous feedback. Repeated interaction fostered trust, enhanced knowledge exchange, and supported sustained innovation across organizational boundaries.

These cases therefore demonstrate that community participation extends beyond beneficiary status to become an integral component of innovation governance, implementation, and evaluation, consistent with contemporary Quadruple Helix theory emphasizing inclusive governance and societal co-creation (Huang, 2025).

Moreover, these integrated configurations resemble platform-based innovation ecosystems in which governance structures, enabling infrastructure, and iterative feedback mechanisms facilitate continuous knowledge recombination, adaptive learning, and collaborative problem-solving (Chen et al., 2026). Their interaction patterns also parallel transdisciplinary sustainability systems that emphasize shared learning, negotiated governance arrangements, and long-term institutional collaboration while acknowledging existing power asymmetries among participating actors (Gugerell et al., 2023). Importantly, coordination strengthened rather than displaced the agency of individual actors, enabling each helix to contribute according to its comparative institutional strengths rather than functioning under centralized institutional control (Nandhlal & Kabanda, 2026).

In contrast, the conditionally included analytical cases (Cases 6–20) reveal substantially weaker Quadruple Helix integration. Structural relationships remained concentrated primarily between government agencies and universities, reflecting their formal mandates, organizational capacities, and access to public resources. Industry participation frequently remained limited to technology adoption, compliance, infrastructure provision, or service utilization, while community actors commonly participated as end-users, beneficiaries, respondents, or data providers rather than active innovation partners. Consequently, although all four helices could often be identified, their participation remained uneven and lacked the reciprocity, co-creation, and collaborative governance characteristic of mature Quadruple Helix systems.

Functionally, these initiatives generated important outputs including applied research, technical systems, digital platforms, capacity-building programs, extension services, and administrative innovations. However, these outputs rarely progressed toward broader institutional transformation, commercialization, policy integration, or sustainable innovation ecosystems. Similar findings have been reported in peripheral innovation systems where innovation performance improves substantially when firms actively collaborate with universities and broader innovation networks rather than relying primarily on government-led interventions (Natário et al., 2012). Additionally, efficiency studies demonstrate that merely assembling innovation actors does not guarantee effective innovation; complementary capabilities must be deliberately integrated through sustained collaboration and institutional coordination (Fidanoski et al., 2022).

Relationally, interactions within the conditionally included cases remained predominantly bilateral or hierarchical, particularly between government agencies and universities. Community participation was frequently consultative or transactional rather than collaborative, while industry actors often functioned as implementers, service providers, or regulatory subjects instead of strategic innovation partners. These interaction patterns constrained iterative learning, shared governance, hybrid institutional development, and long-term innovation capability that characterize mature Quadruple Helix systems (Ranga & Etzkowitz, 2013). Broader international analyses similarly suggest that without adaptive cross-sector coordination and balanced participation among helices, innovation systems remain fragmented despite substantial institutional investment (Lawton Smith & Leydesdorff, 2014).

Taken together, the twenty analytical cases portray a pre-policy, semi-operational Quadruple Helix innovation system. Government agencies and

universities consistently supplied the structural foundations and much of the functional capacity for innovation, while industry and community actors were incorporated unevenly across initiatives. Consequently, many innovation outcomes remained project-specific, geographically localized, and institutionally dependent rather than becoming self-reinforcing components of a coordinated national innovation ecosystem.

This interpretation aligns closely with research emphasizing that transformative innovation requires institutionalized multi-actor governance, structured co-creation, and sustained stakeholder participation rather than isolated project collaboration (Caro-Gonzalez et al., 2025). Similarly, policy integration research argues that innovation systems require clearly defined governance arrangements, coherent actor roles, shared implementation frameworks, and long-term institutional capacity rather than policy coordination alone (Cairney, 2025). Evidence from Global South innovation networks likewise demonstrates that centralized governance, fragmented collaboration, and weak inclusion of peripheral actors constrain knowledge diffusion and innovation upgrading (Aza-Mengoa et al., 2025). Philippine digital transformation initiatives further illustrate that successful scaling depends not only on technological investment but also on interoperability, institutional coordination, and sustained cross-sector collaboration (WorldBank, 2022).

Research on collaborative governance similarly demonstrates that long-term innovation depends upon trust, shared objectives, interdependence, mutual learning, and visible collective achievements rather than isolated incentives or temporary partnerships (Turkelboom et al., 2026). Leadership studies likewise emphasize that adaptive, communicative, and collaborative leadership capacities are fundamental for sustaining innovation ecosystems over time (Aquino et al., 2025). Across the

Philippine cases, institutional leadership was consistently evident; however, distributed leadership and genuinely collaborative governance remained uneven.

Overall, the evidence indicates that successful Quadruple Helix innovation is neither automatic nor guaranteed by the mere presence of multiple actors. Sustainable innovation requires alignment among structural arrangements, functional capacities, relational networks, and governance mechanisms across government, universities, industry, and communities. Without deliberate institutional design, sustained collaborative platforms, effective knowledge exchange, and coherent policy integration, innovation remains incremental, localized, and highly dependent on individual projects.

The Philippine innovation ecosystem during 2013–2018 can therefore be characterized as a pre-policy, semi-operational Quadruple Helix innovation system. Government agencies and universities served as the principal institutional drivers of innovation, while industry and community participation remained uneven and frequently under-institutionalized. Nevertheless, the analytical cases demonstrate that the essential structural foundations for a mature Quadruple Helix ecosystem had already begun to emerge prior to the implementation of the Philippine Innovation Act and related national innovation policies. These pre-policy characteristics establish the analytical baseline against which the post-policy innovation ecosystem (2020–2025) can be examined, enabling a systematic assessment of how subsequent policy reforms influenced the structural, functional, and relational evolution of the Philippine Quadruple Helix innovation system.

B. ANALYTICAL CASE STUDIES (2020–2025)

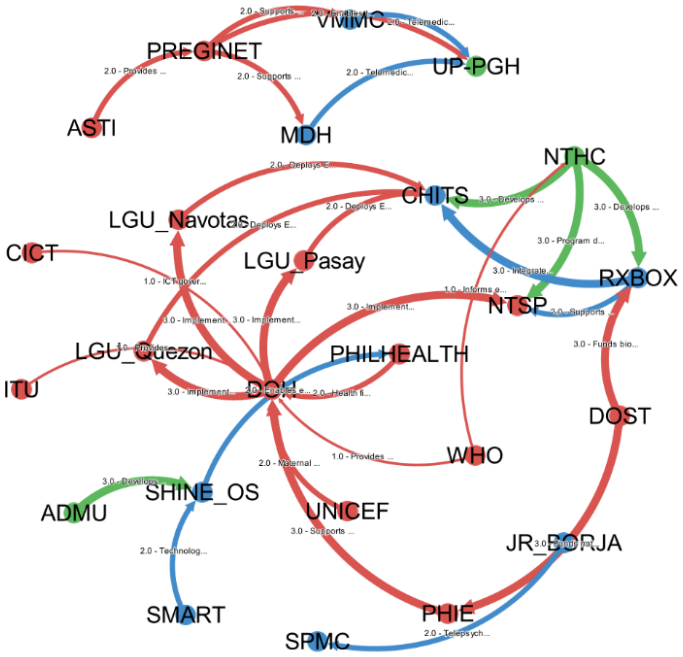
1. Studies that fully satisfied the inclusion criteria (2020-2025)

Case Study 1 (SID-b100): National eHealth System Integration through Government–University–Industry–Community Collaboration

This analytical case examined a nationally coordinated e-Health and telemedicine initiative that operationalizes structured collaboration among government, universities, industry, and healthcare institutions through formal programs, interoperable digital platforms, and institutionalized implementation mechanisms (Lu & Marcelo, 2021). The initiative integrated the National Telehealth Service Program (NTSP), the Community Health Information Tracking System (CHITS), the RxBox biomedical device, and the Philippine Health Information Exchange (PHIE), creating a centralized yet multi-level digital health ecosystem supporting healthcare delivery, information exchange, and national health governance.

The case fully satisfied the inclusion criteria because it demonstrated institutionalized collaboration among the four Quadruple Helix actors through clearly defined governance structures, interoperable technologies, sustainable funding mechanisms, and nationwide implementation. Government agencies provided policy leadership and funding, universities developed and integrated digital health technologies, industry supported technological deployment and telecommunications infrastructure, while hospitals, local government units, and healthcare providers operationalized health services within communities. Figure 4.23 presents the documented network of interactions among participating actors.

Figure 4.23. Case Study 1 (SID-b100): Network visualization of actor interactions in the Philippine eHealth system.



Note: Nodes represent Government, University, Industry, and infrastructure actors involved in policy, development, and service delivery, with roles and engagement levels defined by their function in the system. Directed edges represent reported relationships such as funding, regulation, system development, technical integration, infrastructure provision, interoperability support, and clinical deployment. Edge weights range from 1 to 3, where 3 indicates policy authority, funding, and formal program coordination; 2 indicates operational collaboration in development and implementation; and 1 indicates auxiliary support such as training or deployment assistance. Government actors (DOH, DOST, PHILHEALTH, and related agencies) provide central coordination through national programs (NTSP, PHIE), funding, and ICT infrastructure (e.g., PREGINET, ASTI). Universities (NTHC, ADMU, UP-PGH) act as system developers and knowledge producers, supporting CHITS/RxBox development, EMR systems, and training. Industry actors (SHINE OS+, SMART) and hospitals support infrastructure, telemedicine deployment, and clinical implementation. Overall, the network reflects a strongly institutionalized Triple Helix system with coordinated national-level governance, integrated development processes, and sustained collaboration across government, university, and industry actors.

Government Actors

Government agencies functioned as policy leaders, regulators, funders, and national implementation coordinators. The Department of Health (DOH) led implementation of the National Telehealth Service Program (NTSP) and coordinated

deployment of the Community Health Information Tracking System (CHITS) across multiple local government units (LGUs). The Department of Science and Technology (DOST) funded the development of RxBox and the Philippine Health Information Exchange (PHIE), supporting national biomedical device innovation and health information interoperability. The Philippine Health Insurance Corporation (PhilHealth) strengthened digital financing through the integration of electronic claims (eClaims), while the Advanced Science and Technology Institute (ASTI) and the Philippine Research, Education and Government Information Network (PREGINET) provided the ICT backbone that supports nationwide telemedicine connectivity. International organizations, including the World Health Organization (WHO), the International Telecommunication Union (ITU), and UNICEF, contributed strategic guidance and technical support during program development. Government participation extended well beyond regulation by establishing national digital health programs, providing sustained funding, developing ICT infrastructure, integrating health financing systems, and coordinating nationwide implementation.

University Actors

Universities served as the principal knowledge producers, technology developers, technical integrators, and specialist service providers. The National Telehealth Center (NTHC) developed CHITS and RxBox, coordinated technical implementation, and supported deployment of the National Telehealth Service Program. Ateneo de Manila University developed SHINE OS+, supporting electronic medical records and PhilHealth eClaims integration. The Philippine General Hospital (UP-PGH) served as a national telemedicine referral center, providing specialist consultations and collaborating with Manila Doctors Hospital, Veterans Memorial Medical Center, JR Borja General Hospital, and Southern Philippines Medical Center

on telemedicine services and workforce training. Universities therefore assumed roles extending beyond research by designing interoperable health systems, supporting nationwide implementation, providing specialist healthcare services, and strengthening technical capacity across the health sector.

Industry Actors

Industry actors provided technological infrastructure, interoperability support, and clinical implementation. SHINE OS+ enabled integration of electronic medical records with PhilHealth eClaims, while Smart Communications supported telecommunications infrastructure required for telemedicine connectivity. RxBox technologies facilitated integration of biomedical monitoring data into CHITS and NTSP workflows. Healthcare technology providers and participating hospitals contributed to system deployment by supporting telemedicine implementation, specialist referral systems, digital health integration, and clinical technology adoption. Industry participation therefore reflected sustained operational collaboration in digital infrastructure, health technology deployment, interoperability, and service delivery rather than isolated technology provision.

Community Actors

Community actors served as the primary operational users and beneficiaries of the national eHealth ecosystem. Local government units coordinated implementation of telehealth services within their jurisdictions, while hospitals, healthcare professionals, and referral centers delivered telemedicine services through the integrated digital health infrastructure. Patients and local communities benefited through expanded access to specialist consultations, improved continuity of care, electronic health records, and enhanced health service accessibility. Community

participation was institutionalized through repeated interaction among LGUs, hospitals, healthcare workers, referral centers, and patients, making community actors active participants in healthcare delivery rather than passive recipients of innovation.

Innovation Outcomes

The initiative generated several important institutional and technological outcomes.

- National eHealth Programs: NTSP and PHIE established formal governance mechanisms supporting nationwide digital health implementation and interoperability.
- Integrated Digital Health Systems: CHITS, RxBox, SHINE OS+, and PhilHealth eClaims were successfully integrated into coordinated clinical, administrative, and financing workflows.
- National ICT Infrastructure: ASTI and PREGINET established the communication backbone supporting telemedicine connectivity among hospitals, universities, LGUs, and government agencies.
- Nationwide Telemedicine Services: Telemedicine services were operationalized across hospitals and LGUs through coordinated referral systems and specialist consultation networks.
- Institutionalized Cross-Sector Collaboration: Sustained collaboration among government agencies, universities, hospitals, ICT providers, and healthcare institutions strengthened interoperability, technical integration, and workforce development throughout the Philippine health system.

Together, these outcomes demonstrate the institutionalization of a national digital health ecosystem supporting coordinated healthcare delivery and evidence-based governance.

Challenges and Sustainability Strategies

Although early implementation encountered connectivity limitations, infrastructure constraints, and interoperability challenges, these issues were progressively addressed through institutional integration and national program development.

Major sustainability mechanisms included: institutionalization through NTSP and PHIE; sustained government funding; integration with PhilHealth financing and eClaims systems; nationwide ICT infrastructure through ASTI and PREGINET; recurring implementation across LGUs and healthcare institutions; continuous workforce development and telemedicine training; and national governance through the National eHealth Steering Committee. These mechanisms strengthened institutional resilience and reduced dependence on isolated pilot initiatives by embedding digital health systems within national healthcare governance.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: The case demonstrates a strong structural configuration. Government agencies provide policy leadership, funding, regulation, and national coordination; universities function as technology developers and knowledge producers; industry supplies digital health technologies, telecommunications infrastructure, and interoperability solutions; while community actors, including LGUs, hospitals, healthcare professionals, and patients, support implementation and service delivery. These complementary

roles are institutionalized through formal national programs and interoperable ICT infrastructure.

- Functional Dimension: The case exhibits a strong functional configuration. Government policy, university-generated digital innovations, industry-supported technological deployment, and community-based healthcare implementation are fully integrated into a coordinated national eHealth system. The initiative combines telemedicine, electronic medical records, biomedical devices, health information exchange, insurance integration, specialist referral systems, and workforce development within a single operational ecosystem.
- Relational Dimension: The relational dimension is strong. Sustained collaboration occurs through NTSP implementation, PHIE interoperability, CHITS–RxBox integration, PhilHealth eClaims, PREGINET-enabled telemedicine, specialist referral networks, hospital partnerships, and recurring training activities. Continuous interaction among government agencies, universities, industry partners, hospitals, LGUs, healthcare professionals, and patients demonstrates mature institutional embeddedness and long-term collaborative governance.

Case Summary

Overall, Case Study 1 demonstrates a mature Quadruple Helix innovation system for digital health in the Philippines. Government agencies provide strategic leadership; universities develop and integrate health technologies; industry delivers digital infrastructure and operational technologies; and community actors, including hospitals, LGUs, healthcare providers, and patients, support implementation and service delivery. The resulting ecosystem extends beyond individual projects to institutionalize national governance, interoperable digital health platforms, and

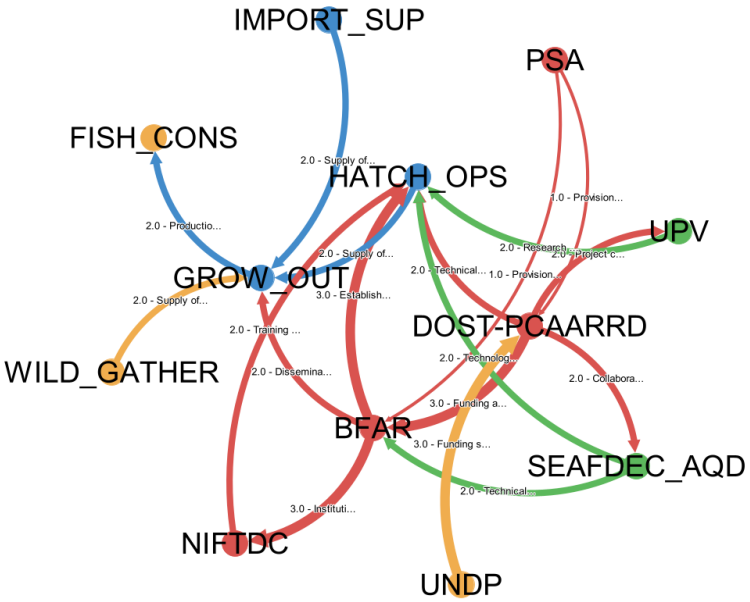
sustained cross-sector collaboration, representing one of the strongest examples of a fully operationalized Quadruple Helix innovation system identified in this meta-synthesis.

Case Study 2 (SID-b171): Integrated Aquaculture Innovation and Commercialization through Government–University–Industry–Community Collaboration

This analytical case examined a nationally coordinated aquaculture innovation and commercialization initiative focused on milkfish (bangus) hatchery development, fry production, and downstream integration into the aquaculture value chain in the Philippines (Garcia et al., 2020). Implemented through the GAINEX project, the initiative integrates broodstock research, hatchery technology development, technical training, commercialization, and production support to strengthen national aquaculture productivity while reducing dependence on wild fry collection.

The case fully satisfied the inclusion criteria because it demonstrates institutionalized collaboration among government agencies, research institutions, industry actors, and community stakeholders through formal funding mechanisms, coordinated technology transfer, structured capacity-building programs, and integrated commercialization pathways. Government agencies provide policy leadership, funding, regulation, and technical extension; universities and research institutions generate and validate aquaculture technologies; industry actors commercialize and scale hatchery production; while community stakeholders participate in production, livelihood activities, and market utilization. Figure 4.24 presents the network visualization, documenting interactions among participating actors.

Figure 4.24. Case Study 2 (SID-b171): Network visualization of interactions in the Philippine milkfish hatchery innovation system.



