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# Research on the Innovation System for Domestic Substitution of Key Core Technologies in Intelligent Manufacturing

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## ABSTRACT

The domestic substitution of key core technologies has gradually become an important way for China to prevent industrial chain and supply chain risks, and enhance control and dominance in key technological fields. This paper studies the innovation system of domestic substitution for key core technologies in China's intelligent manufacturing. First, at the 'direction identification' level, a technology identification model encompassing strategic, application, and physical aspects, along with multi-dimensional evaluation, is constructed. Combined with a dynamic, multi-party participatory technology foresight consensus-building mechanism, this provides methodological support for scientifically determining substitution priorities. Second, at the 'capability cultivation' level, focusing on enterprise innovation as the main body, it proposes breakthroughs in the core elements of intelligent manufacturing and systematically enhances enterprises' core capabilities in connectivity, analysis, and intelligence through two-way resource integration and the construction of an industrial innovation ecosystem. Finally, at the 'system building' level, it emphasizes the necessity of constructing a domestic substitution innovation system guided by the government, led by enterprises, and collaborative between industry, academia, and research. This system, through value chain upgrading, ecosystem co-construction, and policy regulation, forms a synergy to ensure the independent control of key technologies and the security of the industrial chain, thereby propelling the intelligent manufacturing industry as a whole towards the high end of the global value chain.

## KEYWORDS

Intelligent manufacturing; Key core technologies; Domestic substitution system

## 1. INTRODUCTION

With the United States launching trade and tech wars against China, leading Chinese tech enterprises have faced severe external technological blockades, and some key core technologies have been caught in a 'stranglehold' situation. The global COVID-19 pandemic has also triggered a wave of de-globalization, posing severe challenges to the traditional global trade system and supply chain order. The characteristics of regionalization and nearshoring have become increasingly prominent, making it more urgent to enhance the stability and controllability of industrial chains. China needs to leverage its vast domestic market, cultivate independent and controllable supply chains, and gradually promote the domestic substitution of key core technologies where shortcomings exist. The domestic substitution of key core technologies has gradually become an important way for China to prevent industrial chain and supply chain risks, safeguard their security, and enhance control and dominance in key technological fields. It is also the key for China's intelligent manufacturing industry to break through technological bottlenecks, overcome external technological barriers, and maintain industrial technological security. As the institutional logic of China's domestic substitution shifts from efficiency logic to security logic, the public security attribute of domestic substitution activities has become more distinct.

The domestic substitution of key core technologies in intelligent manufacturing is a systematic project. Its focus lies not only in individual Chinese manufacturing enterprises but also in the upgrading of industrial chains, value chains, and innovation chains centered on large manufacturing enterprises. It requires the joint participation and effective collaboration of the government, industries, enterprises, and universities to build a domestic substitution system for key core technologies in intelligent manufacturing. This means that on the one hand, we should emphasize the important role of market-oriented means in the domestic substitution of key core technologies, give play to the market position of enterprises as the main innovation entities, and encourage enterprises to extensively participate in the domestic substitution of key core technologies to improve quality, reduce costs and increase efficiency. On the other hand, the national system driven by national will and led by the government often has better efficiency and effectiveness in tackling key core technologies that are related to the national economy and people's livelihood. Therefore, we should further exert the role of administrative regulation means in the domestic substitution of key core technologies and strengthen the government's role, so as to establish a market-oriented, multi-level domestic substitution system for key core technologies with the participation of industry, university and research institutes.

Therefore, the main problems to be solved in this paper are as follows: First, how to establish a mechanism for identifying and forecasting key core technologies in the field of intelligent manufacturing? Second, how to cultivate enterprises' innovation capabilities to realize the domestic substitution of key core technologies in intelligent manufacturing? Third, how to draw a roadmap for the domestic substitution of key core technologies in intelligent manufacturing? This paper focuses on exploring how China can effectively establish a domestic substitution system for key core technologies in the field of intelligent manufacturing, and carries out research from three parts.

First, identifying directions. To carry out the domestic substitution of key core technologies in intelligent manufacturing, it is first necessary to clarify the technical directions with potential value and R&D foundation. Therefore, this paper conducts research on the identification and forecasting mechanism of key core technologies in intelligent manufacturing from two aspects: the key core technology identification model and the key core technology forecasting consensus-building mechanism. Second, cultivating capabilities. The realization of the domestic substitution of key core technologies in intelligent manufacturing also depends on the integration of enterprises' innovation resources and the improvement of innovation capabilities. Therefore, this paper conducts research from three aspects: clarifying the basic components of the intelligent manufacturing model, constructing a two-way integration mechanism for innovation resources of intelligent manufacturing enterprises, and building an industrial innovation ecosystem for intelligent manufacturing, so as to improve the connectivity, analytical and intelligent capabilities of intelligent manufacturing enterprises. Third, building a system. The domestic substitution of key core technologies in intelligent manufacturing is a systematic project, which requires the establishment of effective institutional mechanisms for joint participation and collaborative cooperation among multiple subjects such as the government, industries, enterprises, and universities. On the basis of the above research, this paper finally discusses the construction of an innovation system for the domestic substitution of key core technologies in intelligent manufacturing.

