Frontiers in Business, Economics and Management
ISSN: 2766-824X | Vol. 25, No. 1, 2026

Mechanism Research on Cross-Regional Innovation Collaboration of Advanced Manufacturing Clusters to Build a Self-Controlled Industrial Chain

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Abstract: Against the dual background of global industrial chain restructuring and the strategy of "self-control," cross-regional innovation collaboration among advanced manufacturing clusters has become a key pathway for building a self-controlled industrial chain. Based on the division of labor pattern within the National Value Chain, this paper systematically analyzes the internal mechanisms through which advanced manufacturing clusters achieve cross-regional innovation collaboration to build a self-controlled industrial chain. The findings reveal that: the "innovative hub–transformation pivot–manufacturing foundation" three-stage division of labor formed by the eastern, central, and western regions based on comparative advantages serves as the realistic foundation and spatial carrier for cross-regional collaboration to build a self-controlled industrial chain; innovation collaboration follows the phased evolution pattern of "traction–embedding → two-way feedback → systematic symbiosis," with each stage corresponding to the progressive upgrading of self-control capability from "basic supporting capacity" to "systemic autonomous capacity" to "ecological leadership capacity" and ultimately to "rule-defining capacity"; the driving force of collaboration originates from the four-layer coupling of national strategy, local governments, cluster (or cross-cluster) networks, and corporate entities, with each layer responding to different levels of demand for industrial chain self-control; and driving strategies must match the life-cycle stages to effectively promote the continuous upgrading of industrial chain self-control. The "foundation–evolution–driving force" three-dimensional analytical framework constructed in this paper provides a systematic theoretical explanation for understanding cross-regional innovation collaboration of advanced manufacturing clusters and industrial chain self-control.

Keywords: Industrial chain self-control; Advanced manufacturing clusters; Cross-regional innovation collaboration; National value chain; Evolution mechanism.

1. Introduction

The global industrial chain is currently undergoing profound restructuring, characterized by three major trends: securitization, localization, and regionalization. Some developed countries are promoting "decoupling and supply chain disruption," continuously escalating their blockade of China's key core technologies. The issue of industrial chain self-control has thus risen from an economic efficiency concern to a matter of national strategic security. Jin Bei pointed out that the core of self-control capability lies in mastering key links and core technologies of the industrial chain, ensuring basic functioning under external shocks [1]. The "15th Five-Year Plan" explicitly proposes to "enhance the level of industrial chain self-control" and positions this as a core task in building a modernized industrial system.

One of the key pathways to achieving industrial chain self-control lies in cross-regional innovation collaboration among advanced manufacturing clusters in the eastern, central, and western regions. The National Value Chain (NVC) is a concept corresponding to the Global Value Chain (GVC), emphasizing a production division system led by domestic indigenous enterprises and based on regional comparative advantages within the country. China's electronic information industry has already formed a three-stage NVC division pattern of "R&D and design in the east, key components in the central region, and final assembly in the west" [2], which serves as a typical practice of cross-regional collaboration in building a self-controlled industrial chain.

However, a theoretical question that urgently needs to be answered is: How can advanced manufacturing clusters in the eastern, central, and western regions build a self-controlled industrial chain through cross-regional innovation collaboration? What are the internal mechanisms? Existing studies have largely focused on the internal innovation networks of individual clusters, lacking in-depth analysis of how innovation collaboration across the eastern, central, and western regions systematically serves the goal of industrial chain self-control. Based on the division of labor pattern within the National Value Chain, this paper systematically analyzes the internal mechanisms of cross-regional innovation collaboration among advanced manufacturing clusters in the eastern, central, and western regions to build a self-controlled industrial chain from the three-dimensional perspective of "realistic foundation–evolution pattern–driving mechanism."

2. The NVC Gradient Division of Labor Among Eastern, Central, and Western Advanced Manufacturing Clusters Provides a Realistic Foundation for Building a Self-Controlled Industrial Chain

Industrial chain self-control first requires that each link of the industrial chain possess the capacity to supply products

that can replace imports domestically. This raises a fundamental spatial question: How should the various links of the industrial chain be laid out domestically to make "control" possible? The NVC gradient division of labor among advanced manufacturing clusters in the eastern, central, and western regions is precisely the spatial foundation for answering this question.