Note: Nodes represent Government, University, and Industry actors involved in aquaculture R&D, regulation, commercialization, and production, with roles and engagement levels defined by their function in the innovation chain. Directed edges represent reported relationships such as funding, coordination, research collaboration, technology transfer, training, regulatory oversight, production linkage, and market exchange. Edge weights range from 1 to 3, where 3 indicates funding, formal coordination, and regulatory authority; 2 indicates operational collaboration such as technology transfer, training, and production linkage; and 1 indicates auxiliary or market-level interactions. Government actors (DOST-PCAARRD, BFAR, PSA) lead funding, coordination, statistical planning, regulatory oversight, and training through national programs such as GAINEX and NIFTDC. University/research actors (SEAFDEC-AQD, UP Visayas) provide support for broodstock research, hatchery technology development, and pilot implementation. Industry actors (hatchery operators, grow-out operators, fry suppliers, wild fry gatherers, and consumers) implement commercialization, production, and market absorption of aquaculture outputs. Overall, the network reflects a strongly institutionalized Triple Helix configuration with an end-to-end innovation pipeline from research to commercialization. It is characterized by formal funding structures, coordinated technology transfer, and sustained multi-actor linkages across government, university, and industry in aquaculture development.

Government Actors

Government agencies functioned as policy leaders, funders, regulators, and implementation coordinators within the national aquaculture innovation system. The Department of Science and Technology–Philippine Council for Agriculture, Aquatic and

Natural Resources Research and Development (DOST–PCAARRD) provided strategic funding, coordinated the GAINEX project, and aligned research activities with national fisheries innovation priorities. The Bureau of Fisheries and Aquatic Resources (BFAR) served as the principal implementation agency responsible for hatchery establishment, technology dissemination, regulatory oversight, and technical extension.

Through the National Integrated Fisheries Technology Development Centre (NIFTDC), BFAR implemented structured training programs on hatchery management, larval rearing, and aquaculture production, facilitating the transfer of research outputs into commercial practice. The Philippine Statistics Authority (PSA) supported planning through production and pricing datasets, while the United Nations Development Programme (UNDP) provided complementary development assistance. Together, these institutions integrated research funding, technical extension, capacity building, technology dissemination, and national fisheries development within a coordinated governance framework.

University Actors

Research institutions served as the primary knowledge producers and technology developers within the aquaculture innovation system. The SEAFDEC Aquaculture Department (SEAFDEC-AQD) led broodstock research, hatchery technology development, pilot hatchery operations, and technical validation of milkfish production systems while providing technical advisory services to hatchery operators and government implementation programs. The University of the Philippines Visayas (UPV) collaborated on applied research, localized technology validation, and the pilot implementation of hatchery innovations, thereby strengthening the transition from experimental research to operational deployment. Together, SEAFDEC-AQD and UPV

generated hatchery technologies, validated production systems under field conditions, supported technology transfer, and linked research outputs with commercialization and national aquaculture development.

Industry Actors

Industry actors translated research outputs into commercial aquaculture production and market distribution. Hatchery operators produced and distributed hatchery-bred milkfish fry, while grow-out operators used these fry in commercial aquaculture systems to supply domestic markets. Imported fry suppliers from Indonesia and Taiwan continued to provide alternative fry sources alongside hatchery production systems. Continuous interaction between research institutions, government extension services, and commercial operators supported technology adoption, production expansion, and commercialization. Industry participation therefore operationalized the research and training outputs generated through the GAINEX project across the aquaculture value chain.

Community Actors

Community participation remained evident throughout the aquaculture production system. Wild fry gatherers continued to contribute naturally collected fry to coastal communities while consumers served as end-users of aquaculture products. Household participation in fry gathering and aquaculture-related livelihood activities reflected the continued importance of local communities alongside emerging hatchery-based production systems. Although formal civil society organizations were not explicitly identified, community stakeholders remained integrated within the innovation system through livelihood activities, traditional fisheries practices, and local market participation, illustrating the coexistence of conventional resource users with modern hatchery technologies.

Innovation Outcomes

The initiative generated several important technological, institutional, and production outcomes.

- National Aquaculture Innovation Program: GAINEX established a coordinated framework integrating research, funding, commercialization, technical training, and technology dissemination.
- Integrated Research-to-Commercialization Pipeline: Broodstock research and hatchery innovations developed by SEAFDEC-AQD and UPV were systematically transferred to commercial hatchery operators through BFAR extension programs.
- Transformation of Fry Production Systems: The initiative promoted a gradual transition from dependence on wild-caught fry toward reliable hatchery-based production, improving production stability and supply security.
- Technical Capacity Development: BFAR, through NIFTDC, institutionalized technical training supporting hatchery management, larval production, and aquaculture operations.
- Hybrid Production Ecosystem: Hatchery operators, imported fry suppliers, and traditional wild fry gatherers coexisted within a diversified production system combining technological modernization with established livelihood practices.
- Evidence-Based Sector Planning: PSA production and pricing datasets strengthened planning, research prioritization, and fisheries policy development.
- Institutionalized Cross-Sector Collaboration: Continuous collaboration among government agencies, universities, industry operators, and community

stakeholders strengthened technology transfer, commercialization, and aquaculture production.

Challenges and Sustainability Strategies

Despite strong institutional coordination, several challenges remained. The continued coexistence of hatchery-based production, imported fry suppliers, and traditional wild fry collection reflected incomplete technological substitution and competition among multiple fry supply systems. Dependence on project-based funding and sustained inter-agency coordination also presented long-term institutional challenges.

To strengthen sustainability, the initiative institutionalized technical training through NIFTDC, embedded implementation mechanisms within BFAR, maintained long-term research collaboration between SEAFDEC-AQD and UPV, and established formal technology dissemination pathways linking research institutions with commercial producers. These mechanisms supported institutional continuity and embedded aquaculture innovation within broader national fisheries governance.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: The case demonstrates a highly institutionalized Quadruple Helix structure. Government agencies provide policy leadership, funding, regulation, and technical extension; universities generate scientific knowledge and hatchery technologies; industry actors commercialize innovations through hatchery and grow-out production; and community stakeholders participate through fisheries livelihoods and product utilization. These complementary roles are coordinated through GAINEX, BFAR, NIFTDC, and long-standing research partnerships.

- Functional Dimension: Functional integration is evident across the entire aquaculture value chain. Government policy, university-led research, commercial production, technical extension, workforce development, and community participation collectively support broodstock development, hatchery technology, commercialization, production, and market distribution within a coordinated national innovation system.
- Relational Dimension: Relationships among actors are strong and sustained through coordinated research, technology transfer, technical advisory services, hatchery training, commercialization partnerships, and production linkages. Vertical collaboration supports the transfer of innovation from research institutions to commercial production, while horizontal interaction occurs among hatchery operators, grow-out producers, traditional fry gatherers, and market participants, reflecting an institutionalized innovation ecosystem.

Case Summary

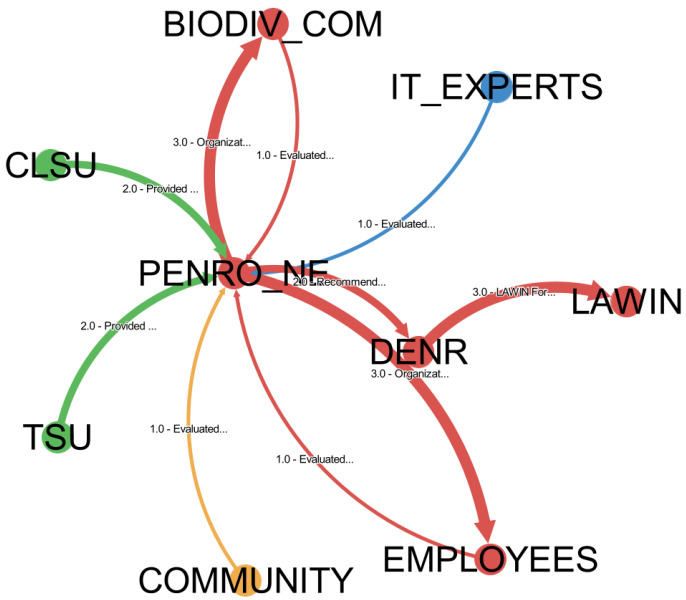
Overall, Case Study 2 demonstrates a mature Quadruple Helix innovation system supporting Philippine aquaculture development. Government agencies coordinate funding, regulation, and technical extension; universities generate and validate hatchery technologies; industry actors commercialize research outputs through integrated production systems; and community stakeholders participate through fisheries livelihoods and product utilization. Together, these actors form an institutionalized innovation ecosystem that supports research, technology transfer, commercialization, workforce development, and sustainable aquaculture production, making this one of the strongest examples of a fully operationalized Quadruple Helix configuration identified in this meta-synthesis.

Case Study 3 (SID-b247): ICT-enabled biodiversity governance and multi-level environmental monitoring through state-led digital infrastructure

This analytical case examined an ICT-enabled environmental governance system implemented in Nueva Ecija, Philippines, to strengthen biodiversity monitoring, environmental data management, and evidence-based decision-making through digital technologies (Milagroso, 2020). The initiative integrated a biodiversity information system operated by the Provincial Environment and Natural Resources Office (PENRO–Nueva Ecija) with institutional support from the Department of Environment and Natural Resources (DENR) and linkage to the LAWIN Forest and Biodiversity Protection System, creating a coordinated digital platform for environmental governance.

The case fully met the inclusion criteria because it demonstrates institutionalized collaboration among government agencies, universities, technical experts, and community users through formal governance structures, integrated ICT infrastructure, continuous system evaluation, and recurring environmental monitoring. Government agencies provided ownership, policy coordination, and operational management; universities contributed technical and methodological expertise; ICT experts supported system evaluation and quality assurance; while community actors participated through system utilization and usability validation. Figure 4.25 presents the network visualization, documenting interactions among participating actors.

Figure 4.25. Case Study 3 (SID-b247): Network visualization of interactions in an ICT-enabled environmental and biodiversity governance system.



Note: Nodes represent Government, University, Industry (ICT experts), and Community actors involved in environmental data management, system evaluation, and inter-agency biodiversity monitoring, with roles and engagement levels defined by their function in system operation and assessment. Directed edges represent reported relationships such as organizational oversight, system development support, technical evaluation, usability validation, data access, and institutional linkage to higher governance systems (DENR and LAWIN). Edge weights range from 1 to 3, where 3 indicates formal organizational linkage and governance authority, 2 indicates structured operational collaboration and system development support, and 1 indicates evaluative or user-level interaction. Government actors (PENRO–Nueva Ecija, employees, biodiversity committees) serve as the core system owners and operators, with formal linkage to DENR and integration with the LAWIN biodiversity system. University actors (TSU, CLSU) provide advisory and technical development support without governance authority. ICT experts contribute structured evaluation of system quality (usability, security, maintainability), while community users actively access and validate environmental information outputs. Overall, the network reflects a strongly institutionalized, government-centered ICT governance system with embedded academic and technical evaluation support. Interaction is sustained through continuous system use, iterative assessment, and formal inter-agency linkages, indicating stable and recurring cross-actor engagement within environmental management.

Government Actors

Government agencies functioned as system owners, governance coordinators, operational managers, and environmental information custodians. The Provincial Environment and Natural Resources Office (PENRO–Nueva Ecija) served as the

principal implementing agency responsible for biodiversity monitoring, environmental data management, and operation of the ICT platform. PENRO personnel and biodiversity monitoring committees managed biodiversity datasets while integrating digital technologies into routine environmental management.

At the national level, the Department of Environment and Natural Resources (DENR) provided governance oversight, policy coordination, and institutional integration through its linkage with the LAWIN Forest and Biodiversity Protection System. This connection enabled provincial biodiversity information to contribute to the national environmental monitoring framework, embedding ICT-enabled biodiversity management within routine government operations.

University Actors

Universities served as technical advisors, knowledge providers, and capacity-building partners supporting implementation of the biodiversity information system. Tarlac State University (TSU) and Central Luzon State University (CLSU) provided methodological guidance, technical expertise, and academic support to improve system quality and strengthen institutional capability in environmental information management.

Their contributions focused on system refinement, technical advisory services, implementation support, and capacity development. Although universities did not exercise operational authority, they strengthened the technical rigor and implementation quality of the environmental monitoring system.

Industry Actors

Industry participation was specialized and focused on technical evaluation rather than commercialization. ICT experts assessed database integrity, system functionality, security, maintainability, usability, and interface quality to ensure that the

platform met operational requirements and supported continuous system improvement. Their involvement remained consultative, with no evidence of commercial software development, technology commercialization, or entrepreneurial activities. Instead, industry expertise strengthened the technical reliability and long-term functionality of the biodiversity information system.

Community Actors

Community actors participated directly as users and validators of the biodiversity information system. Users accessed biodiversity information through the platform and provided feedback on usability, functionality, and overall system performance. This continuing interaction supported iterative refinement while improving transparency, accessibility, and practical application of environmental information. Community participation therefore extended beyond the use of information, contributing to the continuous improvement of the digital environmental governance platform.

Innovation Outcomes

The initiative generated several important institutional, technological, and governance outcomes.

- Institutionalized Digital Environmental Governance: The biodiversity information system became embedded within PENRO's routine biodiversity monitoring and environmental management operations.
- Integrated Multi-Level Environmental Monitoring: Linkages among PENRO, DENR, and the LAWIN Forest and Biodiversity Protection System strengthened coordination between provincial implementation and national environmental governance.

- ICT-enabled Decision Support: The platform improved biodiversity data management, environmental reporting, and evidence-based decision-making.
- Continuous Multi-Actor System Evaluation: Government personnel, universities, ICT experts, and community users participated in recurring evaluation activities that enhanced system quality, usability, and technical robustness.
- Institutional Capacity Development: The initiative strengthened ICT capability within government while improving transparency and inter-agency coordination for environmental management.

Together, these outcomes demonstrate the successful institutional integration of digital technologies within biodiversity monitoring and environmental governance at both provincial and national levels.

Challenges and Sustainability Strategies

Despite strong institutional embedding, several sustainability challenges remained. The system depended on continued government commitment, sustained technical maintenance, and effective coordination between PENRO and DENR. Governance authority remained concentrated within government institutions, limiting the influence of universities and ICT experts on long-term system development. To strengthen sustainability, the initiative institutionalized integration with DENR and the LAWIN Forest and Biodiversity Protection System, embedded the platform within routine provincial environmental governance, maintained recurring multi-stakeholder evaluation and feedback processes, and sustained inter-agency coordination supporting ICT-enabled biodiversity monitoring. These mechanisms reinforced institutional continuity while reducing fragmentation risks.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: The case demonstrates a strong structural configuration. Government agencies provide institutional leadership, operational management, and regulatory oversight; universities contribute technical expertise and implementation support; ICT experts strengthen system quality through structured evaluation; and community actors participate by utilizing the system and validating its usability. These complementary roles are institutionalized through PENRO, DENR, and the LAWIN Forest and Biodiversity Protection System.
- Functional Dimension: The case exhibits strong functional integration. Biodiversity monitoring, environmental data management, technical evaluation, decision support, system refinement, and public access to information are coordinated through an ICT-enabled governance platform that links local biodiversity information to national environmental monitoring systems.
- Relational Dimension: The relational dimension is strong. Sustained interaction occurs among PENRO personnel, biodiversity monitoring committees, DENR, universities, ICT experts, and community users through recurring monitoring activities, technical evaluation, usability assessment, governance coordination, and continuous system refinement. These interactions are institutionalized within routine environmental management rather than occurring through isolated projects.

Case Summary

Overall, Case Study 3 demonstrates a mature Quadruple Helix innovation system supporting ICT-enabled environmental governance. Government agencies provide institutional leadership and operational management; universities contribute

scientific and technical expertise; ICT experts strengthen system quality through continuous evaluation; and community users participate through ongoing system utilization and feedback. Together, these actors form an institutionalized digital governance ecosystem that integrates biodiversity monitoring, environmental information management, technical evaluation, and evidence-based decision-making. This configuration represents a sustained government-led Quadruple Helix system characterized by embedded digital infrastructure, recurring cross-sector collaboration, and long-term institutional integration.

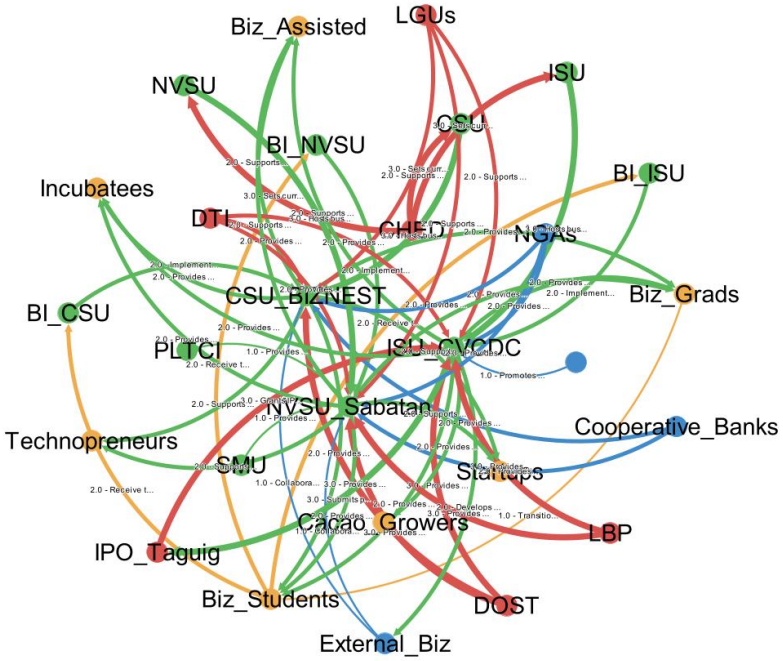
Case Study 4 (SID-b694): University-Based Technopreneurship Incubation Systems and Multi-Actor Innovation Pathways for Enterprise Development

This analytical case examined a structured university-based technopreneurship and incubation ecosystem implemented across multiple higher education institutions in the Philippines, focusing on start-up formation, enterprise development, intellectual property protection, and commercialization support (Valenzuela, 2022). The initiative integrated entrepreneurship education with formal incubation, financing, intellectual property protection, and market linkage mechanisms to strengthen regional innovation capacity through university-based business incubators that support ideation, venture creation, commercialization, and enterprise scaling.

The case fully satisfied the inclusion criteria because it demonstrated institutionalized collaboration among government agencies, universities, industry partners, and community stakeholders through coordinated policy support, structured incubation programs, financing mechanisms, intellectual property protection, commercialization pathways, and entrepreneurial capacity building. Government

agencies provided policy leadership, funding, and regulatory support; universities operated business incubators and innovation programs; industry partners contributed financing, commercialization, and market access; while community actors participated through venture creation, entrepreneurship, and regional enterprise development. Figure 4.26 presents the network visualization, documenting interactions among participating actors.

Figure 4.26. Case Study 4 (SID-b694): Network visualization of interactions in a university-based incubation and technopreneurship ecosystem.