## 2. LITERATURE REVIEW

Tackling key core technologies is an important practical problem and theoretical research topic that China urgently needs to solve. However, academic research on key core technologies is still in its infancy, mainly focusing on characteristic analysis, innovation barriers [1], identification methods [2, 3], capability improvement [4], institutional mechanisms [5], etc. Some basic theoretical issues urgently need to be further clarified.

## 2.1. Conceptual Characteristics of Key Core Technologies

Key core technologies refer to one or more technologies that occupy a crucial position in the industrial technology system, make outstanding contributions to industrial technological development, and play a leading role in industrial market competition. They mainly include key manufacturing technologies, core component technologies, and product architecture technologies [6]. Under the guidance of President Xi's new thought on scientific and technological self-reliance and self-improvement, Hu and Yuan (2022) further emphasized the technological gaps faced by key core technologies and external blockades and suppressions, defining them as ‘technologies, methods and knowledge in core technologies that have technological gaps with other countries in the short term and are subject to blockades and suppressions, need strategic deployment as the cornerstone of a world technological power in the medium and long term, and can continuously maintain national security and play a decisive role in the technology chain and industrial chain, including key generic technologies, cutting-edge leading technologies, modern engineering technologies and disruptive technologies’ [7].

Hu and Yuan (2022) believed that key core technologies have high barriers and monopolistic characteristics in terms of technological status, high investment and long-term nature in the process of tackling key problems, uniqueness and systematisms in the breakthrough mechanism, and public goods and sustainability in innovation achievements [7]. Zhang (2019) summarized the core factors restricting the innovation and breakthrough of China’s key core technologies into the following nine points: insufficient national R&D investment, long-term low profit margins of the manufacturing industry, shortage of R&D talents, high tax and fee levels in the manufacturing industry caused by the indirect tax-based taxation system, real estate bubbles leading to the diversified investment trap, single financing channels, single forms of government innovation and industrial policies, lagging intellectual property protection, and fragmentation of upstream and downstream industrial chains [1].

## 2.2. Identification Methods of Key Core Technologies

Existing literatures mainly use patent analysis methods such as patent citation analysis and co-word analysis to identify key core technologies [2]. However, technology foresight activities relying solely on patent analysis have certain limitations and are not suitable for the early identification of key core technologies in emerging industries. In the early stage of the development of emerging industries, enterprises may not choose to protect their key core technologies in the form of patents for confidentiality purposes, which makes it difficult for patent information to fully and accurately reflect cutting-edge technological directions, thus affecting the timeliness and accuracy of the early identification and forecasting of key core technologies.

## 2.3. Domestic Substitution of Key Core Technologies

Scholars generally agree that domestic substitution of key core technologies is crucial for preventing and mitigating risks in the industrial chain and ensuring the security of the industrial and supply chains. It is also a powerful way for my country to compete with developed countries for high-end segments of the value chain. Innovation and substitution of domestic intermediate products will drive China’s industries to continuously climb to the high end of the global value chain [8]. The idea of domestic substitution originated from the ‘import substitution strategy’ proposed by Prebisch and Singer in the 1960s, which advocated that developing countries should protect their infant industries by restricting the import of manufactured goods and replace imported products with domestic products to promote the process of industrialization. For more than 40 years since the reform and opening up, China’s industrialization process has mainly followed the technological innovation model of ‘importing, importing, substituting, and imitating’, gradually developing from the initial stage to the later stage of industrialization [9]. However, this has also led to a high degree of dependence of China’s manufacturing industry on foreign countries. With China’s catch-up and upgrading in the global value chain, the United States has gradually suppressed the development of

China's high-tech industries and cutting-edge technological fields through trade wars, technology wars and other forms, and Sino-US frictions and conflicts have gradually shown a normalized, long-term and complicated trend [10]. In this context, the basic logic of domestic substitution has gradually shifted from efficiency logic to security logic. At present, scholars mainly discuss how to realize the domestic substitution of key core technologies from the aspects of breakthrough factors [7] and breakthrough paths [3, 11].

As an emerging research field, the domestic research on the domestic substitution of key core technologies is relatively fragmented, lacking systematic and institutional theoretical construction. First, the existing research has a one-sided understanding of the domestic substitution of key core technologies, mainly focusing on the iteration and breakthrough of the technology itself, without considering the concept system, activity system and support system of domestic substitution as an organic whole. Second, regarding the problem of how to realize the domestic substitution of key core technologies, the existing research is still in the early stage of theoretical exploration, mainly carrying out analysis from the aspects of breakthrough factors and paths, and has not yet developed systematic and operable theories and methods. Third, regarding the identification of key core technologies, the existing literatures are mainly based on patent analysis methods, which are difficult to meet the needs of the early identification of key core technologies, and it is necessary to further develop new methods and mechanisms for technology identification and forecasting.

