



# Investigating the Driving Mechanism Behind Independent Research and Development of Industrial Software for Dual Innovation in Enterprises

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**Abstract.** Under the background of "Made in China 2025", China is vigorously promoting the development of industrial software, and is committed to converting Chinese manufacturing into Chinese intelligent manufacturing. From the perspective of enterprises' independent research and development of industrial software, this paper comprehensively reviews the development process of industrial software, analyzes the strategic orientation of enterprises' independent innovation of industrial software, and further discusses its influence on enterprises' dual innovation ability and driving mechanism based on the four-drive theoretical analysis framework of "technology-environment-policy-cognition". Research shows that independent research and development of industrial software can promote the dual innovation of enterprises. Further analysis shows that high-tech manufacturing enterprises, high environmental uncertainty, policy incentives and management foresight can stimulate enterprises to improve the level of dual innovation through independent research and development of industrial software. Through a multi-dimensional comprehensive analysis framework, this paper reveals the key role of independent research and development of industrial software in promoting technological progress and market competitiveness of enterprises, and provides theoretical support and practical guidance for enterprises to formulate innovation strategies and policies.

**Keywords:** Industrial software; Independent research and development; Enterprise innovation; Driving mechanism.

## 1 Introduction

The 20th report of the Party clearly points out the core position of "innovation" in our country's modernization. Innovation can not only introduce new technologies and improve products, but also be the core driving force for enterprises to adapt to and lead market changes. This continuous driving force for innovation is summarized as new quality productivity, which is driven by scientific and technological innovation and covers emerging industries, innovation models, new forms of business and new driving forces<sup>[7]</sup>. In this context, industrial software, as a key production tool, plays an irreplaceable role in promoting enterprise innovation and thus improving the produc-

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tivity of new quality. By integrating advanced computing and analysis technologies, industrial software enables enterprises to optimize their production processes, improve operational efficiency, and accelerate all links from R&D to production<sup>[18]</sup>, becoming a key support for promoting the development of new quality productivity.

For a long time, foreign software has dominated the industrial software market. Although China's product system basically fully covers major industrial software categories, it still relies on a few international enterprises for key technologies<sup>[18]</sup>. Industrial software industry depth report shows that in recent years our country's industrial software presents "management software strong, engineering software weak; Low-end software, high-end software less" development trend. China's manufacturing industry has long relied on imported industrial software, and lacks long-term research and development on core process and industrial technology, so there has been a phenomenon of technology hollowing in many key fields. That dependence has left China exposed to supply-chain risks at critical times, making it particularly vulnerable to international sanctions and severely hamstringing the industrial software sector. The "neck jam" phenomenon not only does not meet the development demand of China's industry accounting for 30% of the world's share, but also is not conducive to the high-end and intelligent transformation of China's manufacturing industry<sup>[38]</sup>.

Therefore, our country needs to promote the independent innovation of domestic industrial software. Due to the lack of long-term accumulation of design principles and data, the large and complex supply chain of industrial system, and the principle differences between different segments, the packaging of industrial software requires a long time of precipitation and accumulation, and enterprises need to consider the R&D cycle and the acquisition of R&D funds in advance. Moreover, industrial software R&D needs compound talents with industrial and software knowledge, and the serious shortage of high-end industrial software talents in China also limits the progress of enterprise R&D. These factors show that the development of domestic industrial software can not rely on a single force. Therefore, this paper proposes a four-driver theoretical analysis framework of "technology- environment- policy- cognition," and explores an effective path to promote the independent innovation of domestic industrial software by comprehensively analyzing the four driving factors of technological capability, environmental adaptation, policy support and executive cognition.

Existing research on industrial software mostly focuses on the development path<sup>[4][21]</sup> and macro driving mechanism<sup>[38][39]</sup>, but there is still a lack of in-depth analysis of the macro evolution and micro driving mechanism of industrial software from a comprehensive perspective combining macro and micro. Based on this, the purpose of this study is to comprehensively explore the specific approach and driving path of self-developed industrial software in enterprise ambivert innovation. The research is divided into three main stages: first, the development of industrial software is examined from a historical perspective, tracing its evolution from the early stage to the mature stage. Next, the study will investigate the impact of independent R&D of industrial software on explorative and developmental innovation of firms. Finally, this paper deeply analyzes the driving mechanism of independent R&D industrial software, including enterprise attributes, environmental promotion, policy guidance and

executive awareness, and reveals how these factors promote the implementation of independent R&D industrial software strategy.