Note: Nodes represent Government, University, Industry, and Community actors involved in innovation policy, incubation services, financing, intellectual property protection, and start-up commercialization, with roles and engagement levels defined by their function in the ecosystem. Directed edges represent reported relationships such as policy regulation, funding provision, incubation support, mentoring, training, IP registration, financial intermediation, partnership facilitation, and commercialization linkages. Edge weights range from 1 to 3, where 3 indicates structural policy authority, formal funding mechanisms, and institutional governance; 2 indicates operational support such as incubation, mentoring, financing access, and technology transfer; and 1 indicates auxiliary or linkage-based interactions such as market exposure and collaboration pathways. Government actors (CHED, DOST, DTI, IPO Taguig, LBP, LGUs) provide policy direction, funding, regulatory oversight, IP protection, financial services, and partnership facilitation. Universities (CSU, ISU, NVSU and their incubators such as BIZNEST, CVCDC, Sabatan Hub) serve as central innovation hubs delivering incubation, mentoring, training, and start-up development services. Industry and community actors (start-ups, technopreneurs, MSMEs, external firms, cacao

growers, graduates) function as innovation adopters and co-creators, engaging in commercialization, production, and enterprise scaling. Overall, the network reflects a strongly institutionalized and mature Triple Helix system with an end-to-end technopreneurship pipeline. It demonstrates sustained, multi-directional collaboration across government, university, and industry actors through integrated incubation, financing, IP protection, and commercialization mechanisms.

Government Actors

Government agencies functioned as policy leaders, regulators, funders, and coordinators of the university-based incubation ecosystem. The Commission on Higher Education (CHED) established curriculum standards and policy support for entrepreneurship education, while the Department of Science and Technology (DOST) and the Department of Trade and Industry (DTI) provided funding, technical assistance, mentoring, and incubation support across participating universities.

The Intellectual Property Office of the Philippines (IPO) facilitated intellectual property registration and protection, enabling commercialization of university-generated innovations. Financial support was further strengthened through the Land Bank of the Philippines (LBP), cooperative banks, and local government units (LGUs), which facilitated financing, partnerships, and localized innovation initiatives. Together, these institutions established the policy, financial, and regulatory environment supporting university-led enterprise development.

University Actors

Universities served as the primary innovation intermediaries and operational hubs within the technopreneurship ecosystem. Cagayan State University (CSU), Isabela State University (ISU), and Nueva Vizcaya State University (NVSU) established formal business incubators, CSU BIZNEST, ISU CVCDC, and the NVSU Sabatan Technopreneurs Hub, to provide structured mentoring, incubation, entrepreneurial training, venture development, and commercialization support. These

incubators guided students, incubatees, technopreneurs, and start-up enterprises through ideation, product development, prototyping, venture scaling, and commercialization. Universities also supported sector-specific innovation initiatives, including agribusiness and cacao processing, while integrating entrepreneurship education into formal academic programs and facilitating the transition from student innovation to commercial enterprise.

Industry Actors

Industry actors supported commercialization, financing, and market expansion within the incubation ecosystem. Financial institutions, including the Land Bank of the Philippines and cooperative banks, provided venture financing that enabled enterprise growth and sustainability. External businesses and international partners, including Kasama Company, facilitated commercialization, export opportunities, and broader market access for incubated enterprises. Industry participation complemented university incubation by strengthening investment opportunities, commercialization pathways, and business development, thereby extending innovation beyond academic settings into competitive markets.

Community Actors

Community actors participated directly in venture development and innovation adoption. Students, incubatees, technopreneurs, entrepreneurs, business graduates, and producer groups served as primary innovators and enterprise developers within university incubation programs. Agricultural producers, particularly cacao growers, participated in value-chain innovation through product development and processing initiatives, while NGOs and local partners contributed networking opportunities, mentoring support, and community-based collaboration. Through continuous

participation in entrepreneurship training, venture development, and commercialization activities, community actors strengthened regional innovation capacity and facilitated the translation of university-generated knowledge into practical economic opportunities.

Innovation Outcomes

The initiative generated several important institutional, entrepreneurial, and commercialization outcomes.

- Institutionalized University-Based Business Incubators: CSU, ISU, and NVSU established structured incubation systems integrating mentoring, entrepreneurial training, and venture development within higher education.
- Integrated Innovation Pipeline: Government agencies, universities, financial institutions, and commercialization partners created coordinated pathways linking entrepreneurship education, incubation, intellectual property protection, financing, and market development.
- Enterprise Development and Commercialization: Incubation programs systematically supported ideation, prototyping, venture scaling, commercialization, and regional enterprise formation.
- Human Capital Development: Entrepreneurship education and incubation strengthened the competencies of students, technopreneurs, and start-up founders while improving graduate employability.
- Sector-Specific Innovation: University-supported initiatives promoted innovation in agribusiness and cacao processing through product development and value-chain integration.
- Institutionalized Cross-Sector Collaboration: Sustained interaction among government agencies, universities, financial institutions, industry partners, and

community stakeholders strengthened regional innovation and enterprise development.

Together, these outcomes demonstrate a coordinated innovation ecosystem supporting entrepreneurship, commercialization, and regional economic development.

Challenges and Sustainability Strategies

Despite strong institutionalization, several sustainability challenges remained. Continued dependence on government funding and sustained university commitment were necessary to maintain incubation operations, while differences in institutional capacity across universities could influence the consistency of innovation outcomes.

To strengthen sustainability, the initiative institutionalized entrepreneurship education through CHED policies, maintained government funding through DOST and DTI, strengthened intellectual property protection through IPO, expanded financial support through public and cooperative banking institutions, and embedded business incubation within university operations. These mechanisms reinforced long-term institutional continuity while supporting sustained venture creation and commercialization.

Interpretation Using the Quadruple Helix Framework

The case demonstrates strong structural, functional, and relational integration within a mature university-centered technopreneurship innovation ecosystem.

- Structural Dimension: The case demonstrates a strong structural configuration. Government agencies provide policy leadership, funding, intellectual property governance, and financial support; universities serve as innovation intermediaries operating business incubators; industry actors contribute financing, commercialization, and market access; while community actors

participate through entrepreneurship, venture development, and enterprise adoption. These complementary roles are institutionalized through formal incubation systems and coordinated innovation support mechanisms.

- Functional Dimension: The case exhibits strong functional integration. Entrepreneurship education, incubation, intellectual property protection, financing, venture development, commercialization, and regional enterprise support are coordinated throughout the innovation lifecycle, creating an integrated pathway from knowledge generation to market application.
- Relational Dimension: The relational dimension is strong. Sustained collaboration occurs among government agencies, universities, financial institutions, industry partners, entrepreneurs, producer groups, and local stakeholders through mentoring, incubation, funding, commercialization, and partnership activities. These recurring interactions support an institutionalized innovation ecosystem rather than isolated entrepreneurial initiatives.

Case Summary

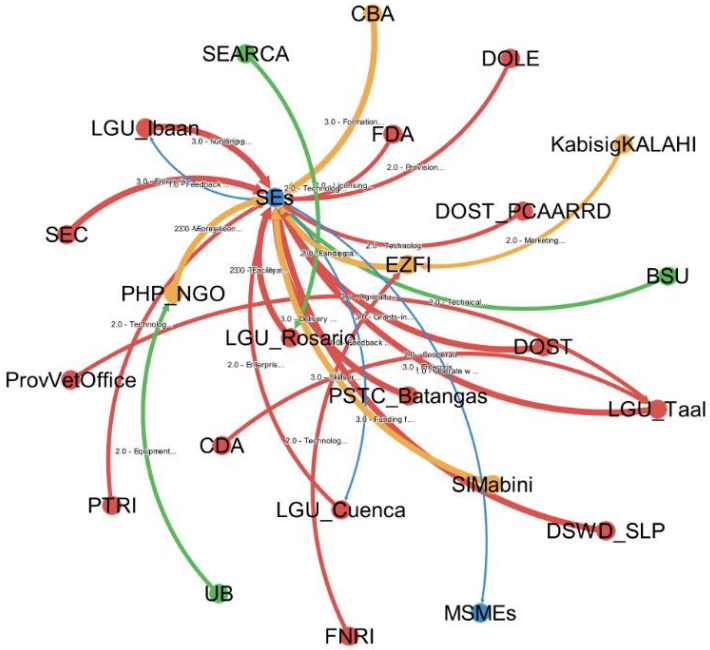
Overall, Case Study 4 demonstrates a mature Quadruple Helix innovation system supporting university-based technopreneurship and enterprise development. Government agencies provide policy, funding, and regulatory support; universities operate business incubators and entrepreneurial training programs; industry partners facilitate financing, commercialization, and market expansion; while community actors actively participate in venture creation, innovation adoption, and regional enterprise development. Together, these actors establish an institutionalized innovation ecosystem that integrates entrepreneurship education, incubation, commercialization, and economic development, representing one of the strongest examples of a mature Quadruple Helix configuration identified in this meta-synthesis.

Case Study 5 (SID-b695): Multi-level Government–University–Community Innovation System for Social Enterprise Development and Inclusive Livelihood Transformation

This analytical case examined a structured social enterprise development and livelihood innovation system implemented in Batangas Province, Philippines, focusing on enterprise formation, production capacity building, and market-oriented commercialization of community-based ventures (Hernandez & Reyes, 2022). The initiative integrated science and technology support, livelihood programs, regulatory mechanisms, and enterprise development to strengthen sustainable livelihood generation and enterprise scalability through coordinated collaboration among government agencies, universities, industry partners, and community organizations.

The case fully satisfied the inclusion criteria because it demonstrated institutionalized collaboration through coordinated funding mechanisms, technology transfer, technical training, enterprise development, regulatory support, and commercialization pathways. Government agencies provided policy leadership, funding, regulation, and enterprise support; universities delivered technical assistance and technology transfer; industry actors facilitated production, commercialization, and market development; while community organizations and social enterprises implemented livelihood and enterprise activities. Figure 4.27 presents the network visualization, documenting interactions among participating actors.

Figure 4.27. Case Study 5 (SID-b695): Network visualization of interactions in a science- and technology-driven social enterprise ecosystem.



Note: Nodes represent Government, University, Industry (social enterprises/MSMEs), and Community/NGO actors involved in funding, regulation, technical assistance, capacity building, production, and commercialization, with roles and engagement levels defined by their function in enterprise development. Directed edges represent reported relationships such as grants-in-aid funding, production facility support, training, technology transfer, regulatory approval, marketing assistance, and enterprise supervision. Edge weights range from 1 to 3, where 3 indicates formal funding, regulatory authority, and institutional governance; 2 indicates operational support such as training, technology transfer, and enterprise facilitation; and 1 indicates auxiliary coordination and feedback-based interactions. Government actors (DOST, DSWD-SLP, LGUs, CDA, SEC, FDA, DOLE, FNRI, PTRI, among others) function as the primary enablers through funding provision, regulatory oversight, technical assistance, and enterprise development programs. University actors (BSU, UB, SEARCA) provide technical training, equipment support, and technology transfer to strengthen enterprise capabilities. Industry and community actors (social enterprises, MSMEs, community-based associations, NGOs) serve as production and commercialization units responsible for operationalizing enterprise activities, including production, marketing, and employment generation. Overall, the network reflects a strongly institutionalized Triple Helix system with a coordinated S&T-driven social enterprise pipeline. It demonstrates sustained, multi-level collaboration across government, universities, and community enterprises through integrated funding, technical support, regulatory systems, and commercialization pathways.

Government Actors

Government agencies functioned as policy leaders, funders, regulators, and implementation coordinators within the social enterprise innovation system. The

Department of Science and Technology (DOST) provided innovation financing, technology transfer, equipment support, and enterprise development through its Grants-in-Aid programs. The Department of Social Welfare and Development (DSWD), through the Sustainable Livelihood Program (SLP), linked social protection initiatives with enterprise development by supporting production facilities and livelihood-oriented enterprises.

Local government units (LGUs) facilitated implementation through funding, supervision, training, marketing assistance, and local coordination. Regulatory agencies, including the Securities and Exchange Commission (SEC), Food and Drug Administration (FDA), and Cooperative Development Authority (CDA), supported enterprise formalization and governance, while the Food and Nutrition Research Institute (FNRI), Philippine Textile Research Institute (PTRI), and Department of Labor and Employment (DOLE) contributed technical assistance, production support, and specialized technologies. Together, these institutions established an integrated governance framework supporting enterprise development and innovation.

University Actors

Universities functioned as technical support institutions and knowledge providers within the social enterprise ecosystem. Batangas State University (BSU), the University of Batangas (UB), and the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) provided technical training, technology transfer, equipment assistance, and capacity-building programs supporting community-based enterprises. Their contributions focused on strengthening production efficiency, product development, entrepreneurship, operational capability, and technology adoption. By supporting technical upgrading and innovation diffusion,

universities enhanced the productivity and sustainability of community enterprises while complementing government livelihood initiatives.

Industry Actors

Industry actors facilitated production, commercialization, and enterprise growth within the innovation system. Social enterprises and micro, small, and medium enterprises (MSMEs) served as operational units responsible for production, marketing, employment generation, and commercialization of products and services. These enterprises translated technical support and government assistance into economic activities supporting local markets and regional development. Financial and market-oriented support from external organizations further strengthened commercialization opportunities, business networking, and enterprise sustainability, enabling innovation to progress beyond technical development toward market application.

Community Actors

Community organizations functioned as the primary implementers and beneficiaries of the innovation system. Community-based associations, cooperatives, non-government organizations, and local foundations participated in enterprise formation, production management, marketing activities, organizational coordination, and livelihood implementation. Community participation extended beyond program beneficiaries by contributing to enterprise management, local production systems, organizational sustainability, and innovation adoption. Through continuous engagement with government agencies, universities, and enterprise partners, community actors strengthened local economic participation and inclusive livelihood development.

Innovation Outcomes

The initiative generated several important institutional, livelihood, and innovation outcomes.

- Institutionalized Social Enterprise Development System: Government agencies, universities, regulatory institutions, and community enterprises established coordinated mechanisms supporting enterprise development and livelihood innovation.
- Integrated Innovation-to-Enterprise Pipeline: Funding, technical assistance, technology transfer, regulatory support, production development, and commercialization were linked within a coordinated innovation system.
- Enterprise Formalization and Governance: Regulatory agencies strengthened enterprise legitimacy through registration, licensing, and cooperative governance mechanisms.
- University-Led Capacity Building: Technical training, equipment provision, and technology transfer enhanced enterprise productivity, innovation capability, and operational performance.
- Community-Based Livelihood Development: Social enterprises generated employment opportunities, strengthened local production systems, and increased household income and economic participation.
- Institutionalized Cross-Sector Collaboration: Sustained collaboration among government agencies, universities, enterprises, and community organizations supported long-term enterprise development and innovation.

Together, these outcomes demonstrate an inclusive innovation ecosystem that integrates livelihood development, enterprise sustainability, and community-based economic growth.

Challenges and Sustainability Strategies

Despite strong institutional support, several sustainability challenges remained. The system depended on continued government funding, sustained inter-agency coordination, and ongoing technical assistance to maintain enterprise performance. The involvement of multiple implementing and regulatory agencies also increased coordination complexity. To strengthen sustainability, the initiative institutionalized university-based technical support, maintained formal regulatory mechanisms, embedded enterprise development within government livelihood programs, strengthened monitoring and technical assistance, and sustained multi-level coordination among funding, regulatory, and implementation agencies. These mechanisms reinforced long-term institutional continuity while supporting enterprise resilience beyond individual projects.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: The case demonstrates a strong structural configuration. Government agencies provide funding, regulation, technical assistance, and enterprise development; universities contribute technology transfer, training, and innovation support; industry actors facilitate production, commercialization, and market development; while community organizations implement enterprise activities and livelihood programs. These complementary roles are institutionalized within formal livelihood and enterprise development systems.
- Functional Dimension: The case exhibits strong functional integration. Government funding, university technical support, enterprise development, regulatory oversight, commercialization, and community participation are coordinated throughout the innovation process, linking social protection initiatives with sustainable enterprise development and local economic growth.

- Relational Dimension: The relational dimension is strong. Sustained collaboration occurs among government agencies, universities, social enterprises, MSMEs, NGOs, community organizations, and regulatory institutions through funding programs, technical assistance, enterprise supervision, commercialization, and livelihood implementation. These recurring interactions support an institutionalized innovation ecosystem rather than isolated development projects.

Case Summary

Overall, Case Study 5 demonstrates a mature Quadruple Helix innovation system supporting inclusive social enterprise and livelihood development. Government agencies provide policy leadership, funding, regulation, and technical support; universities strengthen enterprise capability through technology transfer and training; industry actors facilitate production, commercialization, and market expansion; while community organizations implement enterprise activities and livelihood initiatives. Together, these actors establish an institutionalized innovation ecosystem that integrates technology, enterprise development, commercialization, and community empowerment, illustrating a mature Quadruple Helix configuration for inclusive regional development.

2. Studies that conditionally satisfied the inclusion criteria (2020-2025)

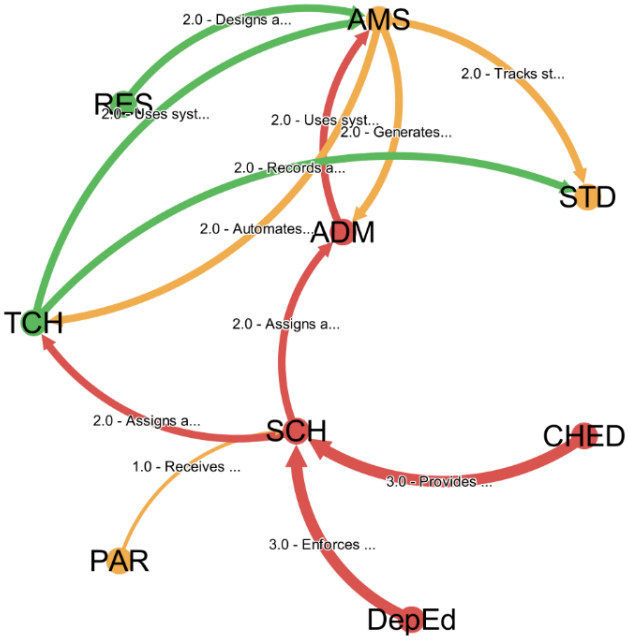
Case Study 6 (SID-b110): ICT-enabled Attendance Monitoring System for Administrative Efficiency in Education Governance

This analytical case examined an ICT-based Attendance Monitoring System (AMS) implemented in Philippine educational institutions to improve attendance recording, reporting, and administrative monitoring through digital technologies (Santos et al., 2021). The initiative supports education management digitalization by

integrating automated attendance tracking into classroom and school administrative workflows, with the objective of improving accuracy, efficiency, and institutional compliance in attendance management.

The case conditionally satisfied the inclusion criteria because it demonstrated collaboration among government agencies, academic institutions, schools, and community users through policy implementation, system development, and operational deployment. Government agencies provided policy oversight and institutional governance; university actors developed and implemented the ICT system; community actors participated as system users and beneficiaries; however, private-sector participation is absent and collaborative innovation remains limited. Consequently, the initiative represents an ICT-enabled administrative governance system rather than a fully institutionalized Quadruple Helix innovation ecosystem. Figure 4.28 presents the network visualization, documenting interactions among participating actors.

Figure 4.28. Case Study 6 (SID-b110): Network visualization of interactions in an ICT-based school attendance monitoring system.