There exist significant gradient differences in the level of economic and technological development among the regions where advanced manufacturing clusters in the eastern, central, and western regions are located, providing internal momentum for domestic industrial gradient transfer and the "fragmented" division of labor within the National Value Chain. Under the pattern of intra-product division of labor, China has initially formed an NVC division structure characterized by "R&D and design concentrated in the east, key component manufacturing undertaken by the central region, and large-scale manufacturing shouldered by the west" [3]. This pattern ensures that the key links of the industrial chain are completely laid out spatially across the eastern, central, and western regions—each link has corresponding production capacity reserves in all three regions, which constitutes the "spatial guarantee" of self-control.

Based on this pattern, the three types of advanced manufacturing clusters in the eastern, central, and western regions have formed clear functional positioning, with each type directly serving different levels of demand for self-control:

The East—The "Innovation Hub" of the NVC. Leveraging dense scientific research resources, active capital markets, and abundant high-end talent, it leads basic research, applied development, core component breakthroughs, and brand operations. Its contribution to self-control lies in providing "technological sovereignty"—core technologies and intellectual property rights are held by domestic enterprises, fundamentally ensuring the industrial chain is not "bottlenecked."

The Central Region—The "Transformation Pivot" of the NVC. Leveraging its solid industrial foundation and its geographical advantage connecting the east and west, it focuses on key component manufacturing and process optimization, providing an industrialization transformation platform for eastern innovation achievements [4]. The contribution to self-control lies in providing "manufacturing support"—key components are industrialized and supported domestically, ensuring the industrial chain does not rely on external supply.

The West—The "Manufacturing Foundation" of the NVC. Leveraging factor cost advantages, it undertakes large-scale, standardized production and manufacturing tasks. Its contribution to self-control lies in providing "production capacity guarantee"—large-scale manufacturing capacity ensures the industrial chain can maintain basic operations when facing external shocks.

The three types of advanced manufacturing clusters in the eastern, central, and western regions form an "innovation–manufacturing" symbiotic relationship based on complementary capabilities: the east needs the central and western regions to provide rapid feedback and production capacity support on the manufacturing side, while the central and western regions urgently need the east's technology spillover and order traction. It is precisely this symbiotic relationship that has formed a spatial closed loop from R&D to manufacturing to mass production within the country—this closed loop is itself the spatial carrier of self-control. Only through systematic collaboration among the eastern, central, and western clusters can dispersed regional advantages be integrated into the overall self-control capability of the industrial chain.

3. The Evolutionary Pattern of Self-Control Capability Upgrading Alongside Stages of Cross-Regional Innovation Collaboration Among Advanced Manufacturing Clusters

Self-control is not a state that can be achieved overnight, but rather a process of gradual accumulation and progressive upgrading. The cross-regional innovation collaboration among advanced manufacturing clusters in the eastern, central, and western regions follows the dynamic evolutionary pattern of "traction–embedding → two-way feedback → systematic symbiosis," with each stage corresponding to a different level of self-control capability.

3.1. Formation Stage: The "Basic Supporting Capacity" Stage of Self-Control

The core task of this stage is to break the single reliance on the Global Value Chain and initially form a domestic industrial chain supporting system with the eastern, central, and western spatial layout as its carrier. Collaboration exhibits a clear "center–periphery" characteristic: leading enterprises in eastern advanced manufacturing clusters implement one-way technological traction toward central and western enterprises by dispatching quality engineers, opening testing platforms, and sharing technical standards; enterprises in central and western advanced manufacturing clusters complete their capability leap from "not knowing how to do it" to "being able to do it" through "learning by doing."

The contribution of this stage to self-control lies in solving the problem of "whether it exists or not"—key components now have basic manufacturing capabilities domestically, and the industrial chain possesses "minimum import-substitution supporting capacity." At this point, self-control is at the "survival level"—capable of production and supporting, but technical standards are still defined externally, lacking autonomous iterative capacity.

