



Industry-Education Integration under the Chain-Chief System of Linyi's Signature Industrial Chains: Pathways for Empowering the High-Quality Development of the Private Economy

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Abstract: The private economy is a major component of China's regional economic development and an important source of employment, innovation, and social vitality. In Linyi, Shandong Province, private enterprises contribute more than 90% of local taxation, urban employment, innovation outputs, and enterprise numbers, making them central to the city's transition from a large commercial city to a stronger industrial city. Under the emerging chain-chief governance system, the key policy issue is how to use industry-education integration to serve the upgrading of private enterprises embedded in signature industrial chains. Taking Linyi's thirteen signature industrial chains as a regional case, this study analyses the institutional framework, implementation carriers, developmental advantages, structural constraints, and optimization pathways of industry-education integration. The paper proposes an analytical framework of "four-chain integration" and "dual-track coordination", integrating the industrial chain, education chain, talent chain, and innovation chain, while coordinating government-led chain governance with enterprise-college collaborative implementation. The findings suggest that industry-education integration can enhance the human-capital supply, technology transfer, and innovation capacity of private enterprises, but its effectiveness is constrained by supply-demand mismatch, limited participation of small and medium-sized private enterprises, barriers to factor mobility, and insufficient depth of collaborative governance. Policy recommendations include building closed-loop chain-based innovation ecosystems, improving chain-oriented financial services, establishing regularized demand-list and service-list mechanisms, and promoting the two-way flow of talent and technology. This study provides a practical policy reference for integrating vocational education reform with industrial-chain governance in resource-based and manufacturing-oriented cities.

Keywords: Chain-chief system; industrial chain; industry-education integration; private economy; high-quality development; Linyi.

1. Introduction

The private economy is one of the most dynamic foundations of Linyi's development and an important source of resilience for the city's industrial transformation. In 2025, Linyi reported a gross domestic product of RMB 686.22 billion, with year-on-year growth of 5.4% [1]. Public reports further indicate that the total number of market entities in Linyi reached approximately 1.561 million in 2025, ranking second in Shandong Province, and that private enterprises contributed more than 90% of the city's taxation, innovation outputs, urban employment, and enterprise numbers [5]. These figures demonstrate that the private economy has become a major driving force for regional high-quality development.

Linyi's industrial development has long faced structural problems often summarized as "numerous but not strong" and "scattered rather than clustered". Problems such as insufficient municipal-county coordination, fragmented departmental governance, weak collaborative innovation, and the small-scale and dispersed structure of many private enterprises have constrained industrial upgrading. Since 2025, Linyi has treated industrial development as a top-priority project and has selected thirteen signature industrial chains, including new-energy commercial vehicles, high-end engineering equipment, intelligent agricultural machinery, modern medicine, and biological manufacturing, for focused cultivation [1], [2]. The chain-chief system provides a new governance mechanism for coordinating industrial upgrading across government departments, counties, leading firms, and supporting institutions. In this system, chain leaders and special working groups identify bottlenecks, organize factor supply, attract projects, and promote technological transformation along specific industrial chains. However, industrial upgrading cannot be achieved solely through administrative coordination. It requires a stable supply of skilled workers, applied R&D capacity, technical services, and continuous knowledge transfer. Industry-education integration therefore becomes a strategic bridge linking the education chain and talent chain with the industrial chain and innovation chain.

This study addresses the following question: How can industry-education integration, embedded within Linyi's chain-chief governance system, empower private enterprises and support high-quality regional economic development? Based on the practice of Linyi's thirteen signature industrial chains, the paper constructs a framework



of four-chain integration and dual-track coordination, analyses the institutional and practical foundation of the model, identifies key constraints, and proposes policy pathways for implementation.

2. Literature Review

2.1 Industry-Education Integration and Vocational Education Reform

Industry-education integration has become an important theme in China's vocational education reform. National policies emphasize that vocational education should serve industrial transformation, improve employability, and connect schools more closely with enterprises [15], [16]. Recent research on China's vocational education system also shows that the reform focus has shifted from internal school development to wider integration among education, technology, talent, and industry [14].