# 3. IDENTIFICATION AND FORECASTING MECHANISM OF KEY CORE TECHNOLOGIES IN INTELLIGENT MANUFACTURING

The primary prerequisite for realizing the domestic substitution of key core technologies in the field of intelligent manufacturing is to establish an identification and monitoring system for key core technologies in the industry, so as to achieve early judgment and overall grasp of the cutting-edge technological directions and industrial development trends of intelligent manufacturing. Existing literatures mainly use patent data analysis to identify key core technologies, among which patent citation analysis and co-word analysis are the most common methods. However, technology foresight activities relying solely on patent analysis have certain limitations and are not suitable for the early identification of key core technologies in emerging industries. In these emerging industries that are still in the early stage of development, enterprises may not choose to protect their key core technologies in the form of patents for confidentiality purposes, which makes it difficult for patent information to fully and accurately reflect the cutting-edge technological development directions of emerging industries, thus affecting the timeliness and accuracy of the early identification of key core technology directions. Based on the current technological development status of China's intelligent manufacturing field, this paper integrates various technology foresight methods, innovatively proposes an identification and analysis framework for key core technologies in intelligent manufacturing, and constructs a foresight process model for key core technologies in the field of intelligent manufacturing, so as to realize dynamic evaluation and identification of key core technologies in intelligent manufacturing.

## 3.1. Evaluation and Identification Model of Key Core Technologies in Intelligent Manufacturing

The intelligent manufacturing system is built on the new generation of information technology, runs through all links of manufacturing activities such as design, production, management and service, and is a general term for advanced manufacturing processes, systems and models. Intelligent manufacturing mainly involves a wide range of technological fields such as sensors, the Internet of Things, artificial intelligence, big data, cloud computing, industrial robots, and industrial software. At present, the gap between China's intelligent manufacturing and developed countries in the field of new-generation information technologies such as artificial intelligence and big data is relatively small, and China is even in a leading position in some technological fields. However, in the fields of traditional core components of industrial robots (such as reducers and controllers), high-end CNC machine tools, and industrial software, there is a large gap in technical level compared with world-leading enterprises. Based on the literature research, this paper summarizes the current situation of technology evaluation research, integrates the existing technology evaluation index systems, and establishes a technology evaluation index system, from five aspects: strategic dimension, social dimension, economic dimension, technical dimension and resource dimension, so as to make the evaluation and identification of key core technologies in the field of intelligent manufacturing more scientific and objective, as shown in Figure 1.

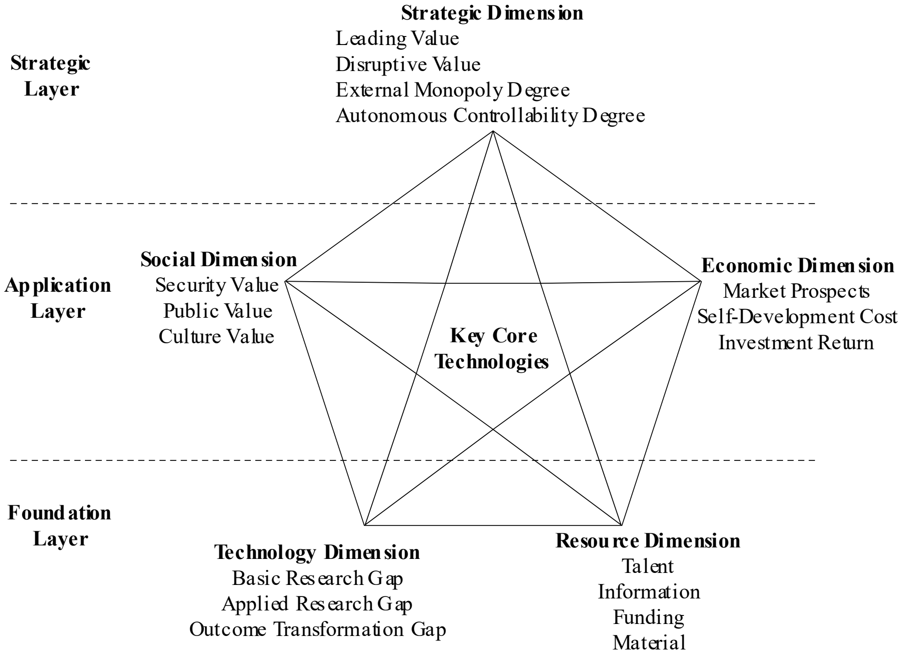


**Figure 1.** Identification Model of Key Core Technologies in Intelligent Manufacturing

### 3.1.1. Strategic Level

At this level, the strategic value of the technology is mainly analyzed, which can be specifically measured from the aspects of leading value, disruptive value, degree of independent controllability, and degree of external blockade.

Leading value measures the core leading role of the technology in the supply chain, industrial chain and value chain. It will play a leading role in promoting industrial development, industrial progress and the overall economic development, generally has broad innovation space and strong industrial relevance, and can bring amplification and multiplication effects to the development of related industries. Disruptive value measures the possible destructive impact of the technology on the existing technological paths and systems, the possible disruptive impact on the existing technological paradigms, competitive situations, business models, etc., as well as the new changes brought to the existing market and consumer expectations, thus subverting the existing market or creating new markets. The degree of independent controllability and the degree of external blockade measure the degree of 'stranglehold' problems faced by China in the technological field from two aspects based on an international perspective. The degree of independent controllability refers to the degree of external dependence on core components, basic materials, technical standards, etc., and the degree of external blockade refers to the degree of being subject to technological transfer controls and sanctions from foreign countries.

### 3.1.2. Application Level

At this level, the social value and economic value of key core technologies are mainly analyzed, and the application of technologies in socialization and industrialization is discussed.