Note: Nodes represent Government, University, and Community actors involved in attendance policy enforcement, system design, classroom implementation, and student monitoring, with roles and engagement levels defined by their function in system governance and use. Directed edges represent reported relationships such as policy enforcement, administrative oversight, system development, classroom implementation, attendance recording, and automated reporting through the Attendance Monitoring System (AMS). Edge weights range from 1 to 3, where 3 indicates formal governance authority and institutional oversight, 2 indicates operational system use and implementation functions, and 1 indicates indirect or user-level interactions. Government actors (DepEd, CHED, school administrators, and schools) provide policy enforcement, institutional governance, and administrative oversight of attendance monitoring. University actors (researchers and teachers) design, develop, validate, and implement the system at the classroom level. Community actors (students and parents) function as system subjects and indirect users, while the AMS serves as the central technological platform enabling automated attendance tracking, reporting, and monitoring. Overall, the network reflects a moderately structured Triple Helix configuration within the education sector. While government, university, and community actors are all present, interaction is largely hierarchical and system-mediated, with limited co-creation or cross-sector innovation beyond functional system implementation.

Government Actors

Government agencies functioned primarily as regulators, policy enforcers, and administrative coordinators. The Department of Education (DepEd) established attendance monitoring requirements and institutional compliance mechanisms, while

the Commission on Higher Education (CHED) provided broader governance frameworks for educational institutions. Schools and administrators operationalized these policies through implementation of the Attendance Monitoring System, report generation, and routine monitoring of attendance records. Government participation, therefore, focused on institutional oversight, policy implementation, and the integration of ICT-enabled attendance monitoring into existing educational governance systems rather than direct involvement in technological development or innovation.

University Actors

University actors functioned as system developers, technical implementers, and operational facilitators. Researchers designed the Attendance Monitoring System, developed its algorithms, conducted system testing, and evaluated operational performance. Teachers simultaneously served as operational users by integrating the system into classroom routines and managing daily attendance records. Collectively, university actors designed and validated the system, facilitated its implementation, and supported operational integration within educational institutions. Their contribution strengthened administrative efficiency but remained largely confined to system development and implementation rather than broader cross-sector innovation.

Industry Actors

Industry participation was minimal. The study did not identify private technology companies, commercial software developers, or other industry partners involved in system development, deployment, or commercialization. As a result, technological development remained institutionally driven without evidence of market-oriented collaboration or private-sector innovation.

Community Actors

Community actors participated primarily as system users and beneficiaries. Students served as the primary subjects of attendance monitoring, while parents received attendance information through system-generated reports and notifications. Their participation was largely limited to system utilization and compliance rather than active involvement in system design, governance, or technological development. Although community engagement supported operational implementation, interaction remained predominantly one-directional, with limited opportunities for collaborative decision-making or co-creation.

Innovation Outcomes

The initiative generated several important administrative and institutional outcomes.

- ICT-enabled Administrative Efficiency: Automated attendance recording and reporting improved the speed, accuracy, and consistency of school administrative processes.
- Institutional Integration: The Attendance Monitoring System became embedded within school governance and routine classroom management.
- Improved Data Management: Automated reporting strengthened attendance monitoring and institutional record management.
- Operational Standardization: Digital workflows reduced manual administrative tasks while supporting consistent implementation across educational settings.
- Enhanced Governance Support: Attendance information provided school administrators with more timely and standardized data for institutional monitoring.

These outcomes demonstrate improvements in administrative efficiency and digital governance but provide limited evidence of broader educational innovation or systemic transformation.

Challenges and Sustainability Strategies

Despite its operational benefits, the initiative remained constrained by several structural limitations. The system relied heavily on continued institutional enforcement, technical maintenance, and routine administrative use. Interaction among participating actors remained largely hierarchical, with limited opportunities for participatory system improvement. Furthermore, the absence of private-sector involvement limited opportunities for technological enhancement, commercialization, and broader diffusion of innovation.

Long-term sustainability was supported by institutional integration into DepEd and CHED governance frameworks, routine use by schools and teachers, standardized administrative procedures, and continued reliance on digital attendance monitoring for institutional reporting. These mechanisms supported operational continuity despite relatively limited innovation-oriented collaboration.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: The case demonstrates moderate structural configuration. Government agencies provide policy oversight and institutional governance; university actors design and implement the Attendance Monitoring System; community actors participate as users and beneficiaries; however, industry participation is absent, resulting in an incomplete Quadruple Helix configuration.

- Functional Dimension: The case exhibits moderate functional integration. Government regulation, university-developed ICT systems, and community utilization are coordinated to improve attendance monitoring, administrative reporting, and institutional efficiency. However, collaboration remains focused on operational administration rather than innovation generation or educational transformation.
- Relational Dimension: The relational dimension is relatively weak. Interaction occurs primarily through hierarchical and system-mediated relationships linking government agencies, researchers, teachers, students, and parents. Community participation remains largely passive, while the absence of private-sector collaboration limits opportunities for co-creation, knowledge exchange, and sustained innovation.

Case Summary

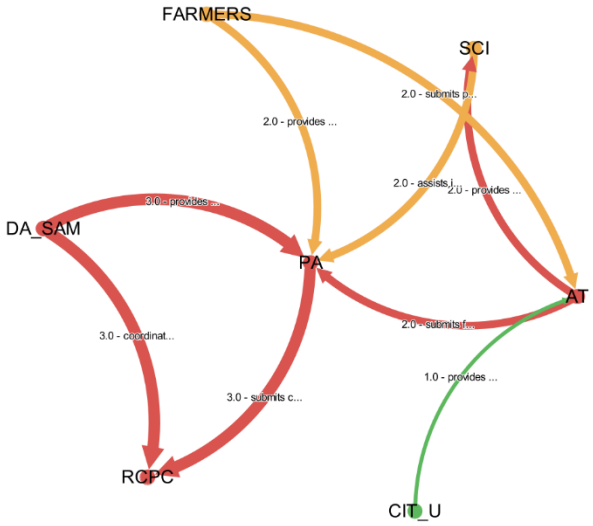
Overall, Case Study 6 demonstrates a partially developed Quadruple Helix configuration supporting ICT-enabled administrative governance within the education sector. Government agencies provide policy oversight and institutional coordination; university actors develop and implement the digital system; community actors participate through routine system use; while industry participation is absent. The initiative successfully institutionalizes digital attendance monitoring and improves administrative efficiency but remains primarily an operational governance system rather than a mature innovation ecosystem characterized by sustained multi-sector collaboration and co-creation.

Case Study 7 (SID-b209): GIS-enabled Agricultural Surveillance System for Hierarchical Pest and Disease Monitoring in Provincial Crop Protection Networks

This analytical case examined a GIS-enabled agricultural surveillance and decision-support system implemented in the Province of Samar, Philippines, to strengthen pest and disease monitoring, field data reporting, and evidence-based agricultural decision-making (Durango, 2022). The initiative integrated mobile and GIS-based technologies into provincial crop protection workflows, enabling structured reporting from farmers and agricultural technologists to provincial and regional agricultural authorities.

The case conditionally satisfied the inclusion criteria because it demonstrated collaboration among government agencies, academic institutions, and community stakeholders through ICT-enabled surveillance, structured reporting mechanisms, and coordinated agricultural monitoring. Government agencies provided leadership, policy implementation, and operational management; university actors contributed technical and software development support; while community stakeholders participated through field-level surveillance and scientific interpretation. However, private-sector participation is absent, and interaction remains largely hierarchical and government-driven. Figure 4.29 presents network visualization, documenting interactions among participating actors.

Figure 4.29. Case Study 7 (SID-b209): Network visualization of interactions in a GIS-enabled agricultural pest and disease surveillance system.



Note: Nodes represent Government, University, and Community actors involved in field data collection, surveillance processing, interpretation, and regional agricultural decision-making, with roles and engagement levels defined by their function in the monitoring system. Directed edges represent reported relationships such as field reporting, data collection, surveillance processing, decision generation, and technical support for system development and interpretation. Edge weights range from 1 to 3, where 3 indicates formal oversight and coordination authority, 2 indicates operational data processing and reporting functions, and 1 indicates interpretive or developmental support. Government actors (DA_SAM, Provincial Agriculturist, Agricultural Technologists, and Regional Crop Protection Center) form a hierarchical surveillance chain responsible for oversight, data processing, reporting, and regional coordination. The university actor (CIT_U) provides technical development context for the GIS-enabled system, while agricultural scientists contribute interpretive support for pest and disease data analysis. Community actors (farmers and scientists) supply field-level data and analytical assistance through reporting and interpretation roles. Overall, the network reflects a government-led surveillance structure with moderate Triple Helix presence. While university and community actors contribute supporting functions, interaction is primarily vertical and data-driven, with limited cross-sector collaboration or co-innovation beyond agricultural monitoring and decision support.

Government Actors

Government agencies functioned as the principal coordinators, operational managers, and decision-makers within the agricultural surveillance system. The Department of Agriculture–Samar (DA–Samar) provided strategic oversight, policy direction, and institutional coordination for pest and disease monitoring. Agricultural Technologists (AT) collected field surveillance data from farming communities, while

the Provincial Agriculturist (PA) analyzed surveillance reports and supported provincial crop protection decisions. At the regional level, the Regional Crop Protection Center (RCPC) consolidated surveillance information to guide regional monitoring, coordination, and response planning. Government participation therefore extended beyond regulatory oversight by integrating field surveillance, data management, decision support, and regional coordination within an institutionalized agricultural monitoring framework.

University Actors

University actors functioned as technical advisors and knowledge-support institutions. Academic partners contributed software development, GIS system enhancement, and methodological support for the surveillance platform. They also provided technical guidance that strengthened system implementation and improved the analytical quality of surveillance outputs. In addition, scientific experts supported interpretation of pest and disease information, assisting provincial agricultural authorities in analyzing surveillance data and strengthening evidence-based crop protection planning. Although universities did not exercise operational authority, they contributed important technical expertise supporting implementation and continuous system improvement.

Industry Actors

Industry participation was minimal. The study did not identify private agricultural technology firms, GIS software companies, or commercial ICT providers involved in system development, deployment, or maintenance. Consequently, technological innovation remained government- and university-driven without evidence of commercialization or private-sector collaboration.

Community Actors

Community actors participated primarily through field-based surveillance and agricultural knowledge sharing. Farmers served as the principal providers of pest and disease information by reporting field observations through structured surveillance mechanisms. Agricultural scientists also contributed by assisting in the interpretation of surveillance data and supporting provincial crop protection analysis. Community participation strengthened the accuracy and responsiveness of agricultural monitoring. However, involvement remained largely limited to data provision and technical support rather than collaborative decision-making or co-development of the surveillance system.

Innovation Outcomes

The initiative generated several important operational and institutional outcomes.

- GIS-enabled Agricultural Surveillance: The system established a structured platform for monitoring pest and disease outbreaks through coordinated field reporting.
- Integrated Multi-Level Monitoring: Formal reporting mechanisms connected farmers, agricultural technologists, provincial authorities, and regional crop protection offices within a coordinated surveillance network.
- Improved Decision Support: GIS-based information strengthened evidence-based crop protection planning and agricultural response.
- Enhanced Reporting Efficiency: Digital reporting improved the timeliness, consistency, and accuracy of surveillance information.

- Strengthened Institutional Coordination: Continuous interaction among provincial and regional agricultural agencies improved coordination of monitoring and response activities

Collectively, these outcomes strengthened agricultural surveillance capacity and institutional decision-making through ICT-enabled governance.

Challenges and Sustainability Strategies

Despite its operational effectiveness, several structural limitations remained. The surveillance system depended heavily on hierarchical government coordination, sustained participation by agricultural technologists and farmers, and continued institutional support from provincial and regional agricultural agencies. In addition, the absence of private-sector participation limited opportunities for technological enhancement, commercialization, and broader innovation diffusion.

Long-term sustainability was supported through institutional integration within Department of Agriculture governance structures, routine use of the surveillance platform, established reporting procedures, and continued coordination among provincial and regional agricultural offices. These mechanisms reinforced operational continuity and institutional stability despite relatively limited collaborative innovation.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: The case demonstrates moderate structural configuration. Government agencies provide leadership, operational management, and decision-making; university actors contribute technical expertise and software development; community actors participate through field surveillance and scientific interpretation; however, industry participation is absent, resulting in an incomplete Quadruple Helix configuration.

- Functional Dimension: The case exhibits moderate functional integration. Government oversight, GIS-based technologies, university technical support, and community-generated surveillance data are coordinated to improve pest monitoring, agricultural reporting, and crop protection planning. Functional interaction primarily supports administrative surveillance and decision-making rather than broader agricultural innovation or commercialization.
- Relational Dimension: The relational dimension is moderate but predominantly hierarchical. Sustained interaction occurs through routine reporting, technical support, surveillance activities, and institutional coordination among government agencies, universities, agricultural technologists, farmers, and scientists. However, collaboration remains largely top-down, with limited co-creation, feedback-driven innovation, or private-sector engagement.

Case Summary

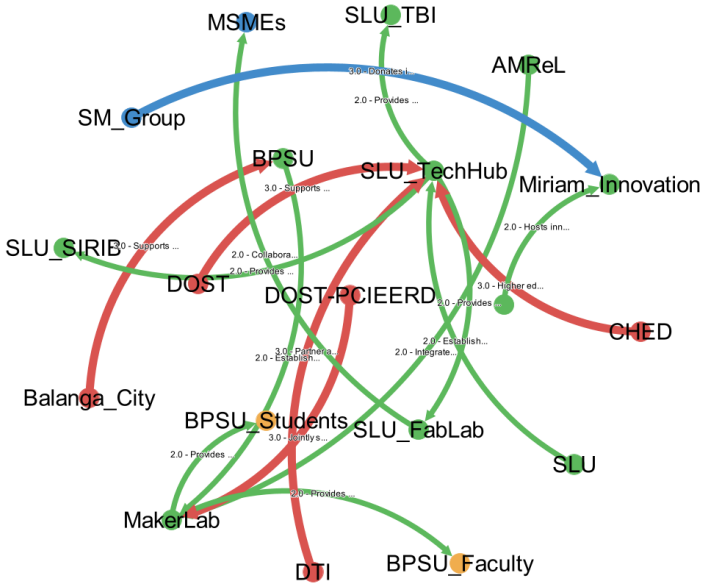
Overall, Case Study 7 demonstrates a partially developed Quadruple Helix configuration supporting ICT-enabled agricultural surveillance and crop protection governance. Government agencies provide institutional leadership and operational coordination; university actors contribute technical expertise and GIS system support; community stakeholders participate through field surveillance and agricultural knowledge; while industry participation is absent. The initiative successfully institutionalizes digital pest monitoring and strengthens evidence-based agricultural governance but remains primarily an administrative surveillance system rather than a mature innovation ecosystem characterized by sustained multi-sector collaboration and co-creation.

Case Study 8 (SID-b318): University-led Makerspace and Technopreneurship Infrastructure System for Distributed Innovation and Prototyping Capacity Development

This analytical case examined a distributed makerspace and technopreneurship infrastructure system established across higher education institutions in the Philippines to strengthen innovation capacity through fabrication laboratories, innovation centers, and technopreneurship hubs (Macaraeg et al., 2021). The initiative integrated physical innovation spaces with entrepreneurship education, prototyping facilities, and institutional support to promote design thinking, product development, and early-stage technological innovation.

The case conditionally satisfied the inclusion criteria because it demonstrated collaboration among government agencies, universities, industry partners, and community users through coordinated funding, infrastructure development, and innovation support mechanisms. Government agencies provided policy direction and financial support; universities established and operated makerspaces and incubation facilities; industry actors contributed limited technical and infrastructure support; while students, faculty, and MSMEs utilized the facilities for learning, experimentation, and early-stage product development. However, collaboration remains largely infrastructure-driven, with limited evidence of sustained co-creation, commercialization, or long-term innovation partnerships. Figure 4.30 presents the network visualization, documenting interactions among participating actors.

Figure 4.30. Case Study 8 (SID-b318): Network visualization of interactions in a makerspace- and technopreneurship-based innovation infrastructure system.



Note: Nodes represent Government, University, and Industry/Community actors involved in funding, establishment, operation, and utilization of innovation facilities such as makerspaces, fabrication laboratories, incubation hubs, and innovation centers, with roles and engagement levels defined by their function in the ecosystem. Directed edges represent reported relationships such as funding provision, policy support, infrastructure establishment, facility operation, prototyping collaboration, donations, and facility usage. Edge weights range from 1 to 3, where 3 indicates formal funding and policy authority, 2 indicates operational support and infrastructure implementation, and 1 indicates peripheral or facility-based engagement. Government actors (DOST, DOST-PCIEERD, CHED, DTI, Balanga City) function as enabling institutions responsible for funding, policy support, and ecosystem facilitation. University actors (BPSU, SLU, Miriam College, AMReL, MakerLab, SLU technopreneurship units) serve as primary operators of innovation infrastructure, managing makerspaces, fabrication labs, and incubation hubs. Industry and community actors (MSMEs, SM Group, faculty, students) participate mainly as users, beneficiaries, or supporting collaborators through prototyping, donations, and learning activities. Overall, the network reflects a structurally complete but weakly integrated Triple Helix configuration. While all three helices are present, interaction is largely infrastructure-driven and role-based, with limited evidence of co-creation, sustained collaboration, or end-to-end innovation development across sectors.

Government Actors

Government agencies functioned primarily as policy enablers, funders, and ecosystem facilitators. The Department of Science and Technology (DOST), through the Philippine Council for Industry, Energy, and Emerging Technology Research and

Development (PCIEERD), provided financial support and strategic direction for the establishment of makerspaces, fabrication laboratories, and innovation centers. The Commission on Higher Education (CHED) supported the integration of technopreneurship within higher education, while the Department of Trade and Industry (DTI) contributed enterprise development and innovation support. Local government units, particularly the Balanga City Government, facilitated partnerships and localized implementation. Government participation therefore focused on establishing the institutional and policy environment necessary for university-based innovation infrastructure rather than directly managing innovation activities.

University Actors

Universities functioned as the principal operators of the makerspace ecosystem. Bataan Peninsula State University (BPSU), Saint Louis University (SLU), and Miriam College established and managed fabrication laboratories, innovation centers, technology business incubators, and technopreneurship hubs that supported ideation, prototyping, experimentation, and entrepreneurship development. Collectively, university actors operated innovation facilities, implemented entrepreneurship programs, supported product development, and provided mentoring and technical assistance. Their role positioned higher education institutions as the primary drivers of infrastructure-based innovation and technological capability development.

Industry Actors

Industry participation remained limited and primarily supportive. MSMEs accessed university makerspaces for prototyping and fabrication activities, while private organizations such as the SM Group contributed infrastructure support for

selected innovation facilities. Industry engagement was largely confined to facility utilization and infrastructure assistance, with little evidence of sustained collaboration in technology development or commercialization.

Community Actors

Community participation occurred mainly through students, faculty members, and aspiring technopreneurs who utilized makerspaces for academic projects, innovation activities, entrepreneurship training, and prototype development. These users benefited from access to shared facilities that strengthened practical skills, innovation capability, and entrepreneurial experience. Although community engagement contributed to innovation learning and experimentation, participation remained centered on facility utilization rather than collaborative governance or long-term innovation co-production.

Innovation Outcomes

The initiative generated several important institutional and capacity-building outcomes.

