

Research on the Path of Improving Innovation Efficiency of High-Tech Enterprises from the Perspective of New Productivity

—A Theoretical Analysis Framework

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Abstract

Under the strategic background of accelerating the evolution of global scientific and technological innovation and developing new productivity in China, high-tech enterprises, as the core carrier, are facing the efficiency dilemma of “high R&D investment and low achievement transformation”. This paper breaks through the static perspective of the traditional Solow residual value model, and reconstructs the theoretical connotation of innovation efficiency based on the triple dimensions of technological revolutionary breakthrough of new productivity, innovative allocation of factors and deep industrial transformation. By deconstructing the dynamic coupling mechanism of technology, factors and industry, this paper reveals the structural resonance of innovation efficiency improvement dependence, and diagnoses the current bottlenecks: three-dimensional imbalance problems such as technology path dependence, lack of data property rights and lagging system adaptability. Based on this, this paper puts forward systematic promotion paths such as technological transition, factor reset, organizational reconstruction and ecological coordination. It is pointed out that the policy level should be changed from “intervener” to “ecological architect”, and three-dimensional empowerment should be catalyzed by system adaptation adjustment, factor marketization acceleration and scene opening. This study provides a whole chain analysis paradigm of “theoretical framework-mechanism diagnosis-path design” for breaking the bottleneck of innovation efficiency, which has theoretical forward-looking and practical guiding value for driving the development of new productivity.

Keywords

New Quality Productivity, Innovation Efficiency, High-tech Enterprises,

1. Introduction

1.1. Research Background and Theoretical Necessity

At present, global scientific and technological innovation has entered an intensive and active period. As the core engine driving Chinese modernization, the essence of new productivity is the advanced productivity quality marked by revolutionary technological breakthrough, innovative allocation of production factors and deep industrial transformation and upgrading (Zheng, 2025). As the core carrier of new productivity, the innovation efficiency of high-tech enterprises is directly related to the national strategic competitiveness. However, the traditional innovation efficiency theory faces three limitations:

(1) Perspective lag: The existing research is mostly based on Solow residual value model to measure efficiency (Liu & Zeng, 2024), which fails to cover the key dimensions of new productivity such as data elements and disruptive technologies;

(2) Mechanism blackbox: lack of systematic deconstruction of the dynamic process of technology-factor-industry collaborative transition;

(3) Policy disconnection: The path of efficiency improvement is not well adapted to the new national system, digital ecology and other institutional environments.

In this context, constructing the theoretical framework of innovation efficiency oriented by new productivity has become the key theoretical infrastructure to solve the dilemma of “high R&D investment and low achievement transformation”.

1.2. Redefinition of Core Concepts: Triple Dimensions of New Productivity and New Connotation of Innovation Efficiency

1.2.1. Triple Dimensions of New Quality Productivity

Drawing on previous research, particularly the structural analysis and interpretation of driving factors related to the concept of new quality productive forces (Liu & Fang, 2025), as well as studies on the connotation and characteristics of new quality productive forces from different dimensions, this paper sorts out three dimensions of new quality productive forces. It compares these forces with traditional productive forces in terms of technological characteristics, element structure, and industrial form (Pan & Tao, 2024), as illustrated in **Table 1**.

Table 1. Triple dimensions of new quality productivity.

Dimension	Traditional productivity	New quality productivity
Technical characteristics	Progressive improvement	Revolutionary breakthroughs (such as AI, quantum computing)

Continued

Element structure	Land/capital/labor-led	New ternary architecture based on data-algorithm-computing power
Industrial form	Linear industrial chain	Multi-chain integration ecology (innovation cluster)

1.2.2. New Connotation of Innovation Efficiency

In the traditional theory, innovation efficiency is simplified as the linear ratio relationship between R&D resources input and innovation output (such as patent output per unit R&D expenditure). However, the new productivity requires reconstructing the essential attribute and evaluation dimension of innovation efficiency, and its new connotation is embodied in three interactive compound levels (Su, 2025):

(1) Efficiency of technological revolution

Focus on the effectiveness of disruptive technological breakthroughs, and measure the ability of enterprises to transform R&D resources into original technologies and underlying paradigms. Its core lies in: First, breakthrough refers to whether it can get rid of the gradual improvement path and realize the transition from 0 to 1 in the frontier fields such as artificial intelligence and quantum information; Second, timeliness refers to the synchronization degree between the technological iteration cycle and the wave of scientific and technological revolution (such as the alternative innovation rhythm after Moore's Law fails); Third, the risk conversion rate, that is, how the fault-tolerant mechanism of high-uncertainty R&D transforms failed exploration into knowledge accumulation.

(2) Efficiency of factor allocation

When data elements replace oil as the core means of production, efficiency evaluation needs to change from "resource possession" to "value mining depth". It is necessary to pay attention to the aggregation value-added efficiency of new production factors, and emphasize the synergy level between new quality factors such as data, computing power and high-end talents and traditional factors: liquidity requires data elements to confirm rights, and circulation and pricing mechanisms can reduce resource allocation costs; Fission requires the combination of algorithm and computing power to trigger the multiplication effect of factor value (for example, AlphaFold2 improves the prediction efficiency of protein structure by 100 million times); Adaptation requires improving the coupling strength between new workers (compound talents) and intelligent tools (industrial Internet platform) (Zhang *et al.*, 2024).

(3) Industrial transition efficiency

Characterizing the speed and quality of industrial qualitative change driven by innovation achievements includes two scales: vertical upgrading speed and horizontal integration breadth, while ensuring a good sustainability threshold. Vertical upgrading speed refers to the cycle of transforming emerging technologies into

real productivity; Horizontal integration breadth refers to the coverage and synergy cost of cross-domain technologies (such as biology + AI) to reconstruct the industrial chain; Sustainability threshold reflects the long-term gain of green and low-carbon innovation to industrial ecology. Typical cases, such as Ningde era, increased the volume utilization rate of power battery by 20% through CTP technology, and simultaneously promoted the reshaping of battery life standard of electric vehicle industry.

The traditional framework regards innovation as a production function optimization problem, while the new qualitative perspective reconstructs it as a complex system transition problem—efficiency improvement no longer depends on the stacking of factors, but depends on the structural resonance intensity of technology, factors and industries. This paradigm shift requires theoretical research to change from “measuring input-output” to “analyzing coupling mechanism”. The above three dimensions constitute an organic whole, and its theoretical particularity lies in: dynamic coupling, that is, technological revolution provides tools for factor allocation (such as AI optimized data flow), and industrial transition creates scenes for technological breakthroughs (such as smart medical demand driving gene editing); Threshold effect, when the efficiency of any dimension is lower than the critical value, the system will degenerate into the traditional efficiency form; Institutional dependence, the synergy level of the three is highly dependent on the institutional environment adapted to new productivity (for example, the rules of cross-border data flow determine the upper limit of factor allocation efficiency).

2. Theoretical Foundation: Coupling Mechanism of New Productivity and Innovation Efficiency

This study examines the synergy between new productive forces and innovation efficiency as a dynamic complex system—a technology-factor-industry resonance system. Its core lies in the deep integration and coordinated resonance among three subsystems: technological revolution, factor allocation, and industrial transformation. The technological revolution subsystem generates disruptive breakthroughs that reshape production logic and value standards. The factor allocation subsystem achieves dynamic optimization of the “data-algorithm-computing power” triad structure. Meanwhile, the industrial transformation subsystem establishes cross-domain integrated ecosystems to create scenarios for efficiency screening and amplification. Through nonlinear interactions, these three subsystems form a positive feedback loop: “enhanced innovation efficiency → resource reinvestment → system transformation,” driving the qualitative evolution of productive forces to higher levels.

2.1. Theoretical Tracing and Essential Deconstruction of New Productivity

The theoretical foundation of new productivity can be traced back to the contemporary evolution of Marxist productivity theory. Marx pointed out that “produc-

tivity is the material force for human beings to transform nature”, while new productivity is the qualitative change form of this force in the digital age. Its essence lies in three transitions: first, the revolutionary dimension of technology: from improved technological progress to paradigm subversion, such as the reconstruction of traditional production logic by artificial intelligence; Second, the fission of factor dimensions: data has become a more critical strategic resource than oil, giving birth to a new ternary structure of “data-algorithm-computing power”; Third, the ecology of industrial dimension: the linear industrial chain disintegrates into a multi-directional interactive innovation cluster, such as the cross-network integration of new energy and energy storage. This qualitative change is not a simple technological upgrade, but a reconstruction of the core of productivity system-its driving force changes from capital accumulation to knowledge creation, and its value source changes from scarcity monopoly to shared appreciation.

2.2. Paradigm Transition of Innovation Efficiency

Traditional innovation efficiency theory falls into two limitations: first, it is a static trap: efficiency is simplified as the ratio of R&D input to patent output, ignoring the creative destruction in the intergenerational transition of technology; Second, islanding cognition: separating the internal relationship among technological innovation, factor allocation and industrial transformation. The perspective of new productivity requires reconstructing the dynamic system view of innovation efficiency: changing from “cost minimization” to “opportunity maximization” in efficiency goal, emphasizing the predictive control of technology track; On the efficiency scale, it should be upgraded from “unit input-output ratio” to “system transition acceleration” to measure the efficiency of industrial niche jump; In terms of efficiency power, we should change from “resource-driven” to “system-driven”, and system adaptability becomes the core variable of efficiency improvement. It is necessary to embody the fundamental turn of paradigm: innovation efficiency is no longer a problem of production optimization, but a problem of system evolution (Zhang & Zhang, 2024).

2.3. Coupling Mechanism: Resonance Effect of Technology-Factor-Industry

The essence of the coupling between new productivity and innovation efficiency is the deep embedding of technology-factor-industry triple subsystems (Yang *et al.*, 2023);

(1) The mutual excitation cycle between technological revolution and innovation efficiency

Disruptive technologies improve efficiency through dual paths: First, shorten the innovation cycle and break through the law of diminishing marginal returns of traditional research and development. For example, generative AI greatly reduces the drug research and development cycle; The second is to reconstruct the

value standard, for example, quantum computing redefines the efficiency of computing power with “quantum superiority”, which makes the traditional supercomputing index invalid. At the same time, high-efficiency innovation feeds back the technological revolution-the superlinear return generated by rapid iteration injects continuous resources into disruptive technologies.

(2) The causal chain between factor reset and efficiency transition

The unique attributes of data elements lead to qualitative changes in efficiency mechanism: in terms of non-competitiveness, data sharing makes the marginal cost of innovation zero and breaks the constraint of resource scarcity on efficiency; In the aspect of autofrettage, the user behavior data feedback algorithm is optimized, forming the flywheel effect of “data accumulation → model improvement → user growth”.

(3) Screening and enlargement of efficiency by industrial transformation

Reconstruction of industrial ecology creates a new efficiency yardstick. On the one hand, from the perspective of screening mechanism: green and low-carbon standards eliminate high-carbon innovations (such as fuel vehicle technology), forcing efficiency evaluation to be included in ecological costs; On the other hand, from the perspective of amplification effect, the intelligent networked automobile industry integrates AI chips, high-precision maps, V2X communication and other technologies, so that single-point innovation can obtain exponential scene empowerment(Shi *et al.*, 2022).

2.4. Law of Contradictory Motion in Coupling

There are three dialectical relations in the coupling process:

(1) Breaking the paradox:

Disruptive technology destroys old industries, but there is a time lag between destruction efficiency and construction efficiency, which leads to short-term efficiency fluctuation.

(2) System distance:

The rapid evolution of technology-elements and the slow adjustment of institutions have tension. When the regulatory rules lag behind the intergenerational replacement of technology (such as the lack of definition of meta-universe property rights), institutional rigidity becomes the damper of efficiency improvement.

(3) Niche competition:

There is a conflict between the maximization of individual efficiency of enterprises and the synergy of industrial ecology. Typically, chip companies pursue the individual efficiency of 3 nm process, but aggravate the fragility of global photoresist supply chain, and finally bite the overall innovation efficiency.

Theoretical enlightenment: The coupling of new productivity and innovation efficiency is the dynamic unity of creative destruction, institutional adjustment and ecological balance. The path of efficiency improvement must be solved in the framework of contradictory movement among the three.

3. The Mechanism of New Productivity on Innovation Efficiency

3.1. Technological Revolutionary Breakthrough: Reconstructing the Underlying Logic of Innovation

The technical dimension of new productivity drives efficiency transition through dual paths;

(1) Path 1: Disruptive innovation replaces gradual improvement

Traditional innovation is limited by the path dependence of technology track (such as the slight improvement of thermal efficiency of internal combustion engine), while disruptive technologies such as gene editing and quantum computing directly open up new track, breaking the law of “marginal decline of R&D investment”. For example, CRISPR technology compresses the genetic modification cycle from several years to several weeks, and rewrites the formula of biomedical innovation efficiency.

(2) Path 2: Shorten the innovation cycle and reduce the cost of trial and error

Generative AI generalizes knowledge by pre-training model, which makes the efficiency of tasks such as chip design and drug target screening jump by order of magnitude. OpenAI proves that the emergence ability of large language models can replace a lot of basic research and development work of human experts and release high-level innovation resources.

Mechanism essence: The technological revolution transforms innovation from “experience trial and error” to “intelligent emergence”, and the efficiency gain comes from the deep coding of the operating laws of the physical world.

3.2. Innovative Allocation of Factors: Activating Fission Value Creation

New elements such as data, computing power and high-end talents reshape efficiency through a triple mechanism:

Mechanism 1: Self-proliferation effect of data elements

Data flow gives birth to the paradigm of “use is production”: Tesla’s automatic driving system returns data in real time through millions of vehicles, and iterates the algorithm version every day, which dwarfs the closed R&D mode of traditional car companies. The non-exclusiveness of data elements leads to a structural decline in innovation costs.

Mechanism 2: Leverage effect of computing power-algorithm cooperation

Cloud computing transforms computing power into rentable public goods, and start-ups can call supercomputing resources at one ten thousandth of the cost. AlphaFold2 proves that the combination of algorithm innovation and computing power expansion can solve the protein folding problem that has plagued biology for decades.

Mechanism 3: Network value-added of talent structure

Compound talents (such as financial engineers who understand quantum computing) promote cross-domain reorganization of knowledge, and their innovation

efficiency increases exponentially. Google's "20% free working time" system reveals that for every 10% increase in talent autonomy, patent quality increases by 34%.

Mechanism essence: Factor allocation changes from static optimization to dynamic evolution, and efficiency improvement depends on chemical reaction among factors rather than simple superposition.

3.3. Deep Transformation of Industry: Creating a New Yardstick of Efficiency

Industrial form transition reconstructs efficiency through selection pressure and synergy effect;

(1) Hard constraint screening of green and low carbon

The goal of "double carbon" includes carbon emissions per unit GDP in the evaluation of innovation efficiency. In Ningde era, CTP technology was used to improve the energy density of batteries, which not only reduced the production cost, but also greatly reduced the carbon intensity of products in the whole life cycle, meeting the entry threshold of the new EU battery regulations.

(2) Scene multiplier of cross-border fusion

The intelligent networked automobile industry integrates AI, 5G, high-precision maps and other technologies, and a single breakthrough (such as lidar price reduction) triggers system-level efficiency improvement. The iteration speed of visual algorithm is multiplied compared with that of closed system because of the feedback of vehicle-road collaborative data (Yang, 2022).

(3) Efficiency polarization of niche competition

Enterprises in innovation clusters are faced with the choice pressure of "transition or elimination". Shenzhen UAV Industry Belt has greatly reduced the research and development cycle of new products through the geographical agglomeration of supply chain, forcing enterprises to build an agile innovation system.

The essence of the mechanism is that industrial transformation expands the efficiency standard from economy to ecology and synergy, and the innovation value needs to be exponentially amplified through industrial resonance.

3.4. Interactive Paradigm of Triple Mechanism

Technology, factors and industries do not work in isolation, but their interaction produces multiplier effect:

The technological revolution provides tools for factor allocation, and blockchain technology solves the problem of data confirmation and activates trillion-dollar data asset transactions; Factor upgrading lays the foundation for industrial transformation, and computing power networks (such as "East Digital West Computing") support cross-domain collaboration between AI R&D in the east and green energy in the west; Industrial demand anchors the direction of technological innovation, and the goal of "double carbon" drives the efficient breakthrough of photovoltaic cell conversion efficiency, and completes the road of traditional en-

ergy for half a century in ten years.

It should be noted that when the technology iteration speed (such as Moore's Law) exceeds the industrial digestion capacity (such as the renewal cycle of chip manufacturing equipment), or the system adjustment lags behind the factor flow (such as the lack of cross-border data supervision), the new productivity will fall into the "efficiency paradox"-the micro-innovation efficiency coexists with the macro-system loss. This tension poses fundamental challenges to enhancing innovation efficiency, encompassing but not limited to: structural barriers to disruptive innovation in technological dimensions; imbalances in data, talent, and capital allocation within factor dimensions; rigid organizational frameworks and fragmented ecosystems in institutional dimensions; and a reinforcing mechanism of three-dimensional imbalance under systemic bottlenecks.

4. Theoretical Diagnosis of Innovation Efficiency Bottleneck

4.1. Technical Dimension: Structural Barrier of Disruptive Innovation

New productivity requires revolutionary technological breakthroughs, but enterprises face triple contradictions:

(1) Path-dependent locking effect

Traditional technology track forms sunk cost advantage (such as fuel vehicle supply chain), which squeezes disruptive technology resource input. Kodak invented the digital camera but died of the binding of film interests, revealing that the essence of "innovator's dilemma" is the dislocation of efficiency evaluation-the old system measures the efficiency of gradual improvement, but stifles the efficiency of paradigm revolution.

(2) Technology maturity fault

There is a "valley of death" between laboratory achievements (such as controlled nuclear fusion) and industrial application. Scientific research in colleges and universities pursues academic efficiency oriented by papers, while R&D in enterprises focuses on short-term profits, which leads to serious shortage of conversion rate of basic research, which is rooted in entropy increase and loss of knowledge flow.

(3) Risk aversion paradox

Disruptive innovation needs to tolerate high failure rate, but the pressure of quarterly financial reports of listed companies forces the marginalization of R&D investment. When the technical risk tolerance is lower than a certain range, the revolutionary breakthrough probability approaches zero. It can be said that the efficiency bottleneck of technical dimension is the rejection reaction of the old productivity evaluation system to the new quality innovation logic.

4.2. Factor Dimension: Unbalanced Allocation of Data-Talent-Capital

The unique attributes of new quality elements cause configuration failure;

(1) Property rights puzzle of data elements

The lack of data confirmation leads to “tragedy of commons”: enterprises hoard user data but it is difficult to circulate it, and the diagnostic accuracy of medical AI stagnates due to fragmentation of training data. When the data sharing rate is low, the factor aggregation effect cannot appear.

(2) The space-time mismatch of talent structure

The global stock of top talents in frontier fields such as quantum computing is seriously insufficient, and enterprises are caught in “sky-high auction” and “zero-sum game”. At the same time, the aging speed of traditional engineers’ knowledge far exceeds the updating ability of training system, resulting in the upside-down depreciation rate of human capital.

(3) Short-term profit-seeking distortion of capital

Venture capital pursues the “two-year exit” cycle and avoids the long R&D chain of hard technology. In 2022, 80% of the financing amount of China’s chip industry will flow to the design link, while the manufacturing/equipment link will only get 12% because the return period exceeds 8 years, which exposes the break between capital time preference and innovation law.

4.3. Institutional Dimension: Organizational Rigidity and Ecological Separation

(1) The innovation suffocation of bureaucratic organizations

The more levels of pyramid structure decision chain, the longer the time lag between market feedback and R&D response. Examination and approval coordination at different levels may miss the innovation window. The ability of tissue entropy reduction determines the innovative breathing rhythm.

(2) Isolated island effect of industry-university-research cooperation

The low patent conversion rate in colleges and universities is not due to immature technology, but to the dislocation of value evaluation: professors pay attention to the advanced technology, and enterprises need engineering feasibility. If the standard deviation of efficiency is too large, the cooperation will break down.

(3) Adaptive time lag of policy supervision

A typical example is that it took three years for the EU Artificial Intelligence Act to be enacted, during which the GPT model has been iterated for five generations. When the regulatory adjustment cycle seriously lags behind the technical iteration cycle, the system will change from a guarantor to a brake.

4.4. System Bottleneck: Three-Dimensional Imbalance Enhancement Loop

Technology, elements and institutional bottlenecks reinforce each other;

Insufficient data circulation (elements) → weakening AI training effect (technology) → reducing policy trust (system) → further tightening data control;

Capital avoids hard technology (elements) → delays technology maturity (technology) → prolongs investment return period (system) → intensifies capital flight.

This negative cycle makes the efficiency loss exponentially enlarged, such as Japan's hydrogen energy industry: leading technology but lagging hydrogen refueling station construction (factor), insufficient policy subsidies (system), and finally overtaken by Sino-US electric vehicle systems.

It can be concluded that the bottleneck of innovation efficiency is a structural pain in the evolution of new productivity system, and it needs to be decoupled synchronously from three aspects: technology path, factor market and institutional flexibility (Zhang *et al.*, 2025).

5. Innovation Efficiency Improvement Path Design

5.1. Technological Transition Path: Building a Disruptive Innovation Channel

Double helix mechanism of basic research-application transformation: set up enterprise basic research institute (such as Huawei 2012 Lab), give 10-year research and development cycle and 30% failure budget. Establish a "proof-of-concept center" simultaneously, and transform academic discoveries (such as perovskite photovoltaics) into financiable prototypes within 18 months to bridge the technology maturity gap.

Agile R&D management revolution: promoting modular R&D: disassembling large projects into parallel subunits (for example, Tesla decomposes battery packs into 4680 cells/CTC chassis/thermal management modules), thus shortening the iteration period by 60%. Establish a culture of quick trial and error: allow 50% of resources to be invested in high-risk projects, and share failed results in the knowledge base.

Technology foresight and ecological card: Use technology roadmap to lock in strategic directions such as quantum computing and synthetic biology. Build technology ecology through open source platform, transform single-point innovation into system standard, and reduce market education cost.

5.2. Element Reset Path: Activate the Kinetic Energy of New Elements

(1) The marketization of data elements is broken

Construct a three-level data circulation system: original data: "available and invisible" through privacy computing; Sharing Model Value: Constructing Learning Output Sharing AI Model; Knowledge crystallization: refining cross-industry knowledge map.

The practice of Shenzhen Data Exchange shows that the model layer circulation can improve the research and development efficiency of medical AI by three times (Lin, 2025).

(2) Talent network value-added project

Create a flexible organization of "leading talents + cross-domain teams": use scientist studios to overcome key technologies (such as the development of Kirin batteries by the Wu Kai team in Ningde era); Realize global expert collaboration

through digital twin platform (such as Boeing Cloud Design Center integrating engineers from 30 countries); Supporting “Innovation Achievement Equity Pool”: Talents can share the long-term benefits of intellectual property rights and solve the short-term incentive dilemma.

(3) Cultivation of capital patience index

Design a new paradigm of hard technology investment: the government parent fund transfers 80% of the income and bears early risks; Issue 10-year technology bonds to lock in long-term funds; Establish non-financial evaluation system (such as technical milestone achievement rate).

5.3. Organizational Reconstruction Path: Creating Agile Innovation Body

(1) Decentralized organizational structure

Implement the “platform + entrepreneurial unit” model: Haier splits 60,000 people into thousands of tiny units, each of which has the right to establish a project, use human rights and distribute, and the new product listing cycle is reduced from 18 months to 3 months.

(2) Entropy reduction mechanism of innovation process

Establish a three-stage decision funnel: creative sandbox: full proposal, digital voting screening (such as Tencent’s “Living Water Plan”); Lean verification: Minimum viable product (MVP) 90-day stress test; Scale incubation: resource allocation through internal venture capital committee. This mechanism increases the success rate of new products in ByteDance from 8% to 35%.

(3) Design of fault-tolerant cultural system

Set up a “Glorious Failure Award” to publicly recognize technology exploration suspension projects (such as Google Glass, which was closed by Google). The key lies in defining fault-tolerant boundaries: correct strategic direction, due diligence in process and precipitation of knowledge assets.

5.4. Ecological Synergy Path: Weaving Innovation Resonance Network

(1) Deep integration paradigm of production, education and research

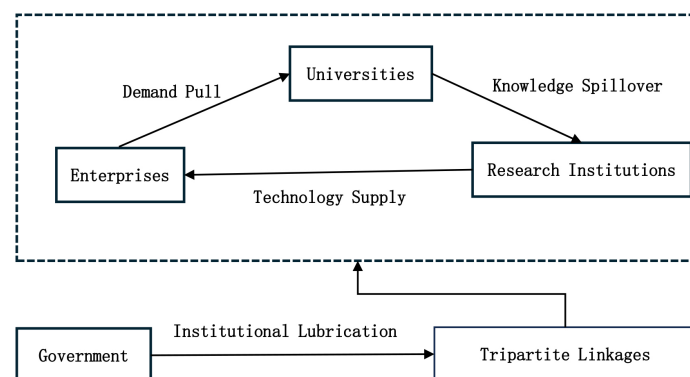


Figure 1. Innovation ecological model.