The evaluation of social value can be carried out from the aspects of providing public value, safeguarding national security, and enhancing cultural confidence. First of all, key core technologies generally have strong public externality. The domestic substitution of key core technologies not only involves competition among market entities, but also involves the security of industrial chains, supply chains and value chains, which is closely related to national security. It is necessary to evaluate the security value of a key core technology from the aspects of information security and economic security. Secondly, key core technologies can promote the improvement of social benefits and provide public value, which is specifically reflected in improving the working environment, promoting ecological protection, increasing employment opportunities, etc. Moreover, the unreasonable application of emerging technologies may bring a series of risks in public security, ethics and morality, so it is necessary to analyze the public value of a key core technology from the above aspects.

The evaluation of economic value can be carried out from the aspects of market prospects of technology application, independent R&D costs and management benefits. Among them, market prospects judge its role in promoting industrial progress according to the market prospects of technological commercialization and application, and identify key core technology fields; independent R&D costs refer to the relevant expenses required for the technology from R&D to final commercial application; management benefits measure the management effectiveness generated by the development and application of a certain technology from the perspective of managers, and evaluate whether the technology can help the organization improve quality, reduce costs and increase efficiency.

### 3.1.3. Foundation Level

At this level, the gaps with developed countries are mainly discussed from the technical and resource dimensions. The technical dimension mainly discusses the gap between a certain technical field and the world’s first-class level from the aspects of basic research, applied research and achievement transformation. The technological gap is an important indicator to measure the relative position of national competition. If there is a large gap between a certain technology and developed countries, and the degree of technological monopoly is high, it is difficult to narrow it through technological transfer, then this technological field is likely to be a key core technology field that needs to be focused on tackling and breaking through in the future. The resource dimension measures the supporting situation of innovation resources required for the R&D activities of a certain technology, reflecting the resource foundation accumulated by China in this field for a long time, including talents, information, materials, finance, etc.

## 3.2. Consensus-Reaching Mechanism for Forecasting Key Core Technologies in Intelligent Manufacturing

After identifying the key core technologies in the field of intelligent manufacturing, it is necessary to carry out technology foresight activities to conduct in-depth analysis of the current development status of key core technologies in intelligent manufacturing, and continuously track and monitor the development dynamics of key core technologies in intelligent manufacturing. We should emphasize the connection between technology evaluation methods and technology foresight methods, based on the current technological development situation, comprehensively use existing technology foresight methods, realize the innovation of technology identification mechanism in terms of method models, summarize the cutting-edge directions, future trends and research priorities of the development of key core technologies in the intelligent manufacturing industry, and provide decision support for the government to issue the list of key core technologies in intelligent manufacturing. On the whole, the technology foresight consensus-reaching mechanism is a comprehensive system involving multi-party participation and coordination, and a dynamic and continuous interactive process, as shown in Figure 2. It evolves from disorder to order and from divergence to consensus, including four core stages: issue formation, analysis and prediction, dialogue and game, and evaluation and feedback.

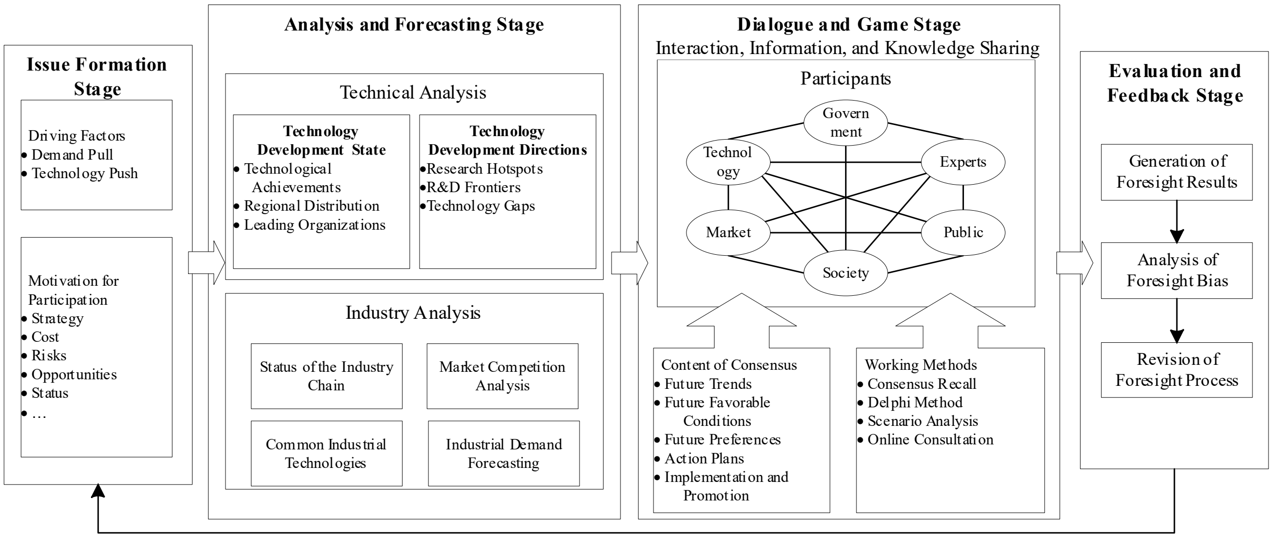


**Figure 2.** Process Mechanism for Forecasting Key Core Technologies in Intelligent Manufacturing

### 3.2.1. Issue Formation Stage

Driven by both external and internal motivations, stakeholders in technology foresight activities put forward issues around relevant technology fields. First of all, stakeholders will discuss the necessity of carrying out technology foresight in the technical field from two aspects of demand pull and technology push. Secondly, stakeholders will also decide whether to put forward issues in the technical field based on their own internal motivations, considering the impact of the technology on their own strategies, costs, risks, market positions, etc.