- Institutionalized Innovation Infrastructure: Universities established makerspaces, fabrication laboratories, innovation centers, and technology business incubators within higher education institutions.
- Expanded Prototyping Capacity: Shared facilities supported design thinking, product development, fabrication, and technological experimentation.
- Strengthened Technopreneurship: Innovation centers promoted entrepreneurship education, venture incubation, and early-stage enterprise development.

- Government-supported Innovation Ecosystem: DOST, PCIEERD, CHED, and DTI collectively strengthened national innovation infrastructure through coordinated funding and policy support.
- Enhanced Institutional Capacity: Universities improved their capability to support innovation-oriented teaching, research, and technology development.

These outcomes strengthened innovation infrastructure and technological capability within higher education institutions while providing limited evidence of broader commercialization or innovation diffusion.

Challenges and Sustainability Strategies

Despite the successful establishment of innovation facilities, several structural challenges remained. The initiative depended heavily on continued government funding, institutional commitment, and sustained utilization of makerspaces. Industry participation remained relatively limited, while commercialization pathways and long-term collaborative innovation networks were not yet fully developed.

Long-term sustainability was supported through institutional integration of makerspaces within university operations, continued support from DOST, PCIEERD, CHED, and DTI, incorporation of makerspaces into entrepreneurship and academic programs, and ongoing maintenance of innovation facilities. These mechanisms strengthened institutional continuity despite relatively weak ecosystem integration.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: The case demonstrates moderate structural configuration. Government agencies provide funding, policy support, and ecosystem facilitation; universities operate makerspaces and innovation centers; industry actors contribute limited infrastructure support and facility

utilization; while students, faculty, and MSMEs participate as users of innovation facilities. Although all four helices are represented, industry participation remains relatively limited.

- Functional Dimension: The case exhibits moderate functional integration. Government support, university-operated innovation infrastructure, industry participation, and community utilization collectively strengthen prototyping, entrepreneurship education, technological experimentation, and innovation capability. However, collaboration remains focused on infrastructure development and early-stage innovation rather than sustained commercialization or technology diffusion.
- Relational Dimension: The relational dimension is moderate. Interaction occurs primarily through shared innovation facilities, institutional partnerships, training activities, and access to makerspaces. Relationships are sustained operationally but remain largely facility-centered, with limited evidence of long-term co-creation, collaborative governance, or integrated innovation networks across the four helices.

Case Summary

Overall, Case Study 8 demonstrates a partially developed Quadruple Helix innovation system centered on university-based makerspaces and technopreneurship infrastructure. Government agencies provide policy support and funding; universities establish and manage innovation facilities; industry actors contribute limited infrastructure support and facility utilization; while community actors participate through innovation learning, prototyping, and entrepreneurship activities. The initiative strengthens institutional innovation capacity and technological capability but remains primarily an infrastructure-driven ecosystem with comparatively limited

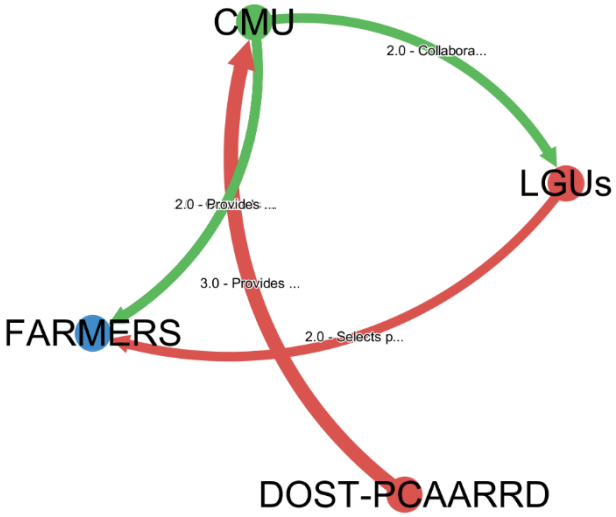
commercialization, private-sector integration, and collaborative innovation across the four helices.

Case Study 9 (SID-b469): University-led Agricultural Extension System for Cacao Plantation Development through Government-funded Rural Innovation Support

This analytical case examined a government-funded agricultural extension initiative implemented in Bukidnon, Philippines, to strengthen cacao plantation development through farmer training, technical assistance, and input provision (Valleser et al., 2020). The initiative integrated government funding, university-led extension services, and local government coordination to improve smallholder cacao production and strengthen rural agricultural development.

The case conditionally satisfied the inclusion criteria because it demonstrated collaboration among government agencies, universities, and farming communities through coordinated extension services, technical assistance, and capacity-building programs. Government agencies provided funding and program coordination; universities delivered technical training and extension services; while community actors participated through farm implementation and adoption of recommended production practices. However, private-sector participation is absent, and interaction remains primarily hierarchical and extension-driven rather than collaborative or innovation-oriented. Figure 4.31 presents the network visualization, documenting interactions among participating actors.

Figure 4.31. Case Study 9 (SID-b469): Network visualization of interactions in a government-funded agricultural extension system for cacao production.



Note: Nodes represent Government, University, and Industry (farmer-cooperators) actors involved in funding, coordination, technical implementation, training, and farm-level production activities, with roles and engagement levels defined by their function in project delivery. Directed edges represent reported relationships such as grant funding, beneficiary selection, training provision, distribution of inputs, technical assistance, and monitoring and evaluation. Edge weights range from 1 to 3, where 3 indicates formal funding and coordination authority, 2 indicates operational implementation and technical service delivery, and 1 indicates indirect or support-level engagement. Government actors (DOST-PCAARRD and LGUs) provide funding and coordination through grant support and beneficiary selection under an agricultural extension framework. The university actor (Central Mindanao University) serves as the primary implementation and technical service provider, delivering training, agricultural inputs, technical assistance, and monitoring and evaluation. Farmer-cooperators act as production-level actors responsible for establishing and managing cacao plantations under project guidance. Overall, the network reflects a structured but hierarchical Triple Helix configuration typical of agricultural extension systems. Interaction is primarily top-down, with government funding, university implementation, and farmer participation, and limited evidence of reciprocal collaboration or co-innovation across actors.

Government Actors

Government agencies functioned primarily as funders, coordinators, and program enablers. The Department of Science and Technology–Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (DOST-PCAARRD) provided financial support for project implementation, agricultural

extension activities, and technical assistance. Local government units (LGUs) coordinated local implementation, facilitated beneficiary selection, and supported project administration within participating communities. Government participation therefore focused on enabling agricultural extension through funding, coordination, and local implementation support rather than direct involvement in technology development or innovation.

University Actors

Central Mindanao University (CMU) served as the principal technical implementer and extension service provider. The university delivered farmer training, technical assistance, monitoring and evaluation, agricultural input support, and advisory services related to cacao plantation establishment and farm management. Collectively, university actors translated government support into field-level extension activities, strengthened farmer technical capability, and facilitated the adoption of improved cacao production practices. Their contribution focused primarily on knowledge transfer and extension delivery rather than collaborative research or innovation co-development.

Industry Actors

Industry participation was minimal. The study did not identify private agribusiness firms, commercial buyers, processing companies, or other industry partners participating in project implementation, technology development, or commercialization. Consequently, the initiative remained largely government- and university-led, with little private-sector engagement.

Community Actors

Community actors consisted primarily of farmer-cooperators who participated in plantation establishment, technical training, and implementation of recommended farm management practices. Farmers received technical assistance, agricultural inputs, and continuous monitoring to improve cacao production and strengthen farm productivity. Although community participation was central to project implementation, farmers primarily functioned as recipients of extension services rather than active partners in technology development or innovation planning.

Innovation Outcomes

The initiative generated several important institutional and capacity-building outcomes.

- University-led Agricultural Extension: CMU established structured training, technical assistance, and monitoring systems supporting cacao plantation development.
- Government-supported Rural Development: DOST-PCAARRD funding and LGU coordination strengthened implementation of agricultural extension activities.
- Improved Farmer Capacity: Technical training and the provision of inputs enhanced farmers' knowledge and cacao production practices.
- Structured Knowledge Transfer: Extension services facilitated the adoption of improved farm management techniques among participating farmers.
- Strengthened Local Implementation: Coordination among government agencies, universities, and local communities supported organized delivery of agricultural development programs.

These outcomes strengthened agricultural extension delivery and farmer capacity while providing limited evidence of broader innovation, commercialization, or institutional transformation.

Challenges and Sustainability Strategies

Despite successful implementation, several structural limitations remained. The initiative depended heavily on continued government funding, university extension capacity, and sustained coordination among implementing institutions. Farmer participation remained largely limited to technology adoption, while opportunities for collaborative innovation and knowledge co-creation were relatively limited. Furthermore, the absence of private-sector participation constrained commercialization and broader value-chain integration. Long-term sustainability was supported through continued government financial assistance, ongoing university extension services, LGU coordination, and institutionalized training programs. These mechanisms strengthened operational continuity but remained largely dependent on sustained institutional support.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: The case demonstrates moderate structural configuration. Government agencies provide funding and implementation support; universities deliver technical expertise and extension services; community actors participate through farm implementation and technology adoption; however, industry participation is absent, resulting in an incomplete Quadruple Helix configuration.
- Functional Dimension: The case exhibits moderate functional integration. Government funding, university-led extension, and community participation

collectively improve farmer capability, agricultural production, and knowledge transfer. Functional interaction remains focused on the delivery of extensions rather than on collaborative innovation, commercialization, or technological development.

- Relational Dimension: The relational dimension is relatively weak. Interaction occurs primarily through top-down extension activities linking government agencies, university extension personnel, LGUs, and farmers. Although collaboration is sustained throughout project implementation, relationships remain largely one-directional with limited reciprocal learning, co-creation, or long-term innovation partnerships.

Case Summary

Overall, Case Study 9 demonstrates a partially developed Quadruple Helix configuration supporting university-led agricultural extension and rural development. Government agencies provide funding and coordination; universities deliver technical assistance and farmer training; community actors implement improved agricultural practices; while industry participation is absent. The initiative strengthens farmer capability and cacao production through structured extension services but remains primarily an agricultural development program rather than a mature innovation ecosystem characterized by sustained multi-sector collaboration and co-creation.

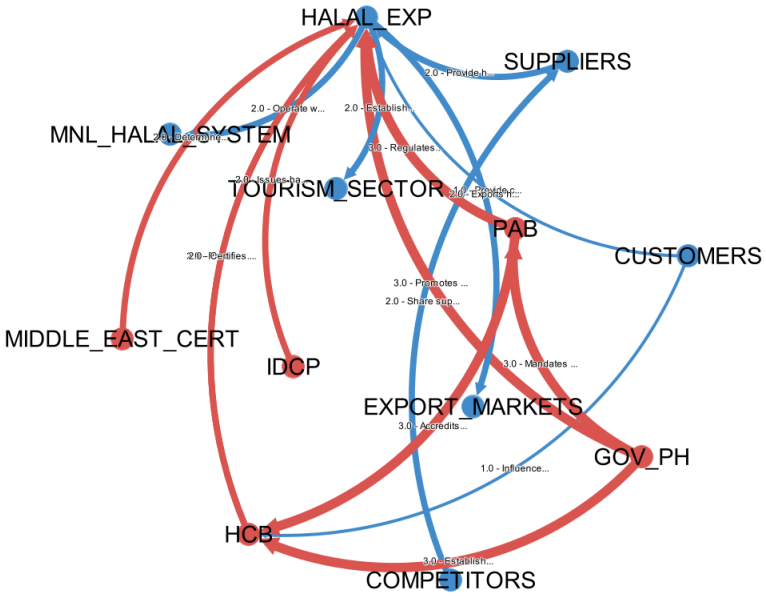
Case Study 10 (SID-b582): State-regulated Halal Industry System and Export-oriented Certification Governance under RA 10817

This analytical case examined the Philippine halal industry system established under Republic Act No. 10817, focusing on the accreditation, certification, and export

compliance mechanisms that govern halal production and international trade (Marciana et al., 2021). The initiative institutionalized a national halal certification framework intended to strengthen export competitiveness, ensure compliance with international halal standards, and improve market access for Philippine halal products.

The case conditionally satisfied the inclusion criteria because it demonstrated structured collaboration between government agencies and industry actors through formal regulatory, accreditation, and certification systems. Government agencies provided policy leadership, accreditation, and regulatory oversight, while industry actors implemented halal production, certification compliance, and export operations. However, universities were absent from operational implementation, and community participation is limited to market consumption and demand, resulting in an incomplete Quadruple Helix configuration. Figure 4.32 presents network visualization, documenting interactions among participating actors.

Figure 4.32. *Case Study 10 (SID-b582): Network visualization of interactions in the Philippine halal certification and export system.*



Note: Nodes represent Government and Industry actors involved in regulation, accreditation, certification, production, and export distribution, with roles and engagement levels defined by their function in the halal value chain. Directed edges

represent reported relationships such as regulatory enforcement, accreditation authority, certification issuance, compliance auditing, supply chain coordination, and export market linkage. Edge weights range from 1 to 3, where 3 indicates formal regulatory authority and accreditation control, 2 indicates operational certification and compliance functions, and 1 indicates market-level or auxiliary supply chain interactions. Government actors (GOV_PH, PAB, HCB, IDCP, Middle East certification authorities) establish and enforce halal regulatory frameworks under RA 10817, defining certification standards and compliance requirements. Industry actors (halal exporters, suppliers, customers, export markets, and tourism-linked partners) operate within this regulatory structure, managing production, certification compliance, supply chain coordination, and international trade activities. The system is structured around certification-driven production and export processes, with interactions primarily flowing from regulators and certifiers toward industry actors. Overall, the network reflects a moderately structured but weakly innovation-oriented Triple Helix configuration. While government and industry interactions are clearly defined within a regulatory-commercial system, the absence of university participation and lack of co-creative or technological collaboration results in a compliance-driven rather than innovation-driven ecosystem.

Government Actors

Government agencies functioned as regulators, accreditation authorities, and institutional coordinators. Republic Act No. 10817 established the national halal governance framework, providing the legal basis for accreditation, certification, and export promotion. The Philippine Accreditation Bureau served as the principal accreditation authority responsible for recognizing halal certifying bodies and ensuring compliance with national and international standards. Government agencies also coordinated halal industry development and supported export market access by aligning domestic certification systems with international requirements. Government participation, therefore, centered on regulatory governance, accreditation, certification oversight, and institutional coordination to support halal industry development and international trade.

University Actors

University participation was absent from the initiative's operational structure. The study provided no evidence of direct involvement by universities or research

institutions in halal certification, technology development, product innovation, research, or capacity-building activities. Consequently, knowledge generation, research collaboration, and technological innovation, core functions typically associated with university participation in the Quadruple Helix, were not evident within the operational governance framework.

Industry Actors

Industry actors formed the operational core of the halal system. Halal exporters implemented certification requirements, managed production processes, and coordinated export distribution in accordance with domestic and international halal standards. Suppliers supported certified production through compliant sourcing of raw materials, while halal certifying bodies conducted inspections and certification activities to ensure regulatory compliance. Industry participation focused on certification compliance, supply chain coordination, export production, and market access rather than collaborative technology development or product innovation.

Community Actors

Community participation was limited and primarily indirect. Consumers and international markets influenced production through demand for certified halal products, while the tourism sector contributed to domestic market expansion. However, the study provided little evidence of active participation by civil society organizations, local communities, or consumer groups in governance, policy development, or innovation processes. Community involvement therefore remained largely market-oriented rather than participatory or collaborative.

Innovation Outcomes

The initiative generated several important institutional and commercial outcomes.

- Institutionalized Halal Governance: Republic Act No. 10817 established a formal national accreditation and certification framework for halal products.
- Strengthened Certification Systems: The Philippine Accreditation Bureau and halal certifying bodies institutionalized standardized auditing and certification procedures.
- Improved Export Readiness: Halal exporters aligned production systems with international certification requirements to strengthen access to global markets.
- Coordinated Halal Supply Chains: Certification requirements strengthened coordination among suppliers, certifying bodies, exporters, and regulatory agencies.
- Enhanced Regulatory Capacity: Government agencies strengthened institutional capability for halal governance and export compliance.

These outcomes demonstrate stronger regulatory coordination and export governance but provide limited evidence of technological innovation, knowledge generation, or collaborative innovation processes.

Challenges and Sustainability Strategies

Despite its strong regulatory framework, several structural limitations remained. The system depended heavily on continued international recognition of Philippine halal certification, sustained regulatory coordination, and industry compliance. More importantly, the absence of universities limited opportunities for research, product development, process innovation, and scientific validation. Community participation

also remained limited, reducing opportunities for broader stakeholder engagement and collaborative governance. Long-term sustainability was supported through continued implementation of Republic Act No. 10817, maintenance of accreditation and certification systems, institutional coordination among regulatory agencies, and sustained compliance by halal producers and exporters. These mechanisms strengthened regulatory continuity but did not substantially expand innovation capacity beyond certification governance.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: The case demonstrates a relatively weak structural configuration. Government agencies provide regulatory oversight and accreditation, while industry actors implement certification and export operations. However, universities are absent from the operational system, and community participation remains limited to market demand, resulting in an incomplete Quadruple Helix configuration.
- Functional Dimension: The case exhibits moderate functional integration. Government regulation and industry compliance are effectively coordinated to support certification, export readiness, and halal governance. However, functions related to research, technological innovation, knowledge production, and collaborative learning are largely absent.
- Relational Dimension: The relational dimension is relatively weak. Interaction occurs primarily through hierarchical regulatory relationships between accreditation authorities, certifying bodies, suppliers, and exporters. Collaboration is largely compliance-driven, with limited knowledge exchange, stakeholder participation, or cross-sector co-creation.

Case Summary

Overall, Case Study 10 demonstrates a partially developed Quadruple Helix configuration centered on regulatory governance and export-oriented halal certification. Government agencies provide institutional leadership, accreditation, and regulatory oversight, while industry actors implement certified production and export activities. Universities do not participate in the operational system, and community involvement remains largely indirect through market demand. The initiative successfully institutionalizes halal governance and export compliance but remains primarily a regulatory-commercial system rather than a mature innovation ecosystem characterized by sustained knowledge generation, technological development, and collaborative interaction across all four helices.

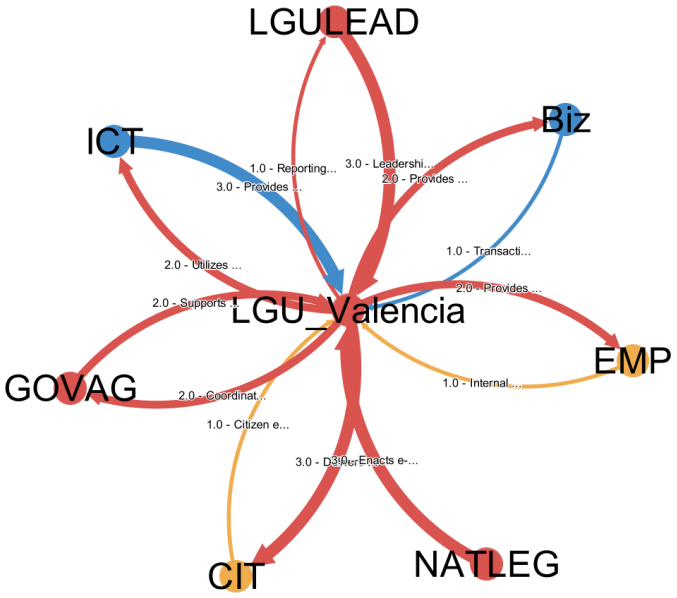
Case Study 11 (SID-b590): LGU-centered E-Government System and Hierarchical Digital Service Governance

This analytical case examined the e-government system implemented by the Local Government Unit (LGU) of Valencia City, Philippines, focusing on ICT-enabled public service delivery and digital governance across Government-to-Citizen (G2C), Government-to-Business (G2B), Government-to-Employee (G2E), and Government-to-Government (G2G) service domains (Abales et al., 2023). The initiative sought to improve administrative efficiency, strengthen inter-agency coordination, and institutionalize digital service delivery through a legislatively supported governance framework.