Existing Chinese studies have discussed school-enterprise cooperation, industrial colleges, order-based classes, apprenticeship training, and regional industry-education communities [20]-[26]. These studies are valuable because they explain how colleges can respond to local economic demand. However, many of them still focus on the bilateral relationship between a college and an enterprise. Less attention is given to how vocational education can be embedded in a whole industrial-chain governance system. This is the gap addressed in this paper.

2.2 Regional Innovation Systems and the Role of Knowledge Intermediaries

The regional innovation systems literature emphasizes that firms do not innovate alone. They rely on local networks of knowledge organizations, training institutions, service agencies, financial actors, and government departments. Asheim and Coenen argue that different industrial sectors depend on different knowledge bases and therefore require different forms of regional innovation support [11]. Asheim and Gertler similarly emphasize that innovation is shaped by territorially embedded learning and institutional coordination [12].

This perspective is useful for Linyi. Traditional industries such as food processing, panels, machinery, logistics, and construction-related production often depend on synthetic, practice-based knowledge. Their innovation needs are closely related to process improvement, equipment maintenance, quality control, and skilled-worker training. Emerging chains such as biological manufacturing, new energy, and smart equipment require stronger links with analytical and digital knowledge. Therefore, industry-education integration should not be designed as a uniform training policy. It should be matched to the knowledge base of each chain.

2.3 Chain-Chief Governance and Industrial-Chain Coordination

The chain-chief system is a recent Chinese local governance mechanism for industrial-chain coordination. It is intended to support chain extension, chain supplementation, and chain strengthening. Research on the Industrial Chain Leader System suggests that the mechanism can coordinate multiple stakeholders, but it also creates risks if administrative power replaces market learning or if performance assessment focuses only on visible project outputs [13].

The chain-chief system therefore needs institutional checks. It should not only count signed projects or output value. It should also evaluate whether chain governance improves firms' technological capabilities, training capacity, talent retention, and access to shared services. This point is important for Linyi because many private firms are SMEs. They need practical support that reduces their transaction costs rather than broad policy slogans.

2.4 Research Gap

The literature provides useful insights, but three gaps remain. First, research on vocational education and industry-education integration often lacks a chain-governance perspective. Second, research on chain-chief governance often emphasizes industrial policy and project coordination but gives limited attention to talent development and vocational education. Third, many policy discussions do not differentiate among chain-leading firms, growth-oriented SMEs, traditional manufacturing SMEs, technology start-ups, and micro firms. This paper addresses these gaps by building a framework that connects chain governance, vocational education, private-enterprise demand, and regional innovation.

3. Research Methodology

3.1 Case-Study Design

This study uses a qualitative regional case-study design. Linyi is selected because it combines three features: a large private economy, a strong manufacturing and logistics base, and an explicit



policy experiment around thirteen signature industrial chains. The case is therefore appropriate for examining how chain-chief governance and industry-education integration can interact in a manufacturing-oriented city.

Figure 1, Distribution map of Linyi City’s iconic industrial chains

The unit of analysis is not a single enterprise or a single college. It is the regional governance arrangement that connects industrial chains, vocational education institutions, private enterprises, and innovation-service platforms. This design is suitable for a policy and governance study, but it does not allow causal claims at the firm level.

3.2 Data Sources and Analytical Procedure

The study uses four types of materials. The first type is official statistical and policy material, including Linyi’s statistical communiqué and policy documents on signature industrial chains and technological innovation. The second type is public news and government-platform reports on chain projects, training alliances, and industry-education communities. The third type is college-enterprise cooperation material, especially public reports on Linyi Vocational College’s industrial colleges, training bases, and enterprise partnerships. The fourth type is academic literature on regional innovation systems, vocational education reform, and chain-chief governance.