### 3.2.2. Analysis and Prediction Stage

The development prediction of key core technologies is mainly carried out from two dimensions: technology and industry.

The analysis from the technical dimension is mainly based on patent and scientific and technological paper data, supplemented by other types of data, mainly analyzing the current development status and development direction of the technology. Through metrological methods to process patent and literature data, we can obtain the total number of technological achievements, annual output situation and trends, regional distribution, and leading organizations in the field within a specific time period. Combined with various metrological methods (such as statistical analysis, data mining, citation analysis, social network analysis) and knowledge graph visualization tools, we can discover R&D hotspots, R&D frontiers and technological opportunities in specific technical fields.

The analysis from the industrial dimension will predict industrial generic technologies, that is, "a type of technology that can quickly drive the technological level, industrial quality and production efficiency of the entire industry or industry, and has huge economic and social benefits". On the basis of clarifying the current situation of industrial development and market prospects, we can extract the future development needs of the industry through scenario analysis, questionnaire surveys and other methods, and on this basis, predict industrial generic technologies combined with methods such as patent mining, knowledge graphs and Delphi method.

### 3.2.3. Dialogue and Game Stage

Based on the technology foresight issues, stakeholders carry out games and compromises based on their own interests through methods such as the Delphi method, focusing on future technological trends, formulation of future technological policies, etc., through strengthening the exchange and sharing of information, knowledge and other resources, and finally form an overall plan for technology foresight. On the basis of predicting the technological development direction and industrial generic technologies, technology foresight subjects can comprehensively analyze the prediction results of the two dimensions according to their own technical capabilities and resource conditions, so as to determine their key R&D fields or directions, and formulate corresponding strategies to promote technological innovation.

#### 3.2.4. Evaluation and Feedback Stage

This stage is crucial for ensuring the continuous optimization and precise control of technology foresight activities, with a focus on establishing a systematic performance evaluation and dynamic feedback mechanism. By setting multi-dimensional evaluation indicators—including the accuracy of technology foresight results, the actual guiding effect on industrial technology development, resource allocation efficiency, and the collaborative satisfaction of participating entities—the entire process and outputs of technology foresight activities are regularly evaluated quantitatively and qualitatively. Based on the evaluation results, a closed-loop feedback and adjustment mechanism is established: continuously optimizing foresight methods, data sources, and participation processes; promptly correcting deviations in the judgment of technology development directions; and dynamically adjusting the list of key core technologies and support strategies. Simultaneously, by sharing evaluation results and experience summaries through an open platform, the transparency and credibility of foresight activities are enhanced, ultimately achieving the goal of self-improvement and self-regulation of the technology foresight system through dynamic iteration.

### 3.3. Mechanism for Improving the Innovation Capability of Intelligent Manufacturing Enterprises

Whether the domestic substitution of key core technologies in intelligent manufacturing can be finally realized depends on the cultivation of the innovation capability of intelligent manufacturing enterprises. First of all, from the perspective of organizational context, this paper puts forward the basic components of the intelligent manufacturing model, summarizes them as ‘one hardware, one software, one network, one platform’, so as to put forward targeted innovation and improvement mechanisms for the basic components. Secondly, from the perspective of innovation networks, focusing on the material, information, technology, human resources, capital and other resources required to build an intelligent manufacturing model, this paper establishes two-way integration of innovation resources, expands the enterprise resource base, and optimizes enterprise resource allocation. Finally, on the basis of in-depth research on the collaborative elements of the intelligent manufacturing industry innovation ecosystem, combined with literature analysis to grasp the current situation of the collaborative development of elements of the intelligent manufacturing industry innovation ecosystem, this paper clarifies the process mechanism of intelligent manufacturing enterprises improving their intelligent manufacturing technology level from three aspects: connectivity capability, analytical capability and intelligent capability by building an industrial innovation ecosystem and strengthening collaborative innovation and cooperation. This mechanism is presented in Figure 3.

### 3.4. Analysis of the Components of the Intelligent Manufacturing Model

From the perspective of system theory, the intelligent manufacturing model can be regarded as a complex giant system, and its components can be summarized as ‘one hardware, one software, one network, one platform’. ‘One hardware’ refers to basic communication hardware such as wired networks, wireless communications, routers and switches, as well as low-human-intervention intelligent hardware such as chips and sensors. It can realize the connection between production factors such as people, equipment, materials and environment in the production process, and improve the enterprise's intelligent capability of information perception and acquisition. ‘One software’ refers to industrial software, which is specially used in the industrial field to improve the management level of industrial R&D, manufacturing, production and services, as well as the use value of industrial products, such as design software, simulation software, scheduling software, etc. The essence of industrial software is to accumulate and precipitate the empirical knowledge in specific industrial scenarios in the form of digital models or professional software tools. Industrial software establishes a digital automatic flow rule system, controls the product full-life-cycle data in the planning, manufacturing and application stages, is a bridge for data circulation, and is the brain of industrial manufacturing. ‘One network’ refers to the industrial Internet, which is a basic information network connecting production factors such as enterprises, machines, materials, people and information systems. Through technologies such as industrial field buses, industrial Ethernet, industrial wireless networks and heterogeneous network integration, it realizes comprehensive perception, dynamic transmission and real-time analysis of industrial data, promotes scientific decision-making and intelligent control, and improves the efficiency of manufacturing resource allocation. ‘One platform’ refers to the industrial Internet platform, namely the industrial cloud and intelligent service platform, which is a highly integrated, open and shared data service platform, and is a distribution center, storage center, analysis center and sharing center of data. Based on the industrial Internet platform, it promotes the development, integration, opening and sharing of basic data and tools such as professional software libraries, application model libraries, product knowledge bases, test and evaluation libraries, and case expert databases, realizes the optimization of resource allocation for the full-factor, full-process, full-industrial-chain and full-life-cycle management of production, so as to improve production efficiency, innovate model formats, and build a new industrial ecosystem.