The case conditionally satisfied the inclusion criteria because it demonstrates institutionalized collaboration between government agencies, ICT infrastructure,

businesses, and citizens through formal digital governance systems. Government agencies provided legislative authority, policy direction, and operational management, while businesses, employees, and citizens participated primarily as users of digital public services. However, universities were absent from the operational network and community participation remains largely transactional, limiting knowledge co-production and collaborative innovation. Figure 4.33 presents the network visualization, documenting interactions among participating actors.

Figure 4.33 Case Study 11 (SID-b590): Network visualization of interactions in a government-led e-governance system.



Note: Nodes represent Government, Industry (ICT platforms), and Community actors involved in digital public service delivery, administrative coordination, and ICT-enabled governance operations, with roles and engagement levels defined by their function in the e-government framework. Directed edges represent reported relationships such as policy enforcement, legislative authority, inter-agency coordination, ICT infrastructure provision, and digital service transactions across G2C, G2B, G2E, and G2G domains. Edge weights range from 1 to 3, where 3 indicates formal governance authority and legislative control, 2 indicates operational service delivery and coordination functions, and 1 indicates transactional or user-level engagement. Government actors (LGU-Valencia City, LGULEAD, GOVAG, and NATLEG) serve as central coordinators responsible for policy direction, administrative oversight, and inter-agency governance. Industry/community actors include ICT platforms, businesses, citizens, and government employees, which function as enabling infrastructure or service users within the digital governance system. The system is structured around ICT-enabled service delivery and administrative processes rather than innovation production. Overall, the network reflects a moderately structured but

weakly innovation-oriented Triple Helix configuration. While government and ICT-enabled actors interact extensively through digital service delivery systems, the absence of university participation and limited evidence of co-creative engagement result in a hierarchical, transaction-based e-governance model rather than an integrated innovation ecosystem.

Government Actors

Government agencies served as the principal coordinators, regulators, and implementers of the digital governance system. National legislative authorities established the legal framework supporting e-government implementation, while LGU Valencia City coordinated digital public services across G2C, G2B, G2E, and G2G platforms. Government leadership also included administrative oversight, inter-agency coordination, and institutional management of ICT-enabled governance processes. Government participation therefore centered on legislative support, policy implementation, administrative coordination, and institutionalization of digital public service delivery.

University Actors

University participation was absent from the operational implementation of the initiative. The study reported no direct involvement of universities or research institutions in system design, software development, governance research, system evaluation, or policy innovation. Consequently, academic knowledge production, research collaboration, and technology development, important functions within a mature Quadruple Helix system, were not represented in the initiative.

Industry Actors

Industry participation occurred primarily through businesses using digital government services and ICT systems supporting digital transactions. Businesses

engaged with the LGU through G2B services, while ICT infrastructure enabled electronic transactions, reporting, and administrative processes. Industry actors therefore functioned mainly as service users rather than active partners in system development or technological innovation.

Community Actors

Community participation consisted primarily of citizens and government employees utilizing digital government services. Citizens accessed public services through G2C platforms, while employees used G2E systems to support administrative operations. Although users interacted regularly with the system, their participation was largely limited to service utilization rather than collaborative governance, system co-design, or innovation activities. Community engagement therefore remained transactional and service-oriented.

Innovation Outcomes

The initiative generated several important administrative and institutional outcomes.

- Institutionalized Digital Governance: ICT-enabled services were integrated into G2C, G2B, G2E, and G2G operations.
- Improved Administrative Coordination: LGU Valencia City strengthened coordination across government offices through digital platforms.
- Enhanced Service Delivery: ICT systems improved efficiency in transactions, reporting, and public service management.
- Legislative Support for Digital Transformation: National legislation provided a formal policy foundation for local e-government implementation.

- Standardized Digital Administrative Processes: Digital platforms strengthened consistency and efficiency in public service delivery.

These outcomes demonstrate successful digital transformation of administrative processes but provide limited evidence of collaborative innovation or cross-sector knowledge creation.

Challenges and Sustainability Strategies

The sustainability of the initiative depended primarily on continued government commitment, stable ICT infrastructure, legislative support, and institutional capacity for system maintenance. The absence of universities limited opportunities for research-driven system improvement, while community participation remained largely passive and service-based. Long-term sustainability was supported through institutionalization of digital governance within LGU operations, continued legislative support, routine use of ICT platforms, and ongoing administrative coordination. These mechanisms strengthened operational continuity but offered limited opportunities for collaborative innovation or adaptive system development.

Interpretation Using the Quadruple Helix Framework

- Structural Dimension: The case demonstrates moderate structural configuration. Government agencies provide policy leadership, regulation, and operational management, while businesses and citizens participate as users of digital services. However, universities are absent and community participation remains limited to service utilization, resulting in an incomplete Quadruple Helix configuration.
- Functional Dimension: The case exhibits moderate functional integration. Government agencies successfully coordinate ICT-enabled service delivery

across multiple governance domains, improving administrative efficiency and inter-agency coordination. Nevertheless, research, technological innovation, and collaborative knowledge production remain limited.

- Relational Dimension: The relational dimension is relatively weak. Interaction is largely hierarchical and transactional, with government agencies delivering digital services to businesses, employees, and citizens. Relationships emphasize service provision and administrative coordination rather than co-creation, collaborative learning, or innovation partnerships.

Case Summary

Overall, Case Study 11 demonstrates a partially developed Quadruple Helix configuration centered on ICT-enabled public service delivery. Government agencies provide legislative authority, policy leadership, and operational management, while businesses, employees, and citizens participate primarily as users of digital government services. Universities are absent from the operational network, and community participation remains largely transactional. Consequently, the initiative represents a structured digital governance system that improves administrative efficiency but falls short of a mature Quadruple Helix innovation ecosystem characterized by sustained collaboration, knowledge co-production, and cross-sector innovation.

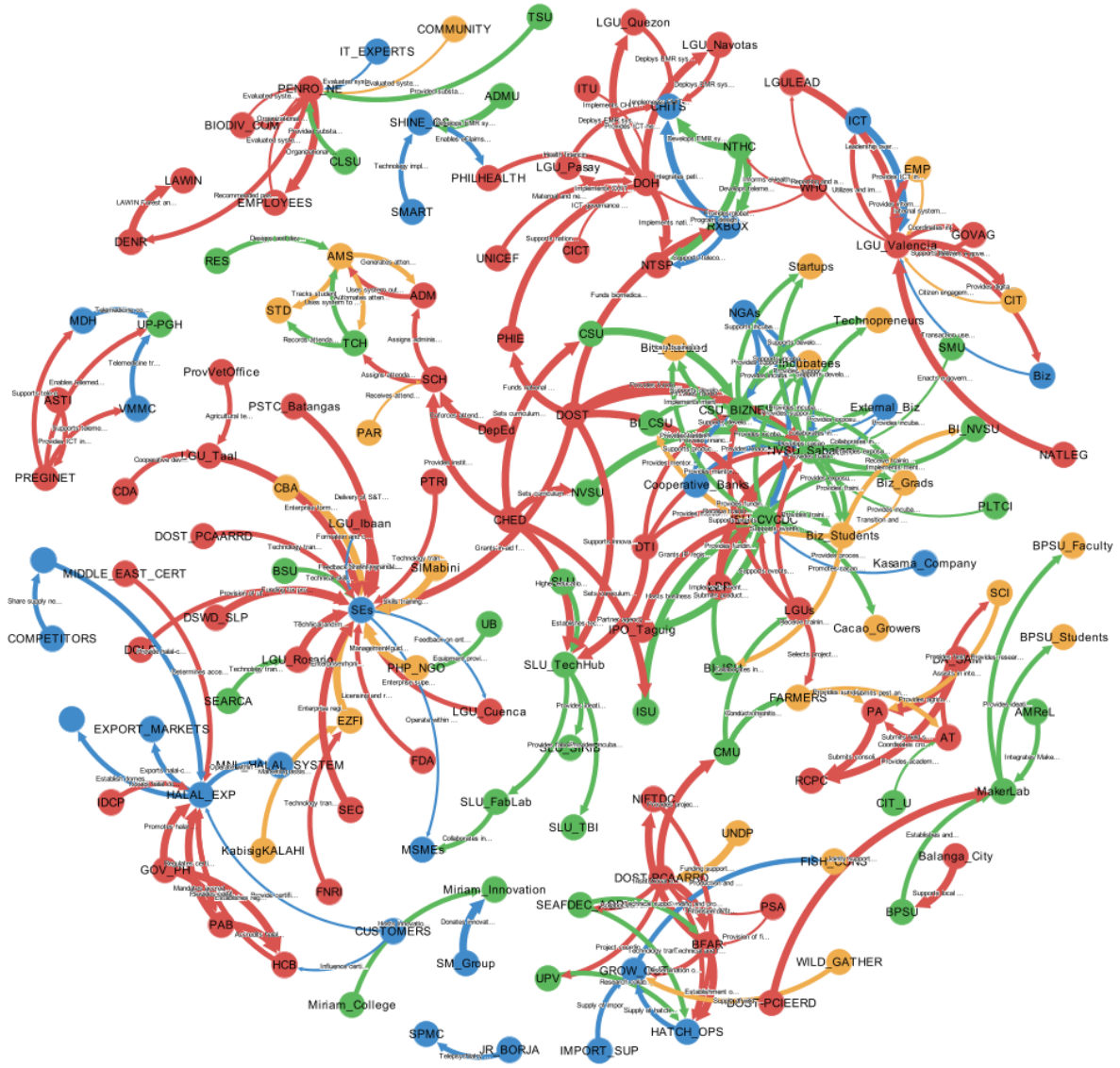
3. System-Level Interpretation of the Philippine Innovation Ecosystem (2020–2025): An Emerging State-Centric Quadruple Helix Innovation System

The synthesis of the fully included cases (Cases 1–5) and the conditionally included cases (Cases 6–11) provides a comprehensive understanding of how the Quadruple Helix Innovation Model (QHIM) was operationalized within the Philippine

innovation ecosystem during 2020–2025, following the enactment of the Philippine Innovation Act (Republic Act No. 11293) and related national innovation policies. Collectively, the cases demonstrated that innovation during the post-policy period increasingly relied on structured interactions among government agencies, universities, industry actors, and community stakeholders through formal governance mechanisms, digital platforms, coordinated implementation systems, and sector-specific innovation programs. Nevertheless, the degree of institutional integration, reciprocity, and collaborative engagement continued to vary across sectors and innovation initiatives.

Figure 4.34 consolidates the eleven analytical cases and illustrates the distribution, intensity, and diversity of Quadruple Helix configurations identified across the post-policy dataset. This demonstrates that all four helices remained present throughout the innovation ecosystem, although their relative influence differed according to institutional mandates, governance arrangements, technological complexity, and sectoral priorities.

Figure 4.34 Case Studies 1–11 (2020–2025): Network visualization of actor interactions.

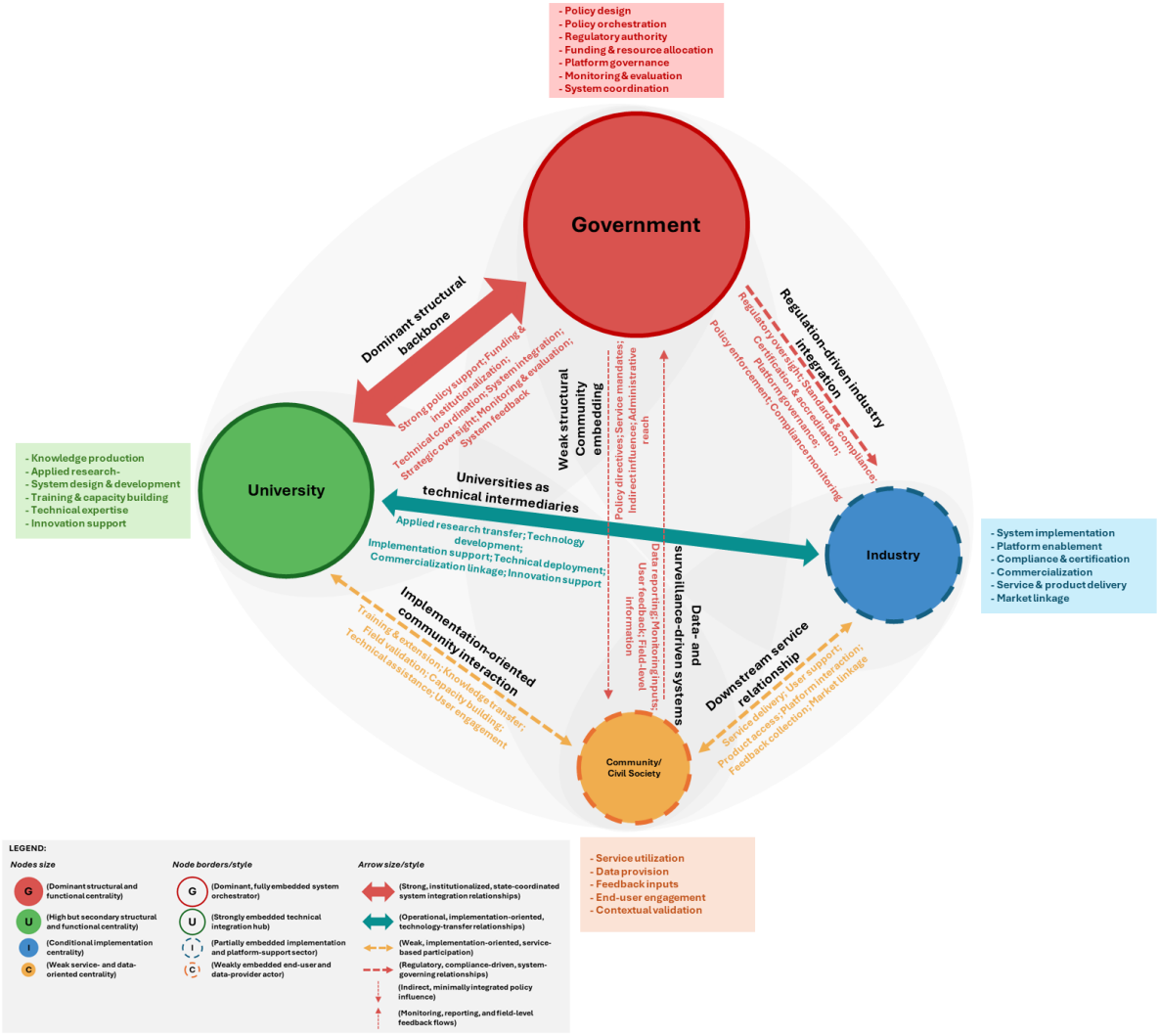


Note: This figure visualizes documented interactions among Government, University, Industry, and Community actors across Cases 1–11. Nodes represent institutional actors and their functional roles in coordination, knowledge production, regulation, implementation, system development, service delivery, commercialization, and data provision. Directed edges denote formally reported relationships, including funding, policy and regulatory oversight, accreditation, technical training, mentorship, system development, infrastructure provision, implementation support, certification, data sharing, workflow development, field validation, capacity building, monitoring, and market linkage. Edge weights range from 1 to 3, where 3 indicates primary funding authority, regulatory mandate, or strategic coordination; 2 denotes structured operational collaboration such as implementation, training, supervision, and technology transfer; and 1 reflects consultation, documentation, user engagement, data provision, or indirect facilitation. Directionality represents flows of authority, resources, technical expertise, or data among actors, with feedback loops where documented. Cases 1–5 illustrate the strongest Quadruple Helix Innovation Model (QHIM) configurations across eHealth, aquaculture innovation, ICT-enabled

environmental governance, university-based technopreneurship, and social enterprise development. Government provides strategic funding, policy direction, regulatory oversight, and coordination; universities serve as knowledge producers, technology developers, and innovation intermediaries; industry supports commercialization, enterprise development, financing, and market integration; while community actors participate as implementers, technology adopters, entrepreneurs, beneficiaries, data providers, and feedback contributors. Together, these cases demonstrate institutionally embedded collaboration integrating governance, knowledge generation, commercialization, and community participation. Cases 6–11 extend these configurations across ICT-enabled attendance monitoring, GIS-based agricultural surveillance, university makerspaces, agricultural extension, halal certification, and e-government systems. These cases remain predominantly government-centered, with universities providing technical development and implementation support. Industry participation is generally compliance-, service-, or platform-oriented, while community actors function mainly as users, beneficiaries, validators, or data providers. Although all four helices are represented, their levels of participation and institutional integration vary considerably. Overall, this demonstrates that collaboration across Cases 1–11 remains program-driven and institutionally anchored, with clear role differentiation and hierarchical flows of resources, authority, knowledge, and information. Government and universities remain the primary institutional drivers of innovation, while industry and community participation varies across sectors. Collectively, the cases depict a post-policy, semi-operational Quadruple Helix innovation system, characterized by stronger institutional coordination following the enactment of national innovation policies but continued uneven integration of industry and community actors. For detailed descriptions and complete network visualizations, refer to the individual case studies.

Building upon these empirical patterns, Figure 4.35 synthesizes the overall system configuration emerging from the eleven analytical cases and presents a conceptual representation of the Philippine innovation ecosystem during the post-policy period. Together, Figures 4.34 and 4.35 move from case-level evidence toward a system-level interpretation of the structural, functional, and relational characteristics of the Philippine Quadruple Helix innovation system after the implementation of national innovation policies.

Figure 4.35 System-Level Interpretation of the Philippine Innovation Ecosystem (2020–2025): An Emerging State-Centric Quadruple Helix Innovation System.