3.2. Growth Stage: The "Systemic Autonomous Capacity" Stage of Self-Control

The core task of this stage is to achieve substantial breakthroughs in technological capabilities based on the eastern, central, and western spatial layout. Collaboration evolves from one-way traction to two-way interaction: leading enterprises in eastern advanced manufacturing clusters integrate global resources to achieve systemic innovation and diffuse technical standards throughout the industrial chain; key enterprises in central advanced manufacturing clusters provide upstream feedback through process improvements, forcing or optimizing the technological solutions of leading enterprises.

The contribution of this stage to self-control lies in solving the problem of "whether it is good enough"—indigenous products now approach international advanced levels in performance and quality, possessing the technological foundation for "autonomous iteration." Self-control upgrades from the "survival level" to the "catch-up level"—the self-

support rate of the industrial chain has significantly improved, but the most upstream core technologies still have weak links.

3.3. Maturity Stage: The "Ecological Leadership Capacity" Stage of Self-Control

The core task of this stage is to build a self-reinforcing system driven by domestic demand and led by innovation. Core technological innovation and key technological innovation are deeply integrated, with eastern, central, and western advanced manufacturing clusters evolving into "symbiotic innovation" based on shared vision and risk sharing [5]. Upstream and downstream enterprises in the industrial chain form a deep coupling of "you have me, and I have you" through mechanisms such as technical standard sharing, joint R&D, and joint patent layout.

The contribution of this stage to self-control lies in solving the problem of "whether it is strong enough"—the industrial chain moves from "single-point breakthroughs" to "systemic advantages," with self-control reaching the "leading level." At this point, not only is technology autonomous, but the operational rules of the industrial chain are also beginning to be defined by domestic enterprises.

3.4. Upgrading Stage: The "Rule-Defining Capacity" Stage of Self-Control

The core task of this stage is to achieve the fundamental transformation from "rule acceptor" to "rule maker" by leading disruptive technological revolutions. Leading enterprises in the east, key enterprises in the central region, and top research institutions form an "exploration community," conducting parallel exploration and rapid trial-and-error in frontier areas such as basic research and prototype development, opening up entirely new technological trajectories.

The contribution of this stage to self-control lies in solving the problem of "whether it leads or not"—self-control reaches its ultimate form, namely "paradigmatic autonomy." The industrial chain is not only technologically autonomous and ecologically autonomous but also masters the "rule sovereignty" of global industrial development.

4. The Driving Mechanism for Advanced Manufacturing Clusters to Build a Self-Controlled Industrial Chain Through Cross-Regional Innovation Collaboration

The continuous deepening of cross-regional innovation collaboration among advanced manufacturing clusters in the eastern, central, and western regions and the sustained generation of self-control capability require ongoing driving forces. The driving forces for cross-regional innovation collaboration among advanced manufacturing clusters originate from the four-layer coupling of national strategy, local governments, cluster (or cross-cluster) networks, and corporate entities [6, 7], with each layer of driving force responding to different levels of demand for industrial chain self-control.

4.1. The National Strategy Level

The national strategy responds to the "directional demand" of self-control—without clear national strategic guidance, cross-regional collaboration among advanced manufacturing clusters in the eastern, central, and western regions may fall into the trap of "each going its own way." The "15th Five-Year Plan" clearly proposes to "enhance the level of industrial chain self-control," pointing the direction for cross-regional collaboration among advanced manufacturing clusters. The state concentrates strategic resources through major national science and technology projects and industrial foundation re-engineering projects to solve "bottleneck" technological problems that a single region or enterprise cannot independently complete. It is precisely the guidance of the national strategy that has provided a unified top-level design for cross-regional collaboration among advanced manufacturing clusters in the eastern, central, and western regions.

4.2. The Local Government Level

Local governments respond to the "implementation demand" of self-control—the complete layout of the industrial chain among advanced manufacturing clusters in the eastern, central, and western regions requires breaking down administrative barriers. Eastern governments focus on creating innovation ecosystems, providing sources of technology spillover for central and western advanced manufacturing clusters; central and western governments systematically lay out supporting industries around the needs of lead enterprises. Local governments establish cross-regional collaboration mechanisms, promoting institutional innovations such as cross-regional mutual recognition of R&D investment, tax revenue sharing, and talent mobility, providing institutional guarantees for the flow of factors among advanced manufacturing clusters in the eastern, central, and western regions.