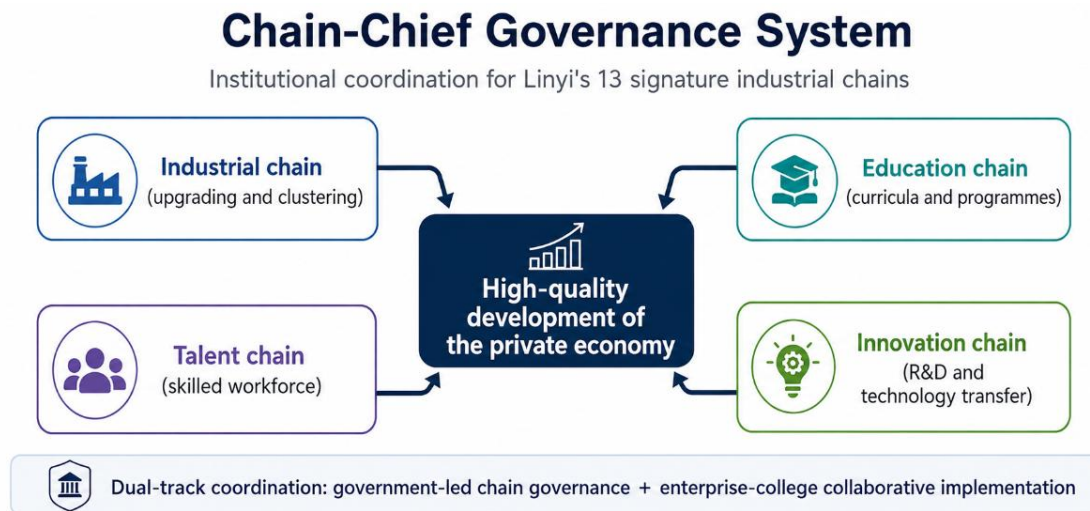


Fig. 2. Analytical framework of four-chain integration and dual-track coordination

As shown in Fig. 2, the proposed framework consists of four-chain integration and dual-track coordination. Four-chain integration refers to the coordinated development of the industrial chain, education chain, talent chain, and innovation chain. Dual-track coordination refers to the interaction between government-led chain governance and enterprise-college collaborative implementation. The former provides institutional coordination, project scheduling, policy incentives, and factor allocation, while the latter transforms industrial demand into curricula, training programmes, technology-transfer projects, and applied research services.

3.3 Critical Use of Data Sources

A key limitation of the evidence base is that many available data are official or semi-official. Such data are useful for identifying policy priorities, institutional arrangements, and reported progress. However, they should be interpreted cautiously. Output value, project-signing numbers, and growth rates indicate scale and policy momentum, but they do not by themselves prove that industry-education integration has caused productivity improvement or firm-level innovation.

Public media reports also have limits. They often highlight successful cases and may underreport failed cooperation, uneven implementation, or SME dissatisfaction. For this reason, this study treats public cases as illustrative evidence rather than as comprehensive evaluation data. Future research should collect firm-level survey data, interview SMEs, trace graduates' employment outcomes, and compare chains with different degrees of industry-education integration.

4. Case Background: Linyi's Signature Industrial Chains and Industry-Education Carriers

4.1 Industrial-Chain Layout and Private-Economy Foundation

Linyi has built its recent industrial policy around thirteen signature industrial chains. According to the 2025 statistical communiqué, the thirteen chains generated RMB 685.13 billion in output value and grew by 5.5%, contributing 4.1 percentage points to the growth of the city's total industrial output [1]. January-November 2025 reports also show 3,291 above-designated-size enterprises in the chains and 346 signed chain-related projects, including 272 industrial projects [2].