Note: This diagram synthesizes the Philippine innovation ecosystem across Cases 1–11 based on the network structures and interaction patterns documented in Figure 4.34. Four primary actors are represented as color-coded nodes: Government (red), Universities (green), Industry (blue), and Communities/Civil Society (orange). Node size reflects relative structural and functional centrality, while solid borders indicate strongly embedded actors and dashed borders indicate partially embedded or context-dependent actors. Arrows represent aggregated relational intensity and direction: thick solid arrows indicate strong linkages involving funding, regulation, and system coordination; medium solid arrows represent operational collaboration such as system development, implementation, training, technology transfer, and commercialization; thin dashed arrows indicate weak or episodic interactions including service delivery, user engagement, data provision, and feedback; and very thin dashed arrows indicate minimal or indirect influence. Arrow colors correspond to the actor providing primary resources, authority, or knowledge. The Government–University relationship remains the strongest structural linkage, reflecting sustained policy support, funding, regulatory coordination, and technical integration. University–Industry interactions are moderate and centered on applied research, innovation support, and commercialization, whereas Government–Industry interactions remain primarily regulatory and

compliance-oriented. Community participation occurs mainly through implementation, technology adoption, service utilization, data provision, and contextual feedback, resulting in comparatively weaker integration with the other helices. Overall, this illustrates a post-policy, semi-operational Quadruple Helix innovation system characterized by strong government–university integration, moderate industry participation, and uneven community embeddedness. Although all four helices are structurally represented, innovation remains largely coordinated through government-led institutional systems, with industry and community participation concentrated in implementation and service-oriented functions rather than sustained co-creation. Collectively, the system reflects a state-centric and institutionally mediated Quadruple Helix configuration (2020–2025) with stronger institutional coordination but uneven integration across the four helices.

Viewed through the Quadruple Helix perspective, the Philippine innovation ecosystem during 2020–2025 demonstrates stronger institutional coordination than the pre-policy period, reflecting the expansion of national innovation governance following the enactment of the Philippine Innovation Act. Government agencies, universities, industry actors, and community stakeholders were consistently represented across the analytical cases, with collaboration increasingly institutionalized through national programs, digital infrastructures, technical extension systems, innovation hubs, and sector-specific governance mechanisms. However, despite these structural improvements, interactions remained uneven in terms of reciprocity, shared governance, and long-term collaborative innovation. Many initiatives continued to emphasize implementation efficiency, administrative coordination, and service delivery rather than distributed co-creation, collaborative leadership, or hybrid institutional arrangements.

This broader pattern reflects continuing national efforts to strengthen institutional coordination, human capital development, technical capacity, and innovation-oriented governance within the Philippine innovation system, consistent with recent national assessments emphasizing the need for systemic educational and innovation reform (EDCOM-II, 2025). It also aligns with broader ASEAN discussions highlighting institutional coordination, ecosystem coherence, and technology-oriented

development strategies as essential foundations for strengthening national innovation systems (Djati & Lelyana, 2025).

The Philippine experience during 2020–2025 demonstrates that the introduction of formal innovation policies and institutional arrangements does not automatically produce a fully integrated Quadruple Helix innovation ecosystem. Although the post-policy period exhibits stronger structural coordination, expanded implementation capacity, and increasingly institutionalized innovation infrastructures, these developments do not consistently translate into distributed co-innovation, hybrid organizational arrangements, or deeply embedded multi-actor collaboration. This observation is consistent with recent innovation ecosystem scholarship suggesting that formal policy frameworks alone are insufficient to generate robust and self-sustaining innovation ecosystems without broader polycentric governance, diversified stakeholder participation, and stronger cross-sector networking mechanisms (Schebesch et al., 2024). Instead, innovation remains strongly embedded within governance systems, implementation platforms, and public-sector service delivery structures shaped by administrative coordination and institutional hierarchy. Likewise, broader innovation governance literature emphasizes that technological and organizational innovation outcomes depend not only on innovation capacity but also on governance quality, regulatory support, institutional maturity, and system integration processes that enable adaptive and inclusive innovation trajectories (Imandojemu et al., 2026).

The fully included analytical cases (Cases 1–5) demonstrated the strongest manifestation of the Quadruple Helix Innovation Model during the post-policy period. Across these initiatives, government agencies functioned as policy leaders, regulators, funders, and implementation coordinators through institutionalized national programs

and innovation policies. Universities served as knowledge producers, technology developers, innovation intermediaries, and technical integrators. Industry actors translated research outputs into commercialization, technology deployment, production systems, and enterprise development, while community actors participated through technology adoption, livelihood generation, service delivery, environmental stewardship, user feedback, implementation activities, and local innovation utilization.

Within these cases, the structural, functional, and relational dimensions of the Quadruple Helix were more closely aligned than during the pre-policy period. Government strengthened the enabling policy environment; universities expanded their role beyond research into innovation implementation and system integration; industry contributed commercialization, production, and operational deployment; while community actors increasingly participated in implementation, contextual adaptation, and service utilization. These institutional arrangements facilitated stronger knowledge exchange, improved technical coordination, and greater continuity across innovation processes. Nevertheless, community participation remained more prominent in implementation and utilization than in collaborative decision-making or innovation governance, indicating that societal engagement, while expanding, had not yet become fully institutionalized.

The integrated cases also resemble platform-oriented innovation ecosystems in which digital infrastructure, institutional coordination, and structured governance mechanisms facilitate knowledge integration and coordinated problem solving (Chen et al., 2026). Their interaction patterns likewise reflect contemporary sustainability-oriented innovation systems emphasizing adaptive governance, cross-sector collaboration, and continuous institutional learning while recognizing persistent differences in actor influence and authority (Gugerell et al., 2023). Although

coordination became more institutionalized following the Innovation Act, government agencies continued to occupy the central coordinating position within most innovation systems, with universities acting as principal technical partners rather than fully autonomous co-governors (Nandhlal & Kabanda, 2026).

In contrast, the conditionally included analytical cases (Cases 6–11) revealed that Quadruple Helix integration remained uneven despite improvements in policy coordination. Structural relationships remained concentrated primarily between government agencies and universities, reflecting their institutional mandates, technical capacity, and governance responsibilities. Industry participation remained largely implementation-oriented, compliance-driven, or service-based, while community actors commonly participated as users, beneficiaries, respondents, data providers, or recipients of innovation outputs rather than active co-creators of innovation.

Functionally, these initiatives generated important outputs including digital governance systems, monitoring platforms, surveillance technologies, innovation infrastructures, extension services, and certification systems. However, these outputs often remained confined to administrative efficiency, technical implementation, or sector-specific service delivery rather than fostering broader commercialization, institutional transformation, or collaborative innovation ecosystems. This observation is consistent with studies demonstrating that innovation performance depends not only on the presence of Quadruple Helix actors but also on the effectiveness of hybrid organizations, ecosystem coordination, and adaptive governance mechanisms that sustain long-term value creation (Kunwar & Ulak, 2023; Linton, 2024; Phonthanukitithaworn & Ketkaew, 2026).

Relationally, many post-policy interactions remained hierarchical and institutionally mediated. Government agencies coordinated implementation,

universities supplied technical expertise, industry actors fulfilled operational or compliance functions, and community actors primarily engaged through service utilization, contextual feedback, or data provision. While interaction became more continuous and institutionalized than during the pre-policy period, reciprocal collaboration, shared governance, and distributed innovation leadership remained limited. These findings reinforce broader evidence that government-led integration alone cannot generate transformative innovation unless intersectoral collaboration evolves into adaptive, operationally integrated innovation ecosystems (Espuny et al., 2025).

Taken together, the eleven analytical cases portray a post-policy, semi-operational Quadruple Helix innovation system. Compared with the pre-policy period, government agencies and universities demonstrated stronger institutional coordination through formal innovation policies, national programs, digital infrastructures, and implementation mechanisms. Nevertheless, industry and community participation remained uneven across sectors, resulting in innovation systems that were frequently implementation-oriented, institutionally mediated, and dependent on government coordination rather than fully distributed collaborative governance.

Overall, the evidence indicates that the Philippine Innovation Act strengthened the structural and functional foundations of the national innovation ecosystem by improving policy coordination, expanding institutional implementation capacity, and reinforcing government–university collaboration. However, the relational dimension of the Quadruple Helix continues to evolve more gradually. Sustained innovation requires not only formal governance arrangements but also stronger industry participation, deeper community engagement, reciprocal knowledge exchange, collaborative

leadership, and institutional mechanisms that support long-term co-creation across all four helices.

Finally, the Philippine innovation ecosystem during 2020–2025 can therefore be characterized as a post-policy, semi-operational Quadruple Helix innovation system. Compared with the pre-policy period, the ecosystem demonstrates stronger institutional coordination, expanded implementation infrastructures, and more visible innovation governance mechanisms. Nevertheless, industry and community participation remain unevenly institutionalized, constraining the emergence of a fully integrated and self-sustaining Quadruple Helix ecosystem. The post-policy period therefore reflects meaningful institutional progress toward national innovation system development while also highlighting the continuing need to strengthen cross-sector collaboration, distributed governance, and societal co-creation to support a more mature Quadruple Helix innovation system.

These findings should also be interpreted within the broader context of the Philippine innovation ecosystem. Recent assessments indicate that the country's innovation system has shown gradual progress, reflected in increasing research productivity, expanding innovation activities, and continued improvements in international innovation indicators (Custodio, 2025). This broader trajectory is likewise reflected in the Global Innovation Index (GII) 2025, where the Philippines ranked 50th among 139 economies, 3rd among lower middle-income economies, and 11th among 17 economies in Southeast Asia, East Asia, and Oceania. Compared with 2024, the country improved in both innovation inputs (59th) and innovation outputs (49th), while continuing to perform relatively better in innovation outputs than innovation inputs (WIPO, 2025). The GII 2025 also reported positive short-term growth in scientific publications, venture capital activity, and labor productivity, suggesting continued

strengthening of the national innovation environment. At the same time, the Philippines has yet to establish an innovation cluster recognized among the world's leading innovation clusters, indicating that ecosystem maturity and innovation concentration remain continuing challenges.

The interaction patterns synthesized across the reviewed analytical cases are generally consistent with this broader national context. The evidence suggests increasing institutional coordination, stronger government–university collaboration, and growing recognition of multisectoral approaches to innovation following the 2019 reforms. However, the reviewed cases also reflect persistent structural constraints identified in previous studies, including relatively low gross expenditure on research and development (GERD), limited private-sector investment, uneven university–industry collaboration, fragmented institutional coordination, and continuing shortages of highly skilled researchers (Custodio, 2025). Taken together, these findings suggest that the Philippine innovation ecosystem is progressing toward a more coordinated and institutionalized innovation system with emerging Quadruple Helix characteristics, while important structural and relational challenges continue to influence the depth, balance, and sustainability of multisectoral collaboration. Accordingly, the findings of this study provide conceptual and analytical insights into how these interaction patterns are represented in the published literature and should not be interpreted as direct evidence of policy effectiveness or national innovation performance.

To further synthesize the interaction patterns identified across the analytical cases, Table 4.2 presents the innovation typologies derived from the cross-case analysis of the structural, functional, and relational dimensions discussed in the preceding sections. Following the innovation interaction framework of Kimatu (2016), each case was classified as a Silo Confinement Model, Push–Pull Model, Science

Park Model, or Quadruple Helix Model based on the degree of institutional integration among government, higher education institutions, industry, and community actors. The analysis identified three of the four typologies across the reviewed cases, with no analytical case meeting the defining characteristics of the Science Park Model. The Push–Pull Model emerged as the dominant innovation interaction pattern across both the pre-policy (2013–2018) and post-policy (2020–2025) periods, while Quadruple Helix configurations became more evident in the post-policy period. In contrast, Silo Confinement cases were identified only among the pre-policy studies, suggesting a gradual transition toward more collaborative and institutionally integrated innovation ecosystems.

These typologies indicate that the Philippine innovation ecosystem remains dominated by reciprocal institutional collaboration, with fully integrated multisectoral partnerships still limited. Although post-policy cases suggest stronger Quadruple Helix integration, these configurations remain sector-specific. The absence of the Science Park Model further reflects reliance on direct inter-institutional collaboration. Overall, the ecosystem appears to be transitioning toward greater integration following the Philippine Innovation Act, although fully operational Quadruple Helix configurations remain limited.

Table 4.2.

Innovation Typologies of the Analytical Cases within the Philippine Innovation Ecosystem (2013–2018 and 2020–2025).

Case No.	Case (Study ID)	Dimensions	Innovation Typology	Interpretation
STUDIES BELOW ARE EXTRACTED FROM 2013–2018 PUBLICATIONS (coded as SID-a)				
1	SID-a90	Structural: Strong Functional: Strong Relational: Strong	Quadruple Helix Model	The case is classified as a Quadruple Helix Model because government, higher education institutions, industry, and community actors demonstrated strong structural, functional, and relational integration throughout the innovation process, reflecting a mature and well-integrated innovation ecosystem.
2	SID-a133	Structural: Strong Functional: Strong Relational: Strong	Quadruple Helix Model	The case is classified as a Quadruple Helix Model because government, higher education institutions, industry partners, and farming communities demonstrated strong structural, functional, and relational integration throughout the agricultural innovation process, reflecting a mature and well-integrated innovation ecosystem.
3	SID-a177	Structural: Strong Functional: Strong Relational: Strong	Quadruple Helix Model	The case is classified as a Quadruple Helix Model because government, higher education institutions, tourism industry partners, and community organizations demonstrated strong structural, functional, and relational integration in workforce and competency development, reflecting a mature and well-integrated innovation ecosystem.
4	SID-a180	Structural: Strong Functional: Strong Relational: Strong	Quadruple Helix Model	The case is classified as a Quadruple Helix Model because government, higher education institutions, industry, and community stakeholders demonstrated strong structural, functional, and relational integration in developing and applying geospatial technologies for resource management and evidence-based planning, reflecting a mature and well-integrated innovation ecosystem.

5	SID-a12	Structural: Moderate Functional: Moderate Relational: Moderate	Push–Pull Model	The case is classified as a Push–Pull Model because government and higher education institutions demonstrated moderate structural, functional, and relational integration through reciprocal collaboration. Limited industry and community participation prevented the interaction from evolving into a Quadruple Helix innovation model.
6	SID-a23	Structural: Moderate Functional: Moderate Relational: Moderate	Push–Pull Model	The case is classified as a Push–Pull Model because government agencies and research institutions demonstrated moderate structural, functional, and relational integration through reciprocal collaboration in biofouling monitoring and environmental management. Limited industry participation and the passive involvement of port personnel prevented the interaction from evolving into a Quadruple Helix innovation model.
7	SID-a24	Structural: Moderate Functional: Moderate Relational: Moderate	Push–Pull Model	The case is classified as a Push–Pull Model because government agencies, research institutions, and local communities demonstrated moderate structural, functional, and relational integration through reciprocal collaboration in sustainable forest management and REDD+ implementation. Limited industry participation and the research-oriented role of universities prevented the interaction from evolving into a Quadruple Helix innovation model.
8	SID-a29	Structural: Moderate Functional: Moderate Relational: Moderate	Push–Pull Model	The case is classified as a Push–Pull Model because government research agencies and the university demonstrated moderate structural, functional, and relational integration through reciprocal collaboration in research training and experiential learning. The absence of substantive industry participation and limited community engagement prevented the interaction from evolving into a Quadruple Helix innovation model.

9	SID-a33	Structural: Weak Functional: Moderate Relational: Weak	Silo Confinement Model	The case is classified as a Silo Confinement Model because the university demonstrated weak structural and relational integration with external stakeholders, resulting in an institution-centered innovation process with limited cross-sector collaboration.
10	SID-a34	Structural: Weak Functional: Weak Relational: Weak	Silo Confinement Model	The case is classified as a Silo Confinement Model because government agencies demonstrated weak structural, functional, and relational integration with universities, industry, and community stakeholders in fisheries governance and resource management. Limited university engagement, the absence of substantive industry participation, and weakly institutionalized community involvement constrained cross-sector collaboration, resulting in a government-centered innovation process.
11	SID-a47	Structural: Moderate Functional: Strong Relational: Moderate	Push–Pull Model	The case is classified as a Push–Pull Model because government, universities, and industry demonstrated moderate structural and relational integration in developing a blockchain-enabled pharmaceutical traceability system. Although the system exhibited strong functional integration, consumers participated primarily as end users, limiting broader multisectoral collaboration and preventing the interaction from evolving into a Quadruple Helix innovation model.
12	SID-a55	Structural: Weak Functional: Moderate Relational: Weak	Silo Confinement Model	The case is classified as a Silo Confinement Model because government and the research team demonstrated weak structural and relational integration in generating evidence on poverty and household vulnerability. The absence of substantive industry participation and the passive role of surveyed households constrained cross-sector collaboration, resulting in a research-centered innovation process.

13	SID-a58	Structural: Moderate Functional: Moderate Relational: Moderate	Push–Pull Model	The case is classified as a Push–Pull Model because government agencies, academic institutions, and community organizations demonstrated moderate structural, functional, and relational integration through reciprocal collaboration in community-based coastal resource management. Limited industry participation prevented the interaction from evolving into a Quadruple Helix innovation model.
14	SID-a59	Structural: Moderate Functional: Moderate Relational: Moderate	Push–Pull Model	The case is classified as a Push–Pull Model because government agencies, research institutions, and community organizations demonstrated moderate structural, functional, and relational integration through reciprocal collaboration in sustainable aquaculture development. Limited industry participation prevented the interaction from evolving into a Quadruple Helix innovation model.
15	SID-a69	Structural: Moderate Functional: Moderate Relational: Moderate	Push–Pull Model	The case is classified as a Push–Pull Model because government agencies and universities demonstrated moderate structural, functional, and relational integration through reciprocal collaboration in developing geospatial digital infrastructure. Limited industry participation and the passive role of end users prevented the interaction from evolving into a Quadruple Helix innovation model.
16	SID-a71	Structural: Moderate Functional: Moderate Relational: Moderate	Push–Pull Model	The case is classified as a Push–Pull Model because government agencies, universities, and community organizations demonstrated moderate structural, functional, and relational integration through reciprocal collaboration in marine conservation and coastal resource management. Limited private-sector participation prevented the interaction from evolving into a Quadruple Helix innovation model.
17	SID-a76	Structural: Strong Functional: Moderate	Push–Pull Model	The case is classified as a Push–Pull Model because government agencies, universities, and community actors demonstrated strong structural

		Relational: Moderate		integration and moderate functional and relational integration through reciprocal collaboration in ecological engineering and participatory resource management. Limited industry participation prevented the interaction from evolving into a Quadruple Helix innovation model.
18	SID-a93	Structural: Moderate Functional: Moderate Relational: Weak	Push–Pull Model	The case is classified as a Push–Pull Model because government agencies and universities demonstrated moderate structural and functional integration through reciprocal collaboration in transportation research and planning. The absence of substantive industry participation and the limited role of community stakeholders constrained relational integration, preventing the interaction from evolving into a Quadruple Helix innovation model.
19	SID-a99	Structural: Moderate Functional: Moderate Relational: Weak	Push–Pull Model	The case is classified as a Push–Pull Model because universities and industry partners demonstrated moderate structural and functional integration through internship-based collaboration supported by a government regulatory framework. Weak relational integration and limited community participation prevented the interaction from evolving into a Quadruple Helix innovation model.
20	SID-a276	Structural: Strong Functional: Moderate Relational: Moderate	Push–Pull Model	The case is classified as a Push–Pull Model because government agencies and universities demonstrated strong structural integration and moderate functional and relational integration through reciprocal collaboration in nationwide geospatial mapping and capacity building. Limited industry participation and indirect community involvement prevented the interaction from evolving into a Quadruple Helix innovation model.
STUDIES BELOW ARE EXTRACTED FROM 2020–2025 PUBLICATIONS (SID-b)				
1	SID-b100	Structural: Strong	Quadruple Helix Model	The case is classified as a Quadruple Helix Model because government agencies, universities, industry

		Functional: Strong Relational: Strong		partners, and healthcare stakeholders demonstrated strong structural, functional, and relational integration in developing and implementing a nationwide telehealth system, reflecting a mature and well-integrated innovation ecosystem.
2	SID-b171	Structural: Strong Functional: Strong Relational: Strong	Quadruple Helix Model	The case is classified as a Quadruple Helix Model because government agencies, universities, industry partners, and local aquaculture communities demonstrated strong structural, functional, and relational integration in developing, commercializing, and adopting aquaculture technologies, reflecting a mature and well-integrated innovation ecosystem.
3	SID-b247	Structural: Strong Functional: Strong Relational: Strong	Quadruple Helix Model	The case is classified as a Quadruple Helix Model because government agencies, universities, ICT specialists, and community stakeholders demonstrated strong structural, functional, and relational integration in developing and implementing a biodiversity information system, reflecting a mature and well-integrated innovation ecosystem.
4	SID-b694	Structural: Strong Functional: Strong Relational: Strong	Quadruple Helix Model	The case is classified as a Quadruple Helix Model because government agencies, universities, industry partners, and community stakeholders demonstrated strong structural, functional, and relational integration in technology business incubation, entrepreneurship, and innovation commercialization, reflecting a mature and well-integrated innovation ecosystem.
5	SID-b695	Structural: Strong Functional: Strong Relational: Strong	Quadruple Helix Model	The case is classified as a Quadruple Helix Model because government agencies, universities, industry partners, and community organizations demonstrated strong structural, functional, and relational integration in developing science- and technology-based social enterprises, reflecting a mature and well-integrated innovation ecosystem.