### 3.5. Innovation Resource Integration Mechanism of Intelligent Manufacturing Enterprises

With the leapfrog development of information technology and the explosive growth of data volume, a single enterprise is difficult to independently occupy all kinds of resources such as materials, information, technology, human resources and capital required for the transformation of the intelligent manufacturing model. Carrying out the integration of innovation resources will bring a wider range of resource acquisition and a more reasonable resource allocation structure for enterprises to carry out the transformation of the intelligent manufacturing model. Intelligent manufacturing enterprises need to establish an innovation resource integration mechanism to realize the integration, absorption and re-innovation of external innovation resource elements such as suppliers, customers, partners, upstream and downstream enterprises. According to the different main bodies of the innovation network of manufacturing enterprises, the types of innovation resource integration can be divided into horizontal integration and vertical integration. Horizontal integration refers to the resource integration among the value chains of core manufacturing enterprises, cooperative enterprises and competitive enterprises. It requires manufacturing enterprises to analyze the gaps and deficiencies of innovation resources based on their own innovation needs, and make up for their weaknesses by horizontally integrating the innovation resources of cooperative enterprises, competitive enterprises and other enterprises. Vertical integration refers to the resource integration among the value chains of suppliers, core manufacturing enterprises and customers, mainly carried out around the upstream and downstream of the supply chain of manufacturing enterprises.

### 3.6. Industrial Innovation Ecosystem of Intelligent Manufacturing

In the digital era, the boundaries of manufacturing enterprises are becoming more and more blurred, and market demands are becoming more and more changeable. In an uncertain environment, enterprises need to cultivate a sound and reliable symbiotic environment through ecological operation. On the one hand, the core organizations in the ecosystem open their own resources to empower the transformation and development of partners; on the other hand, partners feed back to the core organizations to realize resource complementarity and common growth. A complete intelligent manufacturing industry innovation ecosystem involves the interaction and close cooperation among core enterprises, related enterprises, universities and research institutes, scientific and technological intermediaries, venture capital, the government, industry alliances, platform institutions and other subjects. Based on the same development vision, all subjects of the innovation ecosystem build effective channels for integrating economy and science and technology through collaboration and giving play to the maximum ecological effect of innovation elements, promote the industrialization of scientific and technological achievements, and build an innovation network aimed at value co-creation. Specifically, in the intelligent manufacturing industry innovation ecosystem, in addition to the participation of the government and universities, intelligent manufacturing enterprises also need to carry out industry-university-research cooperative R&D by establishing innovation alliances, and establish public service platforms, science and technology financial service platforms, large-scale instrument and equipment sharing platforms, scientific and technological intermediaries and other platforms to realize mutual promotion and close coordination with manufacturing enterprises, promote the sharing, transaction and protection of key generic technologies in intelligent manufacturing, and realize value co-creation among various element subjects.

Compared with the traditional manufacturing model, the digital-driven intelligent manufacturing model will achieve breakthroughs in three aspects of capabilities. First, connectivity capability. It comprehensively uses technologies such as RFID, sensors and GPS to realize perception, and realizes data collection and transmission through network access such as WiFi and 5G, and finally forms an industrial Internet of Things-based data integration system with interconnection of equipment, workshops and factories. Through the industrial big data platform-based warehousing and logistics management system and ERP system, it realizes the connection with partners such as raw material suppliers and product distributors. Finally, the five major systems are connected with government public data platforms and data service providers to achieve seamless connection between people and people, people and things, and things and things. Second, analytical capability. Deploy deep learning platforms, distributed systems, large-scale parallel computing, etc. in the production and manufacturing system to improve the computing capability of the intelligent manufacturing system, and present the analysis results with a visualization system. Third, intelligent capability. It will realize intelligent cognition, intelligent decision-making and intelligent management in all links of production and manufacturing. In the warehousing link, the system can make independent decisions according to the use of materials. For example, if the materials are about to be used up, the system will notify the material suppliers to supply goods in a timely manner, reducing the cost of material inventory. In the production link, the system can independently judge whether the equipment needs maintenance, whether the processes are redundant, etc., helping production personnel manage equipment and technical personnel improve processes.