Yet the data should be read together with structural constraints. Some chains are growing rapidly, such as new-energy commercial vehicles, intelligent agricultural machinery, and premium grain and oil processing. Others, such as high-end stainless steel and advanced special steel, face pressure. This unevenness means that a single industry-education policy cannot fit all chains. Human-capital tools, technology-service tools, and financing tools should be adjusted by chain type. (Table 1)

Table 1. Chain groups and differentiated training implications

Chain group	Representative chains	Main enterprise demand	Implication for industry-education integration
Advanced equipment and vehicles	New-energy commercial vehicles; high-end engineering equipment; intelligent agricultural machinery	Technicians for electric systems, intelligent maintenance, equipment operation, after-sales service, and process improvement.	Build modular training in smart manufacturing, battery systems, equipment diagnostics, and field maintenance.
Materials and industrial inputs	Fine chemicals; stainless and special steel; aluminum-based new materials	Workers and engineers for safety management, process control, quality testing, environmental compliance, and digital production.	Create shared training and testing platforms with safety, quality, and green-production modules.
Food and agriculture processing	Healthy meat products; green fruit and vegetable processing; premium grain and oil deep processing	Skills in food safety, cold-chain logistics, quality control, packaging, digital marketing, and agricultural equipment use.	Connect colleges with processing firms, logistics firms, and rural service platforms.
Health, medicine, and bio-manufacturing	Modern medicine; biological manufacturing; new energy	Talent for laboratory operation, quality systems, data management, technical documentation, and applied R&D.	Strengthen links between vocational training, applied research institutes, and enterprise technology centers.

4.2 Existing Industry-Education Carriers in Linyi

Linyi already has several carriers that can support chain-based industry-education integration. Public reports show that the city has promoted city-level industry-education integration communities and vocational training alliances [4], [6]. These institutions can connect job demand, skills training, skills evaluation, and employment services. They provide an organizational foundation for moving from isolated school-enterprise projects to chain-level service systems.

College-level practices are also relevant. Linyi Vocational College has reported the creation of industry-education unions with Linyi Yihe New Area and Linyi High-Tech Zone, as well as industrial colleges with enterprises and associations such as JD.com, Benteng Laser, and the Shandong flooring industry [17]. The college has also developed enterprise-based industrial colleges with Tianyuan Group and Shandong Liangmeijia, and has worked with enterprises such as Shandong Lingong and Shantui Construction Machinery on modern apprenticeship, order classes, and field-engineer training [17]. Earlier reports also indicate cooperation with enterprises including Lunan Pharmaceutical, Lichen Logistics, Tianyuan Construction Group, and Huazhu Group [18]. These examples show that Linyi has practical cooperation experience, not only policy intention.

On the demand side, new-energy and equipment-related firms illustrate the need for chain-specific talent. Linyi Lingong New Energy Technology Co., Ltd. specializes in lithium battery systems for construction machinery, agricultural machinery, road transport, industrial park logistics, forklifts, AGVs, and special vehicles [19]. Such firms require not only general workers but technicians who understand battery management systems, thermal management, high-voltage safety, diagnostics, and after-sales service. This type of demand can be translated into vocational modules, micro-credentials, and continuing training for employees in the chain.

5. Four-Chain Integration and Dual-Track Coordination: Operating Mechanism

Four-chain integration means that industrial demand is converted into educational programmes, talent standards, and innovation services. Dual-track coordination means that government-led chain governance and enterprise-college implementation work together but perform different functions.

As shown in Fig. 2, the chain-chief track begins with chain mapping and demand diagnosis. Chain leaders, working groups, industry associations, and chain-leading enterprises identify missing links, skill gaps, technology bottlenecks, and SME service needs. These demands are then converted into lists: a talent-demand list, a technology-demand list, an equipment-sharing list, and a training-service list. Government departments coordinate finance, land, subsidies, project approval, public platforms, and assessment rules.

The enterprise-college track translates the lists into action. Colleges adjust professional clusters, develop short-cycle modules, invite enterprise engineers as mentors, organize apprenticeships, build in-factory classrooms, and open training bases. Enterprises provide tasks, standards, mentors, production scenarios, and feedback. Innovation platforms provide

testing, proof-of-concept services, digital transformation consulting, and technology-transfer support. The results are then evaluated and fed back into the chain-chief system.