The possible contributions of the research are as follows: at the theoretical level, based on the perspective of independent R&D of industrial software, this paper aims to deeply explore its specific impact on enterprise ambivert innovation, build a theoretical analysis framework of "technology - environment - policy - cognition," explore the detailed path and driving mechanism in this process, and enrich the existing theoretical category of enterprise ambivert innovation. At the practical level, it provides policy enlightenment for policy makers to formulate supportive measures, and provides strategic guidance for enterprises to effectively use self-developed industrial software to enhance innovation ability.

## **2 The Development of Industrial Software**

Industrial software refers to the application software applied in the industrial field to improve the research and development, production, management level of industrial enterprises and the performance of industrial equipment. Existing studies introduce that the development of industrial software can be divided into four stages. The first stage is the initial evolution of the market. China's industrial software industry started from a stumbling start in the 1980s and went through a difficult start-up period and Renaissance period, and entered the stage of rapid rise of domestic software after 2014<sup>[19]</sup>. In the second stage, the technology is gradually improved. Over time, in order to cope with the performance deterioration and failures of the old software system<sup>[42]</sup>, the theorists proposed to adopt software regeneration technology<sup>[43]</sup> and performance analysis based on operating parameters<sup>[44]</sup> to maintain the system. In addition, in order to improve software reliability, a high-fidelity test environment<sup>[41]</sup> and an automated test method<sup>[8]</sup> are established. The third stage is the deep integration of technical resources. With the deep integration of information technology and manufacturing technology, industrial software is becoming an important carrier for the combination of the two<sup>[26]</sup>. At present, China's industrial software as a whole presents the characteristics of small, scattered and specialized<sup>[30]</sup>, and is transforming into platforming and servitization<sup>[25]</sup>. In the fourth stage, the industry emerges. In order to narrow the gap with the international advanced level, China's industrial software needs to take advantage of the advantages of localization to tap the market demand<sup>[23]</sup>, and at the same time build a perfect "industry-university-research-application" ecosystem to solve the problems of talent and capital supply, and promote the continuous innovation and high-quality development of the industry.

## **3 Enterprise Strategic Orientation of Independent Innovation of Industrial Software**

Based on the macro environment of external uncertainty. In order to break through the blockade of foreign technology, reduce external disputes in CI, and master more or

even all technological intellectual property rights, enterprises need to get rid of the dependence on external technology acquisition to the maximum extent<sup>[20]</sup>. Through independent research and development of industrial software, enterprises can freely explore and achieve radical innovation, ensure the autonomy and control in key technology areas, so as to strengthen the foothold in the market competition. On the one hand, the independent research and development of industrial software endows enterprises with technological autonomy, which helps to protect the intellectual property rights of enterprises and avoid the leakage of core technologies and trade secrets. This is all the more important in an era when the global trading environment is complex and restrictions on technology exports can occur at any time. On the other hand, in the long run, independent research and development of industrial software can avoid the risk of continuous licensing fees and dependence on a single supplier, and at the same time, it is more conducive to the rapid iteration and upgrading of software and maintain the flexibility and competitiveness of enterprises in technology.

Build the internal core competitiveness of enterprises. Although the mature industrial software products in the market can provide plug and play convenience for enterprises and save the long development and debugging process<sup>[36]</sup>, this dependence is often difficult to create unique core competitiveness for enterprises. In contrast, self-developed industrial software can provide enterprises with more highly customized services, which not only allows enterprises to respond quickly to specific operational needs and market changes, but also integrates unique innovative elements and corporate culture into products and services, thus directly enhancing the competitiveness and market adaptability of enterprises. With the support of policies and the demand of the market, the willingness of enterprises to independently develop industrial software will be stronger in the foreseeable future.

## **4 The Driving Mechanism of Independent Research and Development of Industrial Software for Enterprise Innovation**

### **4.1 Independent Research and Development of Industrial Software and Enterprise Innovation**

Research shows that<sup>[6][12]</sup>, when considering costs and risks, enterprises are faced with the choice between adopting technology import and independent R&D. Although outsourcing can reduce the demand for independent R&D, it may lead to the dependence of enterprises on foreign technology, thus inhibiting the innovation motivation of enterprises, and thus losing the core competitiveness. Through independent R&D, enterprises can realize the internalization of technology, fully grasp the intellectual property rights of technology, and significantly improve their innovation ability<sup>[11]</sup>.

Independent research and development of industrial software can promote explorative innovation of enterprises. Exploratory innovation involves using new knowledge or getting rid of the framework of traditional knowledge to bring new design ideas to enterprises, create new market opportunities and open up new distribution chan-

nels<sup>[28]</sup>. Faced with the continuous changes in industry technology and the continuous evolution of consumer demand, enterprises must constantly develop new technologies to adapt to market changes<sup>[33]</sup>. In this process, the self-developed industrial software, due to its highly customized characteristics<sup>[35]</sup>, enables enterprises to accurately develop and optimize their software tools according to specific technical needs and developmental innovation goals. The continuous accumulation of resources in the R&D process not only accelerates the transformation process of new technologies from concept to implementation, but also increases the stock of knowledge and technology of enterprises<sup>[5]</sup>. These technical talents and knowledge capital are important cornerstones for enterprises to continue exploratory innovation. At the same time, the independent research and development of industrial software can break the restrictions brought by the traditional organizational hierarchy, provide enterprises with a more flexible management mechanism, and help strengthen the exploratory innovation of enterprises<sup>[32]</sup>.

Independent research and development of industrial software can promote enterprise exploitative innovation. Enterprises tend to invest R&D resources in known technological fields<sup>[33]</sup> to learn and explore, and to deepen and expand existing technological capabilities, so as to more effectively promote the process of developmental innovation. Independent research and development of industrial software not only provides enterprises with a comprehensive strategy to improve technological innovation ability, but also improves the overall business efficiency and the ability to respond to market changes. First of all, self-developed industrial software can effectively integrate and utilize existing technological assets, reduce innovation costs and improve innovation efficiency<sup>[1]</sup>, and promote enterprises to innovate and improve within the framework of existing technologies. Secondly, the use of independently developed industrial software can realize the standardization of enterprise processes according to the characteristics of enterprises<sup>[3]</sup>, and greatly improve the production efficiency of enterprises<sup>[37]</sup>. Finally, through independent research and development of industrial software, enterprises can continuously optimize and update their software applications according to user feedback and problems encountered in the operation process, and carry out real-time iterative innovation<sup>[14]</sup>, so as to adapt to technological progress and market changes, and further support enterprises' developmental innovation.

## 4.2 Driving Analysis

### 1) Technology Driven Based on Industry Attributes.

It is worth noting that domestic industrial software is mostly derived from high-tech manufacturing enterprises<sup>[17]</sup>. High-tech manufacturing enterprises are at the technological forefront of the industry and face external business needs and their own technical challenges, which cannot be met only by outsourcing software. And through independent research and development of innovative industrial software solutions, high-tech enterprises can not only improve their own operational efficiency and product quality, but also consolidate or enhance their leading position in the industry through technological leadership. On the one hand, independent R&D of industrial

software usually requires enterprises to have certain technical foundation, R&D resources and capital investment capacity<sup>[29]</sup>. However, high-tech industries, due to their resource-rich resources and technology accumulation, are better able to bear the high costs and high risks that may occur in the R&D process, so they are more suitable for independent R&D of industrial software. On the other hand, the development of industrial software relies on two core factors, namely tacit knowledge accumulated by industry and explicit expression of the formation of the software industry. In this process, a developed industrial base is a necessary condition for the development of industrial software<sup>[29]</sup>. As the parent organization of the industrial Internet platform<sup>[2]</sup>, high-end manufacturing enterprises not only provide the basic industrial data and practical application scenarios required by the platform, but also bring profound industry insight to the platform's innovation and service optimization. Due to the rapid development of its own business, it needs high-end manufacturing industry to independently develop industrial software to support its complex operational needs and technological innovation.

## **2) Environmental Drive based on External Uncertainty.**

Environmental uncertainty is a concept proposed within organizational design frameworks, primarily used to gauge the turbulence and complexity of a company's external environment<sup>[34]</sup>. Current research divides it into technological uncertainty and economic policy uncertainty<sup>[9]</sup>.

Technological environmental uncertainty includes unpredictability in technology development paths and instability in technology supply caused by increased competition barriers<sup>[16]</sup>. In the short term, disruptions in external technology can cause significant economic market turbulence<sup>[15]</sup>, particularly affecting enterprises that rely on specific external technology supplies, potentially leading to production delays or the loss of market opportunities. However, from a long-term perspective, this also compels domestic enterprises to explore potential technological innovations and encourages the domestic development of industrial software to ensure survival and promote development.

Economic policy uncertainty refers to the uncertainty in market environments and economic conditions brought about by changes in government policies<sup>[31]</sup>, which increases the risk of future losses for businesses. On one hand, the uncertainty of economic policies places external pressure on enterprises, driving them to actively engage in the development of industrial software to change their passive status. On the other hand, to mitigate the risks and impacts of policy changes, enterprises need enhanced capabilities for dynamic adjustment and adaptation<sup>[27]</sup>. Independent development of industrial software enables enterprises to better manage market risks and enhance their core innovation capabilities. By developing their software, enterprises can quickly adapt to changes in market demands, customize solutions to meet specific business needs, thereby increasing their independence and flexibility in competition, and also facilitating long-term technological advancement and innovative development.

### **3)Policy Driven Based on Government Orientation.**

A sound property rights protection system, a loose financial and financing environment and a healthy relationship between government and business can provide a good external environment for enterprise production and R&D innovation<sup>[10]</sup>. These factors help encourage enterprises to actively rely on independent research and development of industrial software to cope with market competition and technological risks, and carry out long-term technology investment and development within the framework of security and support<sup>[13]</sup>. At this time, policy incentives play a vital role in promoting high-tech industry innovation, providing strong support for the development of domestic industrial software. Supported by the policy of the 14th Five-Year Plan, it has significantly created market demand and restored the driving effect of external market demand, opening up a broader market space for domestic industrial software<sup>[39]</sup>. At the same time, policy incentives also provide necessary innovation resources such as digital technology resources for the independent research and development of industrial software, and promote the communication between enterprises and other market players to form collaborative innovation<sup>[22]</sup>, which promotes the technological progress of the whole industry and the improvement of market competitiveness.

### **4)Cognitive Drive Based on Executives' Awareness of Change.**

Among many organizational elements, managers' strategic focus, corporate culture, employee capabilities, customer needs, pilot projects and resource support are important factors affecting corporate technological change<sup>[24]</sup>. As the executors of corporate strategic control, managers' ability and motivation are the key to the success of corporate innovation<sup>[40]</sup>. Managers with strong ability can tap the market demand and consider the long-term competitiveness of enterprises in the future, and then keenly capture the potential opportunities of independent research and development of industrial software to bring continuous innovation and growth power to enterprises. When managers fully grasp the tuye of independently developed industrial software and apply it to the technological change of enterprises, enterprises can better achieve sustainable innovation and development. On the one hand, managers promote enterprises to invest in independent research and development of domestic industrial software by formulating strategies that match the future market trend, which helps enterprises take the lead in occupying a position in the highly competitive market. On the other hand, the leadership style of managers directly affects the innovative atmosphere of enterprises and the innovative behavior of employees. By encouraging innovation, rewarding innovation and providing innovation guarantee, innovation can be integrated into corporate culture<sup>[13]</sup>, and employees' willingness to innovate can be enhanced and their creativity can be stimulated, so that the strategy of independent research and development of industrial software can be implemented smoothly within enterprises.

## 5 Conclusions

Industrial software provides enterprises with advanced innovative production tools and platforms, enabling them to carry out technological innovation and management optimization at a higher level, so as to enhance the overall competitiveness and the ability to adapt to market changes. This paper explores the potential development opportunities of industrial software from two aspects of macro historical review and micro enterprise innovation strategic orientation, analyzes and explores the impact and driving mechanism of independent R&D of industrial software on enterprise dual innovation, constructs the theoretical analysis framework of "technology - environment - policy - cognition", and draws the following conclusions.

This study reveals the internal mechanism of independent R&D of industrial software to improve enterprise innovation, and focuses on the analysis of the key role of high-tech manufacturing industry attributes, environmental uncertainty, policy support and executives' awareness of change in promoting enterprise innovation. Based on the above analysis, the following suggestions are proposed. First, according to the technical level of the industry, including scale, industry characteristics and resource status, enterprises should formulate their research and development strategy of industrial software to improve technical ability and market adaptability. Second, in the face of environmental uncertainty, enterprises should strengthen their sensitivity and adaptability, and take this as an opportunity to actively carry out self-innovation, so as to seize the market first and ensure competitive advantages. Third, in terms of policy guidance, the government should continue to provide incentives such as financial subsidies, tax incentives and technical support, especially for enterprises involved in new technological fields and new markets, so as to reduce their R&D risks and initial thresholds. Finally, corporate senior leaders need to strengthen their understanding of the importance of innovation, actively promote the construction of innovation culture, and encourage teams to continuously explore and try to develop industrial software through strategic leadership and resource allocation.

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