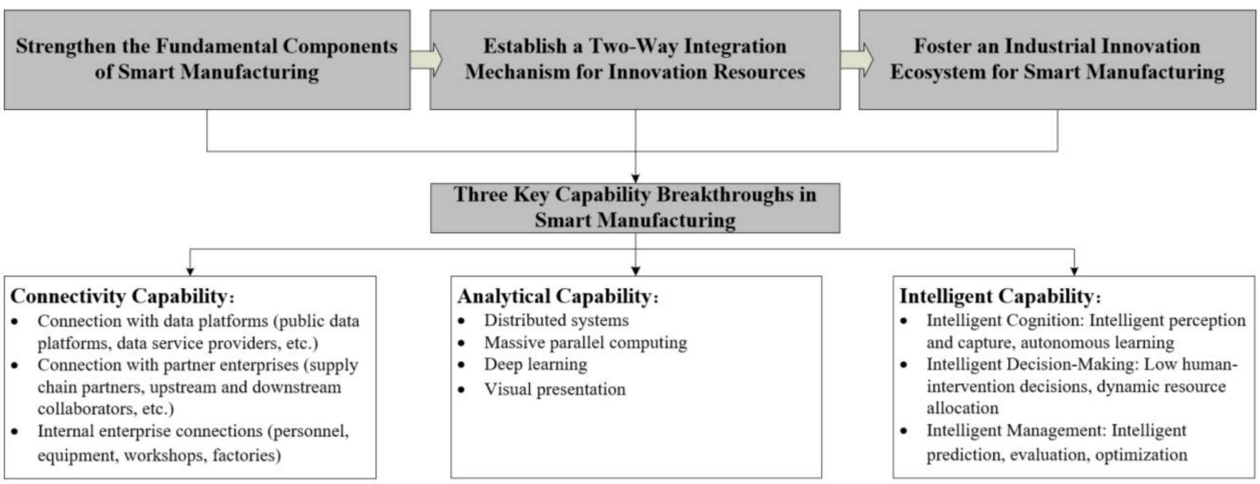


**Figure 3.** Mechanism for Improving the Innovation Capability in Intelligent Manufacturing

# 4. INNOVATION SYSTEM FOR DOMESTIC SUBSTITUTION OF KEY CORE TECHNOLOGIES IN INTELLIGENT MANUFACTURING

Based on the above analysis, considering the long-term complexity of breaking through key core technologies and the strict external technological blockades and sanctions, the domestic substitution of key core technologies in intelligent manufacturing cannot rely solely on the efforts of a single enterprise, but also needs the collaborative cooperation of multiple subjects including the government, industry, universities and research institutes. This innovation system is presented in Figure 4.

(1) Promote the reconstruction and upgrading of the value chain. From the perspective of value chain reconstruction, intelligent manufacturing enterprises will follow the three-step path of 'occupying key nodes in the global value chain → leading the global value chain → upgrading the global value chain', realize the independent controllability of the domestic value chain, supply chain and innovation chain, and continuously extend towards the key links of the international value chain, supply chain and innovation chain.

(2) Build an industrial innovation ecosystem. Focusing on the industrial innovation ecosystem built around the core intelligent manufacturing enterprises, we should give full play to the external coordination and leading role of large core manufacturing enterprises. Core enterprises take heterogeneous innovation strategies as the guide, take data empowerment of three capabilities as the driving force, comprehensively carry out different types of innovation such as independent innovation, secondary innovation and open innovation, promote the development of international innovation cooperation along the path of 'global innovation resource allocation → global innovation chain integration → global innovation network construction', give full play to the innovation synergy effect between large, medium and small enterprises, and between core and supporting enterprises, and establish a comprehensive and in-depth industrial innovation ecosystem.

(3) Strengthen government macro-control. We should actively give play to the incentive and guiding effect of the government in the integration of industrial chains centered on large manufacturing enterprises and the reconstruction and upgrading of value chains, and promote the domestic substitution of key core technologies in intelligent manufacturing through ways such as carrying out generic technology foresight, formulating innovation incentive policies, strengthening institutional mechanism optimization, enhancing talent team training, and building an innovation platform system.

(4) Deepen the collaborative innovation among government, industry, universities and research institutes. Multiple parties including the government, industry, universities and research institutes should work together to promote the breakthrough of key core technologies, accelerate the popularization and application of relevant key core technologies in intelligent manufacturing, promote enterprises to continuously carry out new intelligent manufacturing organizational changes in terms of production management information systems, timely and accurate lean manufacturing systems, intelligent warehousing and logistics systems, workshop industrial Internet integration systems, flexible production systems, etc., and establish global leading advantages in technology, products, markets and industries.