In practice, the framework can be illustrated through the new-energy commercial-vehicle and high-end equipment chains. Chain-chief working groups can collect demand for high-voltage safety, battery-system maintenance, intelligent diagnostics, and after-sales service. Linyi Vocational College or other vocational institutions can then develop modular courses with chain-leading firms. SMEs can send workers to short-cycle training rather than building their own training departments. Training outcomes can be linked to certificates, internship placements, and enterprise performance feedback. The framework can also be applied to food processing and modern medicine. For food-processing SMEs, colleges can provide training in food safety, cold-chain management, packaging, and digital sales. For medicine and bio-manufacturing firms, the focus should be quality management, laboratory operations, technical documentation, and regulatory compliance. These examples show that four-chain integration is not a metaphor. It is a procedure for converting chain-level demand into education, training, talent, and innovation services.(Table 2)

Table 2. Practical operation of the four-chain integration mechanism

Stage	Main actor	Practical action	Expected output
1. Chain diagnosis	Chain-chief office, departments, associations, leading firms	Map weak links, collect SME demand, identify technology and skill gaps.	Demand list for talent, training, technology, and finance.
2. Education translation	Vocational colleges, universities, training institutions	Convert demand into modules, courses, certificates, competitions, and apprenticeship tasks.	Chain-oriented curriculum and training packages.
3. Enterprise implementation	Leading firms and SMEs	Provide production tasks, mentors, equipment, real cases, and internship positions.	Workplace learning and employee upskilling.
4. Innovation service	Research institutes, public training bases, technical-service centers	Offer testing, prototyping, digital transformation, process improvement, and proof-of-concept services.	Lower innovation cost for private firms.
5. Evaluation feedback	Government, colleges, enterprises, third-party evaluators	Assess employment quality, enterprise satisfaction, SME coverage, training effectiveness, and technology-transfer outcomes.	Policy adjustment and resource reallocation.

6. Developmental Basis and Advantages

6.1 Aggregated Demand from a Large Private Economy

Linyi's private economy provides a broad demand base for industry-education integration. Because private enterprises are distributed across manufacturing, trade, logistics, agriculture, food processing, medicine, equipment, and new energy, their demand for skills is diverse. This diversity is a challenge, but it is also an opportunity. It allows vocational institutions to develop multiple chain-specific training products instead of relying only on standard full-time programmes.

6.2 Chain Governance as a Coordination Platform

The chain-chief system can reduce coordination costs. Without chain governance, a college may negotiate separately with many firms, while SMEs may lack the capacity to express their needs. Under chain governance, associations and leading firms can aggregate SME demand. This creates a more efficient channel for curriculum development, training procurement, shared equipment, and technology services.

6.3 Existing College-Enterprise Cooperation Experience

The Linyi Vocational College cases show that local institutions have already experimented with industrial colleges, modern apprenticeship, order classes, public training bases, and enterprise-based teaching spaces [17], [18]. These practices matter because they provide operational experience. The next step is not simply to add more cooperation agreements. It is to connect existing carriers with the thirteen chains and evaluate their contribution to enterprise upgrading.

6.4 Innovation Services for SMEs

The biggest value of industry-education integration may lie in services that SMEs cannot easily build internally. These include employee reskilling, equipment testing, process diagnosis, digital transformation consulting, and small-scale applied R&D. When colleges and public platforms provide these services, vocational education becomes part of the local innovation infrastructure. This point connects the Linyi case to regional innovation systems theory, which stresses the importance of knowledge intermediaries and territorially embedded learning [11], [12].

7. Challenges and Critical Analysis

7.1 Policy Dependence and the Risk of Formalism

The first challenge is excessive dependence on policy mobilization. Government leadership can organize resources quickly, but it may also create formal cooperation. Some projects may focus on signing ceremonies, platform names, or short-term activities rather than deep changes in curriculum, training, and enterprise productivity. Therefore, the chain-chief system should evaluate substantive outcomes rather than only the number of projects or agreements.

