American Journal of Business Practice 2997-934X, Vol 02, No. 11, 2025

University-Industry Collaborative Innovation for County-Level Prosperity-Driven Industries: Dynamic Mechanisms and Implementation Pathways

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Abstract: Against the backdrop of global rural revitalization, county-level prosperity-driven industries (CPDIs) play a pivotal role in boosting rural economies and increasing farmers' incomes. However, their innovation capacity is often constrained by limited technological resources and talent shortages. Universities, as hubs of knowledge and technological innovation, possess the potential to address these bottlenecks through collaborative partnerships. This study explores the dynamic mechanisms and implementation pathways of collaborative innovation between universities and CPDIs, adopting a mixed-methods approach that integrates literature review, theoretical analysis, and case studies. The findings reveal that the collaborative innovation is driven by internal dynamics (e.g., CPDIs' demand for technology upgrading and universities' need for knowledge transfer) and external dynamics (e.g., policy support, market competition, and technological advancement). To realize effective collaboration, four core pathways are proposed: constructing "government-university-industry-user" integrated platforms, improving benefit-sharing and risk-sharing mechanisms, optimizing the sinking of university research resources, and strengthening targeted policy guarantees. This study enriches the theory of triple helix innovation in rural contexts and provides practical references for promoting sustainable collaboration between universities and CPDIs.

Keywords: University-Industry Collaboration, Rural Revitalization, Triple Helix Theory, Collaborative Innovation, County-Level Prosperity-Driven Industries (CPDIs)

1. Introduction

1.1 Research Background

Rural revitalization has become a strategic priority in many countries, with county-level regions emerging as key carriers for balancing urban-rural development [1]. CPDIs—rooted in local resources, such as characteristic agriculture, rural tourism, and light manufacturing—are critical to achieving inclusive growth in rural areas. However, most CPDIs face structural challenges: small-scale operations, low technological content, and insufficient access to high-skilled talent [2]. In contrast, universities accumulate abundant research outcomes, technical expertise, and human

capital, yet a large portion of their research remains confined to laboratories, failing to meet the practical needs of local industries [3].

The gap between university research and CPDI development highlights the urgency of collaborative innovation. For example, in China's Jining County, Tsinghua University's Rural Revitalization Center has successfully upgraded local traditional industries through technology transfer, demonstrating the transformative potential of university-industry collaboration [4]. Similarly, the European Union's Horizon 2020 "Collaborative Agri-Food Chains" project has leveraged university expertise to enhance the competitiveness of territorial food systems [5]. Despite these successes, systematic research on the dynamic mechanisms (i.e., what drives collaboration) and implementation pathways (i.e., how to sustain collaboration) of university-CPDI partnerships remains scarce, especially at the county level.

1.2 Research Significance

Theoretical Significance: This study expands the application of the triple helix theory Etzkowitz & Leydesdorff to rural contexts, focusing on the interactions between government [6], universities, and CPDIs. It also complements the literature on collaborative innovation by unpacking the multi-level dynamics (internal vs. external) that shape university-industry partnerships in less developed regions.

Practical Significance: The proposed pathways provide actionable strategies for county governments to design collaboration platforms, for universities to align research with local needs, and for CPDIs to access technological and human resources. This contributes to accelerating rural industrial upgrading and achieving sustainable rural revitalization.

1.3 Research Methods and Structure

This study adopts three methods:

Literature Review: Synthesizes 20+ recent studies on university-industry collaboration, rural innovation, and triple helix theory [7].

Theoretical Analysis: Uses collaborative innovation theory and demand hierarchy theory to explain the motivations of universities and CPDIs.

Case Studies: Analyzes typical cases, including Tsinghua University-Jining collaboration (China) and the EU's agri-food chains project, to verify the proposed mechanisms and pathways.

The paper is structured as follows: Section 2 reviews relevant literature and defines core concepts; Section 3 establishes the theoretical framework; Section 4 analyzes the dynamic mechanisms of collaborative innovation; Section 5 proposes implementation pathways; Section 6 presents case studies; and Section 7 concludes with findings and future directions.

2. Literature Review and Conceptual Definition

2.1 Literature Review

2.1.1 University-Industry Collaboration in Rural Areas

Previous studies have highlighted the role of universities in rural development. For instance, the Smart Village Movement in India demonstrated that "government-university-enterprise" collaboration can drive digital transformation in rural industries by addressing infrastructure gaps [8]. In Scotland, the University of Aberdeen's partnership with rural cooperatives has accelerated the adoption of renewable energy technologies, improving both environmental sustainability and economic benefits [9]. However, these studies primarily focus on macro models, with limited attention to the county-level context—where industries are smaller, resources are scarcer, and collaboration barriers are more pronounced.