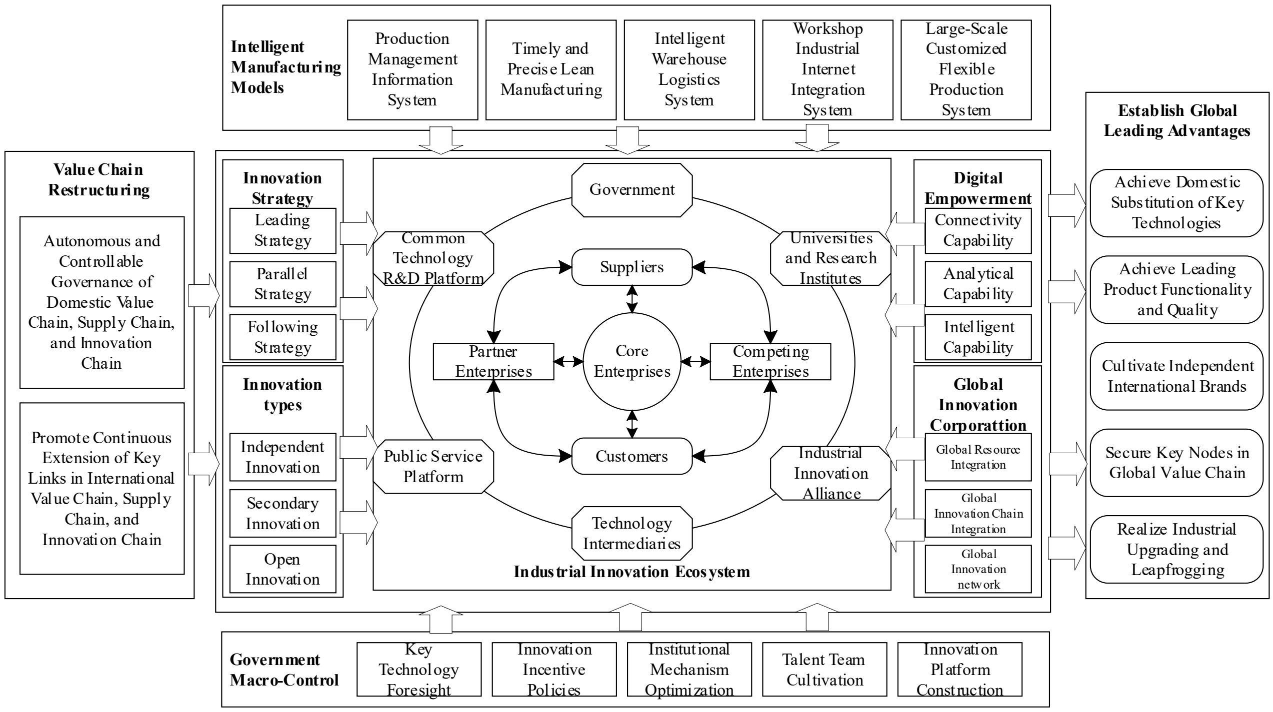


**Figure 4.** Domestic Substitution System of Key Core Technologies in Intelligent Manufacturing

# 5. CONCLUSION

First, construct a ‘three-layer, five-dimensional’ identification and dynamic forecasting mechanism to systematically grasp the key points of domestic substitution technologies. The primary goal of domestic substitution of key core technologies in intelligent manufacturing lies in accurate identification and forward-looking forecasting. This research proposes a ‘three-layer, five-dimensional’ technology evaluation model, which systematically assesses the importance, self-controllability, and urgency of development of technologies from three levels (strategic, application, and physical) combining five dimensions: strategic value, social value, economic value, technological gap, and resource base. Simultaneously, by establishing a closed-loop forecasting mechanism of ‘issue formation → analysis and prediction → dialogue and game theory → evaluation and feedback,’ integrating patent analysis, industry research, expert consensus, and other methods, it achieves dynamic tracking and collaborative judgment of technological development trends. This mechanism not only breaks through the limitations of single patent identification but also forms a multi-party participatory, continuously iterative technology forecasting system, providing a scientific basis for governments and enterprises to clarify key areas of focus and allocate R&D resources, ensuring a clear direction and feasible path for domestic substitution.

Second, enhance enterprises’ intelligent manufacturing innovation capabilities through the synergy of ‘elements-resources-ecosystem’. The fundamental solution to achieving domestic substitution lies in the substantial improvement of enterprises' innovation capabilities. Research indicates that enterprises need to strengthen the self-sufficiency of infrastructure and industrial software, focusing on the core elements of intelligent manufacturing: ‘hardware, software, network, and platform’. Through horizontal and vertical resource integration mechanisms, they can absorb technological, talent, and financial resources from the supply chain and collaborative networks to address innovation shortcomings. More importantly, enterprises should proactively build or integrate into the industrial innovation ecosystem, collaborating with universities, research institutions, governments, and service organizations to promote an overall leap in connectivity, analytical, and intelligent capabilities. This process emphasizes a shift from single-enterprise innovation to systematic and ecological innovation, enhancing enterprises' adaptability, learning ability, and leadership in complex technological environments through data-driven approaches and knowledge sharing, laying the organizational and capability foundation for breakthroughs in key core technologies.

Third, a collaborative ‘government-industry-academia-research-application’ driven system for domestic substitution should be formed. Domestic substitution of key core technologies in intelligent manufacturing is a systematic project requiring the construction of a multi-level, networked collaborative innovation system. This system, framed as ‘value chain restructuring—industrial ecosystem co-construction—government regulation—multi-party collaboration’, propels enterprises to climb up the global value chain through key links, relying on core enterprises to lead the construction of an open and collaborative industrial ecosystem. The government should play a strategic guiding and resource coordinating role, creating an institutional environment conducive to breakthroughs through policy incentives, platform building, talent cultivation, and system optimization. Ultimately, by deepening collaboration among government, industry, academia, research, and application, a virtuous cycle of close integration between technology research and development, industrial application, and market feedback can be formed, accelerating the penetration and application of key core technologies throughout the entire intelligent manufacturing chain, and comprehensively enhancing the self-reliance and controllability of my country's industrial chain and its international competitiveness.

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