7.2 Supply-Demand Mismatch

The second challenge is mismatch between education supply and industrial demand. Some programmes still follow traditional disciplinary categories, while enterprises need compound skills. For example, new-energy commercial-vehicle firms need workers who combine mechanical knowledge, electrical safety, battery management, diagnostic software, and service communication. Food-processing firms need workers who combine production skills, quality control, logistics, and digital marketing. Curriculum reform must therefore be modular and chain-specific.

7.3 Weak SME Participation

The third challenge is weak participation by SMEs. Large enterprises can provide equipment, mentors, and stable internship positions. Many SMEs cannot. They may also fear losing trained employees or exposing commercial information. If integration platforms mainly serve leading firms, they will not solve the needs of the wider private economy. Linyi should therefore design mechanisms that aggregate SME demand through associations, leading firms, and public service platforms.

7.4 Factor-Flow Barriers

The fourth challenge is limited two-way flow of talent, technology, capital, and facilities. College teachers may have limited enterprise practice. Enterprise engineers may lack incentives to teach. School training bases may not be open to SMEs. Research outputs may stop before commercialization. These problems cannot be solved by general calls for cooperation. They require contracts, workload recognition, income-distribution rules, intellectual-property arrangements, and risk-sharing mechanisms.

7.5 Uneven Data Quality and Evaluation Weakness

A further challenge is data quality. Current public data emphasize output value, project numbers, and platform construction. These are important, but they do not measure whether training improved productivity, whether graduates stayed in local firms, or whether SMEs received useful technical services. A stronger evaluation system should include both process indicators and outcome indicators.

8. Optimization Pathways and Differentiated Recommendations

8.1 Build a Chain-Level Demand-List and Service-List Mechanism

Linyi should establish a regular demand-list and service-list mechanism for each signature chain. The demand list should include skill shortages, technology problems, training needs, equipment-sharing needs, and internship capacity. The service list should show what colleges, training institutions, laboratories, public platforms, and financial institutions can provide. A monthly update and quarterly matching mechanism would make cooperation more transparent.

8.2 Move from Bilateral Cooperation to Chain-Based Service Systems

Traditional school-enterprise cooperation often depends on one college and one enterprise. This is insufficient for Linyi's dispersed private economy. The city should promote a chain-based model: one leading college or consortium serves one chain, while multiple SMEs participate through modules, vouchers, shared bases, and association-based coordination. This would reduce the transaction cost for SMEs and avoid concentrating resources only in large enterprises.

8.3 Differentiate Support by Enterprise Type

The policy recommendations should distinguish among enterprise types. Chain-leading firms, growth-oriented SMEs, traditional manufacturing SMEs, technology start-ups, and micro firms face different constraints. A single policy package will be too general. Table 5 presents differentiated pathways. (Table 3)

8.4 Link Finance with Training and Innovation Commitments

Chain-oriented finance should not be separated from industry-education integration. Enterprises that participate in training, apprenticeship, employment absorption, technology-service projects, and SME mentoring should receive more precise support. Financial products such as technology loans, guarantee-based loans, intellectual-property pledge loans, and specialized credit for innovative firms can be linked with measurable training and innovation commitments [9].

8.5 Build an Outcome-Based Evaluation System

Linyi should include industry-education integration indicators in chain-chief assessment. The indicators should be simple, measurable, and connected to enterprise outcomes. Possible indicators include the number of SMEs served, number of jointly developed courses, number of enterprise mentors, number of employees trained, graduate retention in local chain enterprises, enterprise satisfaction, technology-transfer contracts, testing services delivered, and productivity-improvement cases. Third-party evaluation should be introduced where possible.