4.3. The Cluster (or Cross-Cluster) Network Level

Cluster (or cross-cluster) networks respond to the "efficiency demand" of industrial chain self-control—the efficiency of cross-regional flow of knowledge, technology, and talent among eastern R&D highlands, central manufacturing bases, and western production capacity bases determines the accumulation speed of industrial chain self-control capability. Intermediary institutions, industry associations, financial institutions, and university research institutes at the cluster level jointly provide professional services for local clusters and cross-regional collaboration systems. Cross-cluster intermediary institutions (such as chain intermediary institutions or cross-regional co-built intermediary platforms) play key roles in talent mobility, technology transfer, capital circulation, and information sharing among associated clusters. Industry associations within clusters play important roles in maintaining competitive order, cultivating independent brands, and protecting intellectual property rights. Cross-regional cooperation among industry associations helps coordinate competitive relationships among clusters and safeguard the overall interests of associated clusters.

The contribution of cluster (or cross-cluster) networks to industrial chain self-control lies in providing institutionalized channels for knowledge flow among advanced manufacturing clusters in the eastern, central, and western regions. Cross-regional innovation networks, cross-regional industry alliances, and technology transfer platforms constitute three major pillars, enabling frontier knowledge from the east to be

rapidly transmitted to manufacturing links in the central and western regions, accelerating the generation and diffusion of industrial chain self-control capability.

4.4. The Corporate Entity Level

Corporate entities respond to the "execution demand" of industrial chain self-control—no matter how good the institutional design, it ultimately must be implemented by enterprises. Leading enterprises in eastern advanced manufacturing clusters drive the growth of supporting enterprises in the central and western regions through technical standard output and supplier certification [8]. Key enterprises in central advanced manufacturing clusters achieve the leap from "passive supporting" to "active collaboration" and then to "strategic symbiosis" through "learning by doing." Western advanced manufacturing clusters, by undertaking orders from the east, form large-scale production capacity, providing stable production capacity guarantees for the entire industrial chain. It is precisely the micro-actions of enterprises that transform macro-strategic designs into industrial chain-level self-control capability.

5. Case Study: The "East–Central–West" Triangular Collaboration of the Electronic Information Industry in Building a Self-Controlled Industrial Chain

The electronic information industry is the most typical advanced manufacturing industry in China's cross-regional division of labor. Its three-stage NVC division pattern of "R&D and design in the east, key components in the central region, and final assembly in the west" fully demonstrates how cross-regional innovation collaboration among advanced manufacturing clusters in the eastern, central, and western regions systematically builds a self-controlled industrial chain.

5.1. The Formation of the Three-Stage Division Pattern

The eastern "innovation hub" is centered on the advanced manufacturing clusters of Shenzhen, Shanghai, and Beijing, gathering brand headquarters such as Huawei and Xiaomi as well as chip design enterprises, focusing on frontier technology R&D and brand operations. The central "transformation pivot" is centered on the advanced manufacturing clusters of Wuhan Optics Valley and Hefei Economic Development Zone, forming key component clusters such as optical communications and new displays—Wuhan Optics Valley has gathered over 1,000 optical communications enterprises, and Hefei has gathered nearly 150 supporting enterprises around BOE. The western "manufacturing foundation" is centered on Chongqing Xiyong Microelectronics Park, forming a manufacturing capacity of over 100 million intelligent terminals annually. The formation of the three-stage division pattern has given the electronic information industry a complete spatial layout among advanced manufacturing clusters in the eastern, central, and western regions: technology R&D in the east, key components in the central region, and large-scale manufacturing in the west—each link can find alternative production capacity within China. This is precisely the spatial guarantee of self-control.