2.1.2 Dynamic Mechanisms of Collaborative Innovation

Leydesdorff and Etzkowitz argued that the triple helix (government-university-industry) evolves through complementary resources and shared goals, emphasizing policy and institutional drivers [10]. Andreadis et al. further found that technological dynamics—such as AI and

digitalization—mediate the collaboration between universities and local industries by creating new application scenarios [11]. Nevertheless, existing research rarely distinguishes between internal (actor-specific) and external (environmental) dynamics, leading to an incomplete understanding of what sustains long-term collaboration.

2.1.3 Gaps in Existing Research

Three key gaps are identified:

Overemphasis on urban or national-level collaboration, with insufficient focus on CPDIs' unique needs.

Inadequate analysis of how internal and external dynamics interact to shape collaboration.

Lack of actionable pathways tailored to county-level resource constraints.

2.2 Conceptual Definition

County-Level Prosperity-Driven Industries (CPDIs): Industries located in county-level regions that prioritize farmers' income growth, rely on local resources (e.g., agriculture, culture, ecology), and have strong links to rural communities [12].

University-CPDI Collaborative Innovation: A process where universities and CPDIs jointly engage in technology R&D, product upgrading, and talent training, sharing resources, risks, and benefits to achieve mutual development [7], [13].

2. Materials and Methods

2.1 Theoretical Framework

This study draws on two core theories to guide the analysis:

2.1.1 Triple Helix Theory

Proposed by Etzkowitz and Leydesdorff, the theory posits that innovation emerges from the interactive dynamics of three actors: government, university, and industry. In the county-level context:

Government: Provides policy support (e.g., subsidies, tax incentives) and coordinates resource allocation.

University: Supplies technological expertise, research outcomes, and talent training.

CPDIs: Offers practical application scenarios, market feedback, and production resources.

The synergy of these three actors forms the foundation of collaborative innovation (Leydesdorff & Etzkowitz, 2023).

2.2.2 Collaborative Innovation Theory

This theory emphasizes that innovation is a collective process involving resource integration and goal alignment among multiple actors. For universities and CPDIs, collaboration requires aligning their heterogeneous goals: universities prioritize academic impact and social service, while CPDIs focus on market efficiency and profit (European Commission, 2023). Effective collaboration occurs when both parties' needs are met through resource exchange.

3. Results

3.1 Dynamic Mechanisms of University-CPDI Collaborative Innovation

The collaborative innovation between universities and CPDIs is driven by a combination of internal dynamics (actor-specific motivations) and external dynamics (environmental factors), which interact to form a "dynamic loop" (Figure 1).

3.1.1 Internal Dynamics: Actor-Specific Motivations

3.1.1.1 Motivations of CPDIs

Technology Upgrading Demand: Most CPDIs face pressure to improve product quality and reduce costs (e.g., digitalizing agricultural production or developing high-value-added food

products). Universities provide critical technologies to address these needs [14].

Talent Shortage: CPDIs struggle to attract high-skilled workers. Collaborative programs (e.g., university-led training or student internships) help bridge this gap [15].

3.1.1.2. Motivations of Universities

Knowledge Transfer Demand: Universities need to translate laboratory research into practical applications to enhance their social impact. CPDIs offer real-world scenarios for 成果 validation [16].

Disciplinary Development: Collaborating with CPDIs helps universities identify emerging research topics (e.g., rural digitalization), enriching their disciplinary 体系 [17].

3.2 External Dynamics: Environmental Drivers

3.2.1 Policy Support

Governments play a guiding role through policies such as funding for collaborative projects, tax breaks for university-industry partnerships, and the establishment of coordination platforms. For example, China's 2025 "Rural Revitalization Technology Innovation Plan" explicitly supports university-CPDI collaboration (State Council of China, 2025), while the EU's Horizon 2020 provides grants for agri-food chain innovation [18].

3.2.2 Market Competition

Increasing market competition (e.g., from homogeneous products or urban enterprises) forces CPDIs to seek technological upgrades through university partnerships. For instance, rural tourism enterprises in Mongolia have collaborated with universities to develop cultural tourism products, enhancing their competitiveness [19].

3.2.3 Technological Advancement

Digital technologies (e.g., AI, IoT) have reduced collaboration costs by enabling remote technical guidance and data sharing. Andreadis et al. found that universities in the U.S. use AI to analyze CPDIs' production data, providing customized technical solutions [20].

3.3 Interaction Between Internal and External Dynamics

External dynamics reinforce internal motivations: for example, policy support reduces collaboration risks, making CPDIs more willing to invest in university partnerships. Conversely, strong internal motivations (e.g., a CPDI's urgent need for technology) attract more policy and market attention, creating a positive feedback loop.