8.6 Strengthen Two-Way Talent and Technology Flow

The two-way flow of teachers and engineers should be institutionalized. College teachers should receive workload credit and professional-title recognition for enterprise practice and technical services. Enterprise engineers should receive compensation and recognition for teaching, mentoring, and curriculum development. Technology flow should be supported through open laboratories, shared workshops, proof-of-concept platforms, and public technical-service centers. These arrangements would help vocational education become a service infrastructure for private firms.

Table 3. Differentiated recommendations for private enterprises

Enterprise type	Main constraint	Recommended industry-education pathway	Practical policy tool
Chain-leading enterprises	Need high-level technicians, engineers, field-service staff, and innovation partners.	Jointly build industrial colleges, field-engineer programmes, enterprise courses, and applied R&D projects.	Recognition as chain training hubs; fiscal support linked to SME service obligations.
Growth-oriented SMEs in emerging chains	Need rapid reskilling but lack internal training systems.	Use short-cycle modules in battery systems, digital production, quality control, and equipment maintenance.	Training vouchers; shared training bases; subsidized access to public testing platforms.
Traditional manufacturing and processing SMEs	Need process improvement, quality control, safety, logistics, and digital marketing.	Provide on-site diagnosis, modular staff training, and productivity-improvement projects.	County-level mobile training teams and association-based training procurement.
Technology start-ups and R&D-intensive firms	Need prototyping, proof-of-concept, testing, and specialized talent.	Link firms with college labs, research institutes, graduate teams, and IP services.	Proof-of-concept funds; IP service windows; joint laboratories.
Micro and small service/logistics firms	Need basic digital skills, compliance training, and stable labour supply.	Offer low-cost continuing education, e-commerce operations, customer service, safety, and logistics modules.	Online courses, evening/weekend training, and employment-service platforms.

9. Discussion

The Linyi case shows that industry-education integration becomes more powerful when it is embedded in industrial-chain governance. Conventional cooperation is often bilateral and project-based. Chain-based integration can aggregate scattered demand, especially from SMEs, and can connect training, innovation, finance, and evaluation in one governance system.

However, the model also has clear boundaries. Government coordination is useful, but it cannot replace enterprise demand, market discipline, or institutional incentives. If the chain-chief system focuses only on output value and project signing, industry-education integration will remain peripheral. If it includes talent, training, technology services, and SME participation in regular assessment, vocational education can become a strategic tool for industrial upgrading.

Compared with the Triple Helix model, which emphasizes university-industry-government interaction [10], the Linyi model adds an industrial-chain layer. In manufacturing-oriented cities, the relevant interaction is not simply among government, colleges, and firms. It is among chain segments, leading firms, SMEs, vocational institutions, innovation platforms, finance, and local governments. This more granular structure is the main value of the four-chain integration framework.

The study also suggests that regional innovation systems should pay more attention to vocational education. Colleges are not only providers of graduates. They can act as local knowledge intermediaries, especially for SMEs that lack internal R&D and training capacity. In Linyi, the policy challenge is to turn this potential into routine services, measurable outcomes, and durable cooperation rules.

10. Conclusion

This paper revised and strengthened the analysis of industry-education integration under Linyi's chain-chief system. It added a literature review, clarified the research method, critically discussed data sources, explained the operation of the four-chain integration framework, and provided more practical and differentiated recommendations for private enterprises. The main conclusion is that industry-education integration can empower Linyi's private economy only when it becomes part of chain-based governance. The industrial chain provides demand. The education chain converts demand into programmes and modules. The talent chain supplies skilled workers, mentors, and engineers. The innovation chain provides technical services and applied R&D. Dual-track coordination links government-led chain governance with enterprise-college implementation.

For Linyi, the next step is to move from platform construction to outcome-oriented operation. The city should build chain-level demand lists and service lists, strengthen SME participation, link finance with training and innovation, institutionalize two-way talent flow, and evaluate substantive outcomes. Such reforms can help Linyi shift from scattered cooperation to an integrated ecosystem that supports the high-quality development of the private economy. The model may also offer a reference for other manufacturing-oriented cities, although its transferability should be tested through comparative and firm-level studies.

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