6	SID-b110	Structural: Moderate Functional: Moderate Relational: Weak	Push–Pull Model	The case is classified as a Push–Pull Model because government agencies, universities, and community stakeholders demonstrated moderate structural and functional integration in developing and implementing an ICT-enabled attendance monitoring system. The absence of industry participation and weak relational integration prevented the interaction from evolving into a Quadruple Helix innovation model.
7	SID-b209	Structural: Moderate Functional: Moderate Relational: Weak	Push–Pull Model	The case is classified as a Push–Pull Model because government agencies, universities, and farming communities demonstrated moderate structural and functional integration in developing and implementing a GIS-enabled agricultural monitoring system. The absence of industry participation and weak relational integration prevented the interaction from evolving into a Quadruple Helix innovation model.
8	SID-b318	Structural: Moderate Functional: Moderate Relational: Weak	Push–Pull Model	The case is classified as a Push–Pull Model because government agencies, universities, industry partners, and community stakeholders demonstrated moderate structural and functional integration in establishing makerspaces, fabrication laboratories, and innovation hubs. Weak relational integration and limited sustained cross-sector collaboration prevented the interaction from evolving into a Quadruple Helix innovation model.
9	SID-b469	Structural: Moderate Functional: Moderate Relational: Weak	Push–Pull Model	The case is classified as a Push–Pull Model because government agencies, the university, and farming communities demonstrated moderate structural and functional integration in technology transfer and agricultural extension for cacao production. The absence of industry participation and weak relational integration prevented the interaction from evolving into a Quadruple Helix innovation model.
10	SID-b582	Structural: Moderate	Push–Pull Model	The case is classified as a Push–Pull Model because government agencies,

		Functional: Moderate Relational: Weak		industry partners, and community stakeholders demonstrated moderate structural and functional integration in implementing the halal certification and regulatory system. The absence of university participation and weak relational integration prevented the interaction from evolving into a Quadruple Helix innovation model.
11	SID-b590	Structural: Moderate Functional: Moderate Relational: Weak	Push–Pull Model	The case is classified as a Push–Pull Model because government agencies, industry partners, and community stakeholders demonstrated moderate structural and functional integration in implementing an ICT-enabled e-government system. The absence of university participation and weak relational integration prevented the interaction from evolving into a Quadruple Helix innovation model.

Note: Innovation typologies were identified through cross-case analysis of actor engagement and the structural, functional, and relational dimensions in Table 4.1. Cases were classified using the four innovation interaction models proposed by Kimatu (2016): Silo Confinement Model (limited actor interaction), Push–Pull Model (reciprocal collaboration), Science Park Model (innovation coordinated through science or technology parks), and Quadruple Helix Model (integration of government, university, industry, and community actors). Actor interactions were interpreted using the Triple Helix Innovation Model (Etzkowitz & Leydesdorff, 2000) as the underlying framework for analyzing inter-institutional collaboration.

The innovation typologies in Table 4.2 provide a nuanced view of how institutional interactions evolved across the reviewed studies. Although the Push–Pull Model remained predominant across both periods, the disappearance of Silo Confinement cases and modest increase in Quadruple Helix configurations suggest strengthened multisectoral collaboration following the Philippine Innovation Act. However, the continued dominance of the Push–Pull Model indicates that many initiatives still rely on reciprocal collaboration among selected actors rather than fully institutionalized engagement across government, universities, industry, and communities.

Table 4.3 further contextualizes these patterns by synthesizing dominant themes and innovation ecosystem orientations across the pre-policy (2013–2018) and post-policy (2020–2025) periods. The findings indicate a shift from sector-specific, program-driven, and extension-oriented activities toward more institutionalized, digitally enabled, and ecosystem-oriented approaches. The pre-policy period emphasized agriculture, environmental governance, workforce development, and localized government–university collaboration, whereas the post-policy period placed greater emphasis on digital governance, innovation infrastructure, technopreneurship, social enterprises, and integrated regulatory systems. These shifts suggest increasing institutional coordination and gradual movement toward a more integrated innovation ecosystem, although government–university collaboration remained central, with industry and community participation varying across sectors and cases.

Table 4.3

Dominant thematic concentrations and innovation ecosystem orientations across pre-policy (2013–2018) and post-policy (2020–2025) Triple Helix cases in the Philippines.

Period	Dominant Themes / Sectors	Representative Focus Areas	Higher-Level Interpretation
Pre-Policy (2013–2018)	Agriculture, rural development, and extension systems	Cacao development, aquaculture, farmer clustering, fisheries management, agricultural extension	The pre-policy literature concentrated heavily on sectoral development programs focused on agriculture, livelihoods, and local capacity-building. Innovation activities were largely project-driven, extension-oriented, and implemented through localized government–university partnerships.
	Environmental governance and resource management	REDD+, marine conservation, mangrove rehabilitation, ecological engineering, biodiversity management	Environmental innovation was primarily governance- and sustainability-oriented, emphasizing community participation, conservation management, and resource monitoring rather than commercialization or technological scaling.
	Education, training, and workforce development	OJT systems, internships, practicum programs, tracer studies, curriculum evaluation	Universities functioned mainly as educators, trainers, and evaluators, reflecting a strong emphasis on human capital formation and workforce alignment rather than entrepreneurial ecosystem development.
	Geospatial, mapping, and disaster governance systems	LiDAR mapping, GIS systems, flood hazard mapping, resource mapping	Innovation activity is frequently centered on technical problem-solving and government-supported research implementation, particularly through geospatial

			technologies and decision-support systems.
	ICT-enabled monitoring and analytical systems	Blockchain medicine verification, poverty analytics, biofouling monitoring	Digital and analytical systems emerged during the pre-policy period but remained limited in ecosystem integration, commercialization, and sustained cross-sector collaboration.
	Overall Ecosystem Orientation	Program-driven, semi-integrated Triple Helix configuration with emerging Quadruple Helix tendencies	Overall, the pre-policy ecosystem exhibited asymmetric but expanding Triple Helix interactions, with strong government–university coordination, moderate university–industry collaboration, and limited community participation. Innovation remained largely organized through formal programs and project-based partnerships rather than fully integrated, co-creative networks.
Post-Policy (2020–2025)	Digital governance and ICT-enabled implementation systems	eHealth systems, e-government platforms, biodiversity information systems, attendance monitoring, GIS-enabled agricultural surveillance	The post-policy literature shifted strongly toward digitally mediated governance systems, integrated platforms, surveillance infrastructures, and ICT-enabled implementation architectures embedded within state-supported governance systems.
	Innovation infrastructure and technopreneurship ecosystems	Business incubators, makerspaces, fab labs, technopreneurship hubs, innovation centers	Universities increasingly operated as institutional innovation hubs, while government agencies expanded funding, incubation, and ecosystem-building functions supporting entrepreneurship and commercialization.

Social enterprise and inclusive innovation systems	MSMEs, livelihood enterprises, community-based enterprises, technology transfer systems	Innovation became more institutionally coordinated and linked to formal enterprise development, inclusive innovation, and socio-economic development objectives.
Regulatory, certification, and compliance infrastructures	Halal certification systems, blockchain verification systems	Governance infrastructures became more formalized and system-oriented, emphasizing regulation, accreditation, interoperability, traceability, and standards compliance.
Integrated agricultural and aquaculture innovation systems	Aquaculture commercialization, pest surveillance, cacao extension systems	Agricultural innovation became more technologically integrated and system-coordinated, although interactions remained largely hierarchical and state-mediated.
Overall Ecosystem Orientation	System-driven, state-centric semi-operational Triple Helix configuration with emerging Quadruple Helix tendencies	Overall, the post-policy ecosystem showed stronger institutionalization and centralized coordination, primarily through government–university relationships. Industry participation remained focused on implementation and commercialization, while community engagement centered on service delivery and data provision rather than sustained co-creation. Thus, structural integration improved after 2019, but relational embeddedness and cross-sectoral collaboration remained uneven.

CHAPTER V

SUMMARY, CONCLUSION, RECOMMENDATION

This study examined 31 publications to evaluate the operationalization of the Quadruple Helix Innovation Model within the Philippine innovation ecosystem across the pre-policy (2013–2018) and post-policy (2020–2025) periods. Using qualitative case meta-analysis and network analysis, it investigated interactions among government, universities, industry, and community actors across the structural, functional, and relational dimensions of innovation in sectors such as health, agriculture, environmental governance, technopreneurship, social enterprise, digital governance, certification systems, and innovation infrastructure. By comparing cases before and after the enactment of the Philippine Innovation Acts, the study examined how innovation governance evolved and whether the policy reforms were associated with stronger innovation ecosystem integration.

The synthesized evidence indicated that the Philippine innovation ecosystem did not evolve linearly toward a fully operational Quadruple Helix innovation system. Instead, the findings suggest a transition from a program-driven, semi-operational configuration during the pre-policy period (2013–2018) to a more system-driven and state-centric semi-operational configuration in the post-policy period (2020–2025). Although the post-policy period demonstrated stronger institutional coordination, implementation capacity, governance infrastructure, and policy integration, these advances were not consistently accompanied by stronger relational integration among innovation actors. Across both periods, government and universities remained the primary institutional anchors of the innovation ecosystem, while industry and community participation continued to be uneven, particularly in collaborative

governance, shared decision-making, and sustained co-creation. These findings suggest that, despite significant institutional and policy advancements following the Philippine Innovation Act, the country's innovation ecosystem remains in transition toward a more integrated and collaborative Quadruple Helix configuration.

These conclusions should be interpreted in light of the study's qualitative design and the unequal composition of cases across the two policy periods. Because the synthesized cases differed in number, sectoral focus, and institutional context, the findings represent evidence-based patterns of Quadruple Helix operationalization rather than definitive assessments of the Philippine innovation system.

The findings are consistent with previous studies that have identified persistent challenges in the Philippine innovation ecosystem, including weak government–university–industry linkages, fragmented institutional coordination, limited commercialization, and low investment in research and development despite continuing policy reforms (Aldaba, 2018; Billones et al., 2020). Although the country has established key innovation support mechanisms, such as research institutions, grant systems, technology transfer offices, and proof-of-concept funding, challenges related to interoperability, continuity, and ecosystem-wide integration remain (Billones et al., 2020). Across both policy periods, government and universities consistently served as the principal institutional anchors, while industry and community participation remained comparatively weaker and unevenly institutionalized.

These findings also align with the concept of network failure, which suggests that innovation systems may underperform not because institutional actors are absent, but because collaborative networks lack sufficient trust, coordination, knowledge exchange, and long-term relational integration (Keller & Negoita, 2013). Similarly,

evidence from developing countries indicates that stronger institutional embedding can enhance coordination without necessarily producing balanced multisectoral collaboration or fully integrated innovation ecosystems (Han, 2025). Collectively, these findings suggest that the Philippine innovation ecosystem remains in a transitional stage, where improvements in institutional coordination following the Philippine Innovation Act have not yet translated into consistently stronger relational integration, cross-sector collaboration, or sustained co-creation among Quadruple Helix actors.

The prominent role of universities identified in this study is supported by recent evidence from the Philippines. State universities and colleges (SUCs) primarily contribute to public-sector collaboration, regional development, and community engagement, whereas private universities demonstrate stronger industry partnerships, commercialization, and international linkages (Armas, 2025). Despite these complementary roles, both continue to face constraints in research funding, infrastructure, technology transfer, and industry collaboration, reinforcing the position of universities as the principal knowledge anchors of the Philippine innovation ecosystem while highlighting differences in institutional mandates and capacities.

More broadly, persistent challenges within Philippine higher education continue to constrain innovation ecosystem integration. Although universities have expanded their international engagement, limitations in research productivity, funding, global competitiveness, and regional research capacity remain significant barriers (Castulo & Marasigan, 2026; Constantino & Antonio, 2025). Continued investment in research capability, STEM education, regional innovation participation, and inclusive knowledge-production systems will therefore be critical to strengthening the country's innovation ecosystem.

These findings are further supported by analyses of Philippine science and technology policy, which document the gradual expansion of innovation institutions through R&D programs, technology transfer initiatives, innovation funding, and government–university–industry coordination (Custodio, 2025). While these reforms have strengthened the institutional foundations of the national innovation system, persistent challenges, including low R&D investment, infrastructure gaps, shortages of scientific human resources, weak commercialization, and uneven industry participation, continue to constrain the full operationalization of the Quadruple Helix Innovation Model in the Philippines.

The synthesized cases indicate that the pre-policy period (2013–2018) reflected a program-driven, semi-operational Quadruple Helix configuration, in which innovation was primarily organized through formal programs, project-based collaborations, and institution-specific initiatives. Government and universities functioned as the principal structural and functional anchors by providing policy direction, funding, research, technical expertise, and implementation support, while industry participation remained largely sector-specific and community involvement was primarily limited to implementation, contextual validation, and feedback. Although all four helices were represented, collaboration was generally fragmented and project-dependent, emphasizing technology transfer and administrative coordination rather than sustained co-creation. Stronger Quadruple Helix operationalization was evident only in cases where structural coordination, functional integration, and relational embeddedness converged.

In contrast, the post-policy period (2020–2025) reflected a transition toward a more system-driven and state-centric semi-operational Quadruple Helix configuration. Following the enactment of the Philippine Innovation Act and related policies,

innovation became increasingly institutionalized through digital platforms, governance systems, certification mechanisms, implementation infrastructures, and centralized coordination. Government assumed a stronger role in system integration, regulation, and implementation, while universities became more deeply embedded as knowledge intermediaries and technical integrators. Consequently, the government–university relationship emerged as the dominant structural backbone of the post-policy innovation ecosystem, reflecting stronger institutional coordination but not necessarily more balanced multisectoral collaboration.

The reviewed cases indicate that post-policy reforms were associated with stronger institutional coordination, implementation capacity, governance visibility, and the integration of innovation into national development systems. However, comparable improvements in relational integration were less evident. Industry participation remained largely implementation- and compliance-oriented, while community actors continued to engage primarily through service utilization, data provision, contextual feedback, and beneficiary-oriented activities rather than sustained co-governance or innovation leadership. Consequently, the post-policy innovation ecosystem appears more administratively coherent than collaboratively integrated.

Viewed comparatively, the synthesized evidence indicates that the Philippine innovation ecosystem evolved from a program-driven, semi-operational Quadruple Helix configuration during the pre-policy period toward a more system-driven and state-centric semi-operational configuration after 2019, rather than achieving a fully operational Quadruple Helix innovation system. Although intermediary organizations, including technology transfer offices, incubators, innovation hubs, Living Labs, and collaborative platforms, are already established in the Philippines (Billones et al.,

2020), their ecosystem-wide integration and sustained interaction were not consistently evident across the reviewed cases.

Based on these findings, several policy and institutional implications emerge. First, innovation policies should strengthen mechanisms that promote sustained university–industry–community collaboration beyond project implementation and regulatory compliance by expanding long-term collaborative research, commercialization initiatives, Regional Inclusive Innovation Centers (RIICs), and university–industry partnership platforms. Second, community participation should be institutionalized throughout the innovation process by integrating local knowledge into innovation design, implementation, evaluation, and governance. Third, improving coordination among intermediary organizations, including technology transfer offices, incubators, innovation hubs, Living Labs, and collaborative platforms, may reduce institutional fragmentation, enhance interoperability, and strengthen ecosystem connectivity.

Future research should examine the long-term effects of post-2019 innovation reforms using longitudinal, comparative, and network-based approaches. Greater attention should be given to regional innovation ecosystems, intermediary organizations, Quadruple Helix maturity, and the balance between state coordination and collaborative governance to provide a more comprehensive understanding of the continuing evolution of the Philippine innovation ecosystem.

Overall, this study demonstrates that the Philippine innovation ecosystem has progressed toward greater institutionalization following the enactment of the Philippine Innovation Act, but its evolution remains incomplete. While post-policy reforms have strengthened governance coordination, implementation capacity, and innovation

infrastructure, the transition to a fully operational Quadruple Helix innovation ecosystem remains constrained by uneven industry participation, limited community co-creation, and varying levels of relational integration. By providing a qualitative synthesis of innovation interactions before and after the Philippine Innovation Act, this study contributes to the growing body of Quadruple Helix scholarship and offers evidence to inform future innovation policy, institutional development, and ecosystem governance in the Philippines.

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APPENDICES

The complete appendix materials are available in the Open Science Framework (OSF) repository: https://osf.io/tecnx/. The repository contains the following appendices:

APPENDIX A – Bibliographic and screening characteristics of studies identified (2013–2018) – [https://osf.io/tecnx/]

APPENDIX B – Analytical Screening for Triple Helix Meta-Synthesis (2013–2018) – [https://osf.io/tecnx/]

APPENDIX C – Bibliographic and screening characteristics of studies identified (2020–2025) – [https://osf.io/tecnx/]

APPENDIX D – Analytical Screening for Triple Helix Meta-Synthesis (2020–2025) – [https://osf.io/tecnx/]

APPENDIX E – Full list of nodes and their attributes for studies (2013–2018) – [https://osf.io/tecnx/]

APPENDIX F – Full list of edges and their attributes for studies (2013–2018) – [https://osf.io/tecnx/]

APPENDIX G – Full list of edges and their attributes for studies (2020–2025) – [https://osf.io/tecnx/]

APPENDIX H – Full list of edges and their attributes for studies (2020–2025) – [https://osf.io/tecnx/]