4. Discussion

4.1 Implementation Pathways of University-CPDI Collaborative Innovation

Based on the dynamic mechanisms and case evidence, four implementation pathways are proposed:

4.1.1 Construct "Government-University-Industry-User" Integrated Platforms

County governments should lead the establishment of collaboration platforms to address information asymmetry. For example:

Demand Matching Centers: Collect CPDIs' technological needs and connect them with university research teams (e.g., Tsinghua University's Jining Center) [21].

Industry-Specific Labs: Jointly built by universities and leading CPDIs to focus on key technical bottlenecks (e.g., Taizhou University's collaboration with the Zhejiang Academy of Agricultural Sciences on citrus cultivation) [22].

4.1.2 Improve Benefit-Sharing and Risk-Sharing Mechanisms

Benefit-Sharing: Adopt flexible models such as technology licensing, equity participation, and profit , based on each party's contribution. For example, in Brunei's agricultural sector, universities receive royalties from CPDIs' sales of products developed through collaboration [23].

Risk-Sharing: Establish a joint risk fund (funded by government, universities, and CPDIs) to cover R&D failures. The EU's agri-food projects use this model to reduce CPDIs' investment risks

[24].

4.2 Optimize the Sinking of University Research Resources

Talent Mobility: Implement a "dual mentor" system—university professors serve as technical advisors for CPDIs, while CPDI managers teach practical courses at universities [1].

Technology Adaptation: Universities should adjust their research to meet CPDIs' resource constraints (e.g., developing low-cost, easy-to-operate technologies instead of "high-end" solutions) (Smart Village Movement, 2025).

4.3 Strengthen Targeted Policy Guarantees

Policy: Clarify funding standards, tax incentives, and intellectual property rights (IPR) protection for collaborative projects. For example, China's policy specifies that universities can retain 70% of IPR income from collaborative research (State Council of China, 2025).

Cross-Department Coordination: Establish a joint working group (including departments of science and technology, education, and agriculture) to resolve inter-departmental barriers (North Sea Region, 2022).

4.4 Case Studies

4.4.1 Case 1: Tsinghua University-Jining CPDI Collaboration (China)

4.1.2 Background

Jining County (Shandong Province) has a strong focus on traditional industries (e.g., textile manufacturing, agricultural processing) but faces low product added value. In 2023, Tsinghua University established a Rural Revitalization Center in Jining to drive collaborative innovation.

4.1.2.1 Dynamic Mechanisms

Internal Dynamics: Jining's CPDIs needed digitalization technology; Tsinghua sought to apply its AI and IoT research.

External Dynamics: Shandong Province provided a ¥5 million grant for collaborative projects; market demand for high-quality textiles increased competition.

4.1.3 Implementation and Outcomes

Platform Construction: The center established a "demand-technology" matching system, connecting 12 CPDIs with 8 university research teams.

Resource Sinking: 15 Tsinghua professors served as technical advisors, and 50 students interned at CPDIs.

Outcomes: CPDIs' product added value increased by 30%, and 200+ farmers were employed. Tsinghua also published 10 research papers based on the collaboration (Tsinghua University, 2025).

4.5 Case 2: EU Horizon 2020 "Collaborative Agri-Food Chains" (Europe)

4.5.1 Background

The project aimed to enhance the competitiveness of small-scale agri-food CPDIs in rural Europe, involving 12 universities and 30 CPDIs across 8 countries.

4.5.2 Dynamic Mechanisms

Internal Dynamics: CPDIs needed to improve food safety and traceability; universities sought to test their blockchain and sensor technologies.

External Dynamics: The EU provided €10 million in funding; consumer demand for "sustainable food" drove market pressure.

4.5.3 Implementation and Outcomes

Risk-Benefit Mechanisms: A joint risk fund covered 50% of R&D costs; universities received 15% of sales revenue from products using their technology.

Outcomes: CPDIs' market share increased by 25%, and 8 new food products were launched. The project also established a pan-European university-CPDI collaboration network (European Commission, 2023).

5. Conclusion

5.1 Main Findings

University-CPDI collaborative innovation is driven by the interaction of internal dynamics

(actor motivations) and external dynamics (policy, market, technology).

Effective collaboration requires four pathways: integrated platforms, benefit-risk mechanisms, resource sinking, and policy guarantees.

Case studies confirm that these mechanisms and pathways are adaptable to different regional contexts (e.g., China, Europe).

5.2 Research Limitations

The case studies focus on agricultural and manufacturing CPDIs; future research could explore rural tourism or digital industries.

The study primarily uses qualitative data; quantitative analysis (e.g., surveys of 100+ CPDIs) could further validate the findings.

5.3 Future Research Directions

Compare collaborative models across different county types (e.g., agricultural vs. industrial counties).

Explore the impact of digital technologies (e.g., metaverse) on collaboration efficiency.

Analyze the role of rural communities in university-CPDI collaboration.

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