Build a platform of “demand crowdsourcing-capability matching-revenue sharing”: enterprises publish technical requirements (such as “1 million to find fast charging solutions” in Ningde era); After the university is unveiled, it will enter the enterprise joint laboratory; The income from achievements is distributed according to “50% of enterprises + 30% of teams + 20% of universities”. This model improves the research and development efficiency of millimeter wave chips in cooperation between Huawei and Tsinghua by 200%. The specific innovation ecology model is shown in **Figure 1**.

(2) Industrial chain-innovation chain double-chain coupling

Establish an innovation consortium led by chain owners: define industry standards (such as the State Grid New Energy Access Agreement); Open test scenarios (such as BYD Intelligent Driving Open Road); Share supply chain resources (such as JD.COM board technology empowering Xiaomi); Global innovation resource allocation (Song *et al.*, 2018).

Adopt the “Moon Lighthouse Strategy”: independently tackle key problems in root technology (such as SMIC 14nm chip); The application layer is globally open source (such as Ali Dragon Lizard operating system); Co-construction of standard-side alliance (such as essential patents of 5G standard led by China).

5.5. Digital Intelligent Empowerment: Penetrating Efficiency Engine

(1) AI reshapes the whole process of research and development

Prospective prediction: using DeepMind AlphaFold to crack protein structure; Virtual verification: NVIDIA Omniverse implements digital twin testing; Intelligent decision: Huawei Pangu model optimizes base station energy consumption.

(2) Integration of industrial Internet platform

Build a “cloud-edge-end” collaborative system: Sany Heavy Industry’s “root cloud platform” accesses 500,000 devices, and the efficiency of R&D data feedback increases by 90%; Improvement of real-time driving design of C919 operation and maintenance data of China Eastern Airlines.

(3) Blockchain builds a trust base

Automatic execution through intelligent contracts: data transaction profit sharing (such as Shanghai Digital Exchange model); Intellectual property pledge financing; Carbon footprint tracking certification.

6. Strengthen Policy Coordination

6.1. Paradigm Reconstruction of Policy Role: From Manager to Ecological Architect

Traditional policies focus on market failure correction (such as subsidizing R&D), but new productivity requires policies to play a more essential role (Wang *et al.*, 2024).

(1) The underlying architect of the innovation ecology

The government needs to build digital infrastructure (such as national compu-

ting power network), institutional infrastructure (such as data property rights rules) and knowledge infrastructure (such as open source patent pool). China's "East-to-West Computing" project lays a physical foundation for the national circulation of data elements by coordinating the demand for green electricity in the west and computing power in the east.

(2) Strategic investors of the future track

Through long-term and high-risk investment (such as the National Integrated Circuit Industry Fund), fill the "innovation fault zone" where private capital is afraid to get involved. Its essence is that the state capital confronts the short-term profit-seeking of the market.

(3) The weaver of collaborative network

Policy needs to break through the blocking point of production, education and research transformation. A positive attempt is the "reward system" scientific research project in Shenzhen: enterprises put forward technical needs, the government provides 30% funds and matches the university team, and enterprises return double investment after the achievements are transformed, forming a closed loop of "demand-supply-feedback".

Theoretical core: The effectiveness of policy depends on whether it can change from "intervening in the market" to "cultivating ecology", and the core is to reduce the entropy increase (disorder) of the system.

6.2. Multi-dimensional Synergy Mechanism of Policy Toolbox

(1) System adaptability regulator

First, improve the agile legislative mechanism: the EU Artificial Intelligence Act sets up a "regulatory sandbox": allowing enterprises to test new technologies (such as autonomous driving) in a safe space, collecting risk data synchronously and dynamically adjusting rules, so that the iteration period of the system is reduced from 5 years to 18 months.

Secondly, give full consideration to the design of policy redundancy layer: China Pilot Free Trade Zone implements the authorization of "suspending the implementation of laws and regulations", and reserves trial and error space for new formats such as cross-border e-commerce and offshore data. When the fault tolerance rate of regional policies increases, the innovation activity of regional enterprises will be simultaneously improved or even enlarged.

(2) Factor marketization accelerator

It is necessary to coordinate a package of policy tools to empower data elements, talent elements and capital elements. In terms of data elements, for example, Beijing International Big Data Exchange initiated the "Data Asset Certificate", which converts data resources into assets that can be pledged for financing, and enterprises can obtain up to 50 million yuan of credit with data assets. In terms of talent elements, similar to Singapore Tech. Pass's plan to exempt top scientific and technological talents from income tax for 10 years and attract the top 5% AI experts in the world to settle in are all measures that can be used for reference. In terms

of capital elements, the state can set up a risk compensation fund to bear the bulk of R&D failure costs with basic and general attributes, thus effectively enhancing the risk appetite of enterprises (Zhang & Ma, 2025). The three-dimensional empowerment of factor markets by specific policy tools is shown in **Figure 2**.

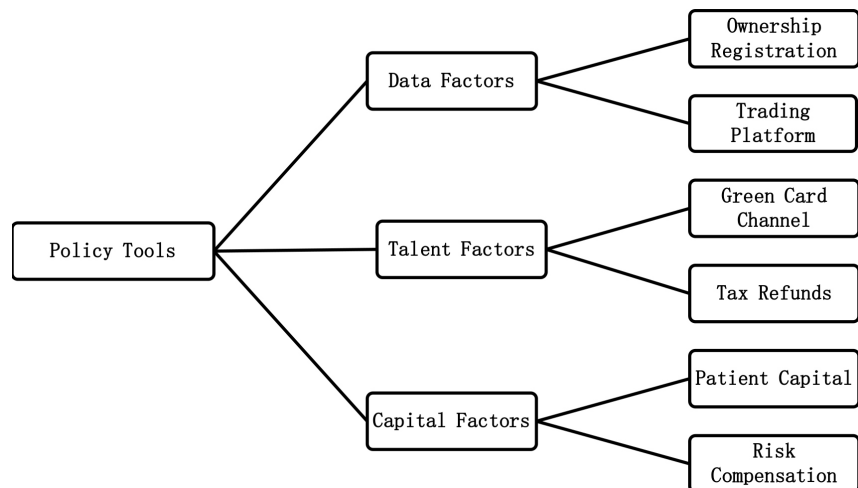


Figure 2. Three-dimensional empowerment of policy tools to factor markets.

(3) Industrial transition catalytic converters

On the premise of ensuring national security, the scene opening strategy is implemented: Shanghai has opened 615 automatic driving test roads (accounting for 50% of the whole country), allowing enterprises to collect millions of kilometers of road test data, so that the maturity speed of local algorithms is twice that of overseas competitors.

Implementing green innovation procurement: The German government requires that public project procurement must include a certain proportion of low-carbon technologies (such as hydrogen bus), and forcing enterprises to include carbon intensity in the core index of innovation efficiency is a positive example of this strategy.

6.3. Practical Dialectics of Policy Coordination

System coordination should be fully considered in policy design. Coordinate the balance between centralization and decentralization, protect and open the scale, and encourage and restrain simultaneously.

(1) Balance between centralization and decentralization

Give full play to the advantages of China's national system, concentrate on tackling the problem of "root technology" in the neck, and shorten the research and development cycle; Decentralizing resources stimulates "grassroots innovation" and encourages various "maker funds" to support a large number of small and micro teams. The birth of disruptive products such as DJI UAV verifies the effectiveness of the "ant soldier" strategy.

(2) Scale of protection and opening

On the one hand, we should have the necessary boundary of technology protection, and at the same time see the strategic benefits of open innovation. Japanese photoresist technology maintains global monopoly through patent barriers, but over-protection leads to innovation inertia of local enterprises, which is finally overtaken by Korean enterprises bypassing patents. Tesla's open source electric vehicle patent attracts supply chain enterprises to jointly reduce battery costs, but consolidates its ecological dominant position.

(3) Incentive and restraint simultaneously

Encourage enterprises to increase investment in research and development through tax reduction or increase.

6.4. Risk Warning of Policy Failure

When the policy coordination is out of balance, it will lead to systemic risks. It is necessary to establish the awareness of "a chess game in the whole country", and pay attention to avoid repeated investment caused by local departmentalism. The overheated data center construction caused the vacancy rate of the national data center to reach 35% in 2022. Attention should be paid to streamlining management institutions, improving administrative efficiency, and reducing the phenomenon that institutional friction costs crowd out R&D investment. At the same time, it is necessary to prevent the distortion of innovation resource allocation, and to prevent some industries from being given abnormally high treatment, which leads to excessive influx of capital and neglecting other innovations (Chen et al., 2022).

In a word, effective policy coordination should follow the principle of "three matches"-matching with the intergenerational cycle of technology, matching with the stage of factor evolution and matching with the rhythm of industrial transition.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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