5.2. The Parallel Evolution of Cross-Regional Collaboration and Self-Control Capability

This case fully confirms the parallel evolution of cross-regional innovation collaboration and self-control capability among advanced manufacturing clusters in the eastern, central, and western regions. During the formation stage, the east started with OEM manufacturing while the central region undertook low-end manufacturing, with self-control capability remaining at the "basic supporting" level, addressing the question of "whether it exists or not." During this period, enterprises in the central and western regions initially developed specialized supporting capabilities through the process of industrial transfer and absorption. During the growth stage, the east upgraded to independent R&D while the central region extended into key component manufacturing, with self-control capability advancing to the "systemic autonomous" level, addressing the question of "whether it is good enough." Regularized technological collaboration and joint R&D mechanisms began to emerge across the eastern, central, and western regions. During the maturity stage, the three-stage division of labor became fully established, with deep coupling among the three regions, and self-control capability reaching the "ecological leadership" level, addressing the question of "whether it is strong enough." Upstream and downstream firms formed tightly integrated relationships through joint R&D and co-patenting activities, creating a landscape of deep mutual embeddedness.

5.3. The Case's Confirmation of the Theoretical Framework

The cross-regional collaboration evolution of the electronic information industry demonstrates that during the formation stage, the east started with OEM manufacturing while the central region undertook low-end manufacturing, with self-control capability at the "basic supporting" level; during the growth stage, the east upgraded to independent R&D while the central region extended into key component manufacturing, with self-control capability advancing to the "systemic autonomous" level; during the maturity stage, the three-stage division of labor became fully established with deep coupling among the eastern, central, and western regions, and self-control capability reaching the "ecological leadership" level. This case fully confirms the "realistic foundation–evolution pattern–driving mechanism" three-dimensional theoretical framework constructed in this paper, demonstrating that the continuous improvement of cross-regional innovation collaboration among advanced manufacturing clusters in the eastern, central, and western regions is precisely the micro-mechanism through which self-control capability progressively upgrades from "basic supporting" to "systemic autonomous" to "ecological leadership."

6. Conclusions

Based on the NVC division of labor pattern, this paper systematically analyzes the internal mechanisms of cross-regional innovation collaboration among advanced manufacturing clusters in the eastern, central, and western regions to build a self-controlled industrial chain. The main conclusions are as follows:

First, the NVC gradient division of labor among advanced manufacturing clusters in the eastern, central, and western regions is the realistic foundation for cross-regional

collaboration to build a self-controlled industrial chain. The three-stage division of labor—the east as the "innovation hub," the central region as the "transformation pivot," and the west as the "manufacturing foundation"—has formed a complete spatial layout of industrial chain links across the eastern, central, and western regions, providing "spatial guarantee" for self-control.

Second, cross-regional innovation collaboration among advanced manufacturing clusters follows the dynamic evolutionary pattern of "traction–embedding → two-way feedback → systematic symbiosis," with each stage corresponding to a different level of industrial chain self-control capability—from "basic supporting" to "systemic autonomous" to "ecological leadership" and ultimately to "paradigmatic autonomy." The level of industrial chain self-control progressively upgrades with the deepening of collaboration among advanced manufacturing clusters in the eastern, central, and western regions.

Third, the driving force of collaboration originates from the four-layer coupling of national strategy, local governments, cluster (or cross-cluster) networks, and corporate entities, with each layer responding to different levels of demand for industrial chain self-control—directional demand, implementation demand, efficiency demand, and execution demand. The four layers of driving force mutually support each other, jointly driving the continuous deepening of cross-regional innovation collaboration among advanced manufacturing clusters in the eastern, central, and western regions.

Fourth, driving strategies must match the life-cycle stages to effectively promote the continuous upgrading of industrial chain self-control.

Acknowledgements

The authors gratefully acknowledge the financial support from the Shandong Provincial Natural Science Foundation, China, for the project "Research on the Mode and Mechanism of Collaborative Innovation of Advanced Manufacturing Clusters to Build a Self-Controlled Industrial Chain" (Grant No. ZR2022MG030), and from the Key R&D Program (Soft Science Project) of Shandong Province for the project "Research on the Path of Sci-Tech Innovation and Policy for Low-Altitude Economy in Shandong Province" (Grant No. 2025RZB0204).

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