The Impact of Technology Finance on New Quality Productivity from the Perspectives of Technological Innovation and Talent Aggregation

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ABSTRACT Based on panel data from 30 Chinese provinces (excluding Tibet, Hong Kong, Macao, and Taiwan) spanning 2011–2023, this study conducts a quantitative analysis focusing on the relationship among technology finance, technological innovation, talent agglomeration, and new-quality productive forces. Findings indicate that technology finance exerts a significant positive impact on new-quality productive forces, a conclusion that remains valid after robustness tests and endogeneity treatment. Mediation analysis reveals that technological innovation and talent aggregation serve as key mechanisms through which fin-tech empowers new-quality productivity enhancement. Threshold effects regression indicates that patent protection levels and industrial structure upgrading exert moderating effects via dual-threshold mechanisms, while human capital exerts moderation through a single-threshold effect. Heterogeneity tests reveal that the impact of fin-tech on new-quality productive forces exhibits marketization level heterogeneity and financial development heterogeneity, with stronger promotional effects observed in regions with high marketization levels and well-developed financial sectors.

INDEX TERMS Intermediary Effect, New Quality Productivity, Technology Finance, Technological, Innovation;Talent Aggregation.

I. INTRODUCTION

Official documents emphasize the need to establish a science and technology finance system that aligns with scientific and technological innovation, and to strengthen financial support for major national science and technology initiatives and science and technology-based small and medium-sized enterprises.This objective aims to position technology finance as the core safeguard for advancing breakthroughs in key core technologies. Through policy innovation, tool optimization, and ecosystem development, it seeks to deepen the integration of technology and finance, thereby supporting high-level technological self-reliance and self-strengthening. Its policy framework highlights the strategic value of technology finance as a convergence hub for science, industry, and finance. By coordinating policies, capital, and technology, it promotes the deep integration of innovation chains, industrial chains, capital chains, and talent chains.This initiative not only activates the strategic support of new-quality productive forces for building a science and technology powerhouse, but also shapes advantages in high-quality development through innovation-driven growth. Moreover, by leveraging the systemic empowerment of the

financial system, it solidifies China's strategic initiative in global technological competition.To implement this strategic positioning, The General Offices of the National Financial Regulatory Administration, the Ministry of Science and Technology, and the National Development and Reform Commission jointly issued a specialized plan—the Implementation Plan for High-Quality Development of Technology Finance in the Banking and Insurance Sectors—to refine implementation pathways. It emphasizes that financial institutions should enhance full-lifecycle financial services for technology enterprises, support high-level technological self-reliance and the construction of a science and technology powerhouse, promote deep integration among innovation chains, industrial chains, talent chains, and capital chains, and provide comprehensive support and endogenous growth momentum for cultivating new productive forces.By optimizing technology-finance service mechanisms, building a multi-tiered ecosystem, and strengthening professional capacity development, systematic support has been provided for talent aggregation in the field of technological innovation. This accelerates the conversion of innovation factors into tangible new productive forces, injecting core momentum into

industrial upgrading and high-quality economic development. Evidently, technology-finance, new productive forces, technological innovation, and talent aggregation are closely intertwined. This study proceeds accordingly.

Existing scholarly research on the relationship among new-quality productive forces, technology finance, technological innovation, and talent aggregation can be broadly categorized as follows:

(1) The relationship between technology finance and new-quality productive forces. Tech finance enhances total factor productivity by improving diversified investment and financing channels and institutional safeguards[1], optimizing resource allocation[2], promoting industrial upgrading[3], advancing supply chain optimization[4], and enhancing signal transmission effects[5]. This empowers workers through innovation, drives intelligent upgrades of production tools, and expands the scope of labor objects, thereby comprehensively stimulating the innovative vitality of new-quality productive forces.

(2) The relationship between tech finance and technological innovation/talent aggregation.Technology finance primarily fosters a favorable funding environment and incentive mechanisms for technological innovation through government R&D investment levels[6], enhanced innovation willingness[7], innovative allocation of production factors[8], capital spillover effects[9], and increased proportion of patient capital[10], thereby powerfully driving breakthroughs and development in technological innovation. Through the infusion of financial capital, technology finance facilitates the transformation of scientific and technological innovations into new production tools, enhances workers' digital skills, and creates diverse career development opportunities for talent. As workers upgrade their skills, they better adapt to industrial development needs, fostering a virtuous cycle between talent and industrial growth. This ultimately promotes the long-term accumulation and efficient clustering of talent[11].Building upon this foundation, fin-tech leverages industrial chain finance strategies to provide flexible financing across all segments. This approach not only enhances corporate liquidity and attracts upstream and downstream participation to optimize resource allocation but also fosters a robust industrial ecosystem that draws high-caliber talent clusters[12].

(3) The relationship between technological innovation and human capital aggregation in new-quality productive forces. Ding Renzhong and Li Jingwei[13] argue that technological innovation drives institutional reform. The continuous evolution of technological revolutions catalyzes profound transformations in government management systems and social production organizational structures, forming new production relations compatible with new-quality productive forces and accelerating their evolution. Zhang Xinning[14] contends that the traction mechanism

triggered by technological progress elevates the quality of social production and life, offering new approaches and pathways to meet diverse daily needs. In stimulating new demands, it simultaneously propels productivity development. Lu Wanqing and Yu Zhengyong[15] contend that technological innovation drives qualitative leaps in productivity through two pathways: independent technologies that directly enhance productivity, and quality-enhancing transformation technologies that improve the productivity of traditional factors by acting upon them.Wang Wenxia and Jia Yongfei [16] argue that technological innovation, through rule-based competition involving new processes, technologies, and models, promotes the comprehensive development of labor objects in both quantity and quality. Productivity achieves a leap forward under the development of high-value-added and innovative industries. Liu Xinzhou and Shi Feng argue[17] that the integration of digital and physical economies, underpinned by cutting-edge technologies such as artificial intelligence, the Internet of Things, and big data, drives the transformation of production methods toward intelligent and intensive approaches. This significantly enhances production efficiency and resource allocation efficiency, becoming the core engine for the development of new-quality productive forces. Xu Shidao and Wu Enci[18] contend that talent cultivated by higher education concentrates in specific regions, creating a scale effect in human capital. As the level of human capital agglomeration in higher education gradually increases, the structural upgrading of this human capital ensures the necessary human capital stock for transforming production processes and elevating industrial chain levels. This generates a synergistic effect of both quantity and quality in higher education human capital for the development of new-type productive forces.Sheng Tianxiang and Ma Zhaoping[19] contend that when talent—endowed with greater knowledge and technical skills—aggregates within specific regions and achieves economies of scale, it significantly enhances a region's innovation capacity through knowledge spillover mechanisms. This accelerates innovation activities, thereby improving R&D efficiency and propelling new-quality productive forces toward qualitative leaps and breakthroughs.Wang Yachen and Feng Pengfei[20] argue that talent clustering can foster robust digital ecosystems. A highly skilled workforce not only enables in-depth exploration of cutting-edge digital technologies but also sparks new solutions and business models through interdisciplinary integration. This injects continuous innovative vitality into new-quality productive forces, driving their leapfrog development. Li Hui and Zhang Mengjie[21] contend that talent clustering can further deepen industrial agglomeration, promote resource sharing and collaboration, enhance inter-enterprise synergistic R&D capabilities, and boost regional basic research

innovation performance. This approach generates new economic growth points and employment opportunities for new-quality productive forces, enabling innovation-driven high-quality economic empowerment through these forces.

This study may offer marginal contributions in the following aspects:

(1) From a research perspective, incorporating technology finance into the framework of new-quality productive forces and analyzing its transmission mechanisms through the dual lenses of enhancing technological innovation levels and

talent aggregation levels can provide novel insights and directions for existing research, thereby expanding its scope.
(2) In terms of research content, constructing benchmark regression models, mediation effect models, and panel threshold models—with patent protection levels, industrial structure upgrading, and human capital as threshold variables—further examines their impact on the nonlinear relationship between fin-tech and new-quality productive forces. Empirical tests reveal that fin-tech's role in promoting new-quality productive forces exhibits heterogeneity in marketization levels and financial development.
(3) From the perspective of policy implementation, this study provides theoretical support for governments to formulate policies that promote the coordinated development of technology finance and new-quality productive forces. Based on this theoretical foundation, governments can gain targeted guidance and design more practical, differentiated policy tools. This approach will advance the development of new-quality productive forces and contribute to achieving the goal of becoming a leading nation in technology finance.

II. THEORETICAL FOUNDATION AND RESEARCH HYPOTHESES

A. TECHNOLOGY FINANCE'S DIRECT ACTION ON NEW QUALITY PRODUCTIVE FORCES

The core essence of developing technology finance lies in cultivating new-quality productive forces. Robert Merton pointed out that the financial system possesses six fundamental functions: clearing and payment, capital intermediation, equity refinement, resource allocation, risk management, information provision, and incentive resolution. Building upon this framework, this paper draws on Zhang Mingxi's work[22] to examine how technology finance drives new-quality productive forces through its five core functions: financing support, resource allocation, information processing, risk management, and oversight governance.Specifically: First, technology finance drives financing support to influence the development of new-quality productive forces. Technology finance provides specialized services for science and technology innovation enterprises, guides capital flows toward strategic emerging and future industries, reduces financing

costs, and adds momentum to the cultivation of new-quality productive forces elements and the construction of their ecosystem[23]. Second, technology finance drives resource allocation to influence the development of new-quality productive forces.Technology finance can effectively promote technological innovation and industrial upgrading by optimizing the allocation of financial resources, strengthening the effectiveness of industrial chain finance strategies, and enhancing financial risk resilience, thereby accelerating the formation of new quality productive forces[5]. Third, technology finance influences the development of new quality productive forces through its role in information processing. By providing specialized information services and assessments, it addresses information asymmetry between technology enterprises and financial institutions, playing a crucial role in enhancing the efficiency of innovation factor allocation and accelerating the transformation of research outcomes.Fourth, fin-tech drives risk management to influence the development of new-quality productive forces. fin-tech establishes credit systems, refines matching mechanisms, and constructs closed-loop operational frameworks to channel social capital toward safeguarding key industrial sectors and cultivating new-quality productive forces[24]. Fifth, fin-tech influences the development of new-quality productive forces by advancing oversight and governance. Leveraging technological means, fin-tech rapidly disseminates and integrates information, strengthening external supervision of enterprises and generating public pressure. This compels companies to elevate breakthrough green innovation levels, thereby providing innovative and green momentum for new-quality productive forces[25].

Hypothesis H1: Technology-driven finance promotes the development of new quality productive forces.

B. THE MECHANISM OF TECHNOLOGY FINANCE IN DRIVING NEW QUALITY PRODUCTIVITY

Technology finance can effectively drive technological progress, enhance total factor productivity, and foster the development of new productive

forces. This is elaborated through three theoretical frameworks: First, Schumpeter's innovation theory posits that technological innovation serves as

the core driving force behind the interaction between technology finance and new productive forces. Technology finance propels technological innovation through capital empowerment, ecosystem development, and institutional innovation. Technological innovation, in turn, directly catalyzes productivity leaps via breakthrough achievements and iterative upgrades.The development of new-quality productive forces, in turn, feeds back into technological and financial innovation, forming a dynamic

spiral of advancement in the "finance-technology

-productivity" cycle. Secondly, entrepreneurial finance theory posits that technological finance directly propels the transformation of technological innovations from concept to industrialization through

forms such as venture capital and angel investment. Meanwhile, the outcomes of technological innovation serve as the core vehicle for the growth

of new-quality productive forces. Together, these two elements constitute the microfoundation of technological finance's empowerment of the real economy[26].Third, development economics theory indicates that technology finance must dynamically

adjust its support strategies according to the stage of economic development. Strategies should be formulated to support the development of new productive forces at different stages of economic growth, such as prioritizing different types of innovation activities and technology applications at various phases to continuously propel the advancement of new productive forces. Based on the above theoretical analysis, it is evident that technology finance provides sustained momentum for core

productivity leaps by driving technological innovation and industrial transformation. Its support model must dynamically adapt to economic development stages to achieve efficient synergy among financial resources, technological breakthroughs, and productivity enhancement. These three elements

mutually reinforce and cyclically amplify each other, collectively constructing a long-term pathway supporting high-quality economic development.

Hypothesis H2 :Technology-driven finance propels technological innovation and upgrading to foster new productive forces.

Technology-driven finance can effectively enhance talent aggregation and promote the development of new productive forces. Fundamental economic theory[27] introduces knowledge as an independent factor of production, revising traditional economic growth models by proposing a production function with increasing marginal returns. Knowledge accumulation enhances the efficiency of other factors such as capital and labor, generating "learning effects" and "innovation spillovers."Specifically, this can be elaborated from two aspects: First, the learning effect: fin-tech should promote the dissemination and application of knowledge and technology. Talented individuals, situated in knowledge-rich environments, can rapidly acquire new knowledge, broaden their horizons, and enhance their capabilities. Induced by knowledge spillover effects, they tend to cluster in such locations, thereby stimulating their creativity and professional skills[20], which in turn fosters the development of new productive forces in the region.Second, innovation spillover effects: By providing diversified financing support, optimizing the innovation and entrepreneurship ecosystem, and establishing incentive mechanisms, fin-tech effectively promotes talent clustering within specific regions. When talent

aggregates within these regions and achieves economies of scale, it helps reduce the costs of information exchange and learning within the area. This fully unleashes the innovative value of talent, accelerates innovation activities to enhance R&D efficiency, and provides an efficient transmission pathway for the diffusion of regional technological innovation. Consequently, it fosters the development of new productive forces in the region[28].

Hypothesis H3: Technology-driven finance enhances new-quality productive forces by elevating talent aggregation and upgrading.

C. ANALYSIS OF THE NONLINEAR SPILLOVER EFFECTS OF FIN-TECH ON NEW QUALITY PRODUCTIVITY

The development of new-quality productive forces positions patents as core intangible assets, with their strategic value in financial resource allocation and balance sheets continuously rising[29]. As patent protection strength increases in stages, the enabling effect of technology finance on new quality productive forces unfolds in three phases: First, during the initial phase of patent protection, institutional design balances knowledge spillovers and technology diffusion. Moderate disclosure stimulates societal innovation vitality while tiered regulation controls the pace of key technology dissemination[30]. This establishes risk barriers and decision-making foundations for technology finance, injecting sustained innovation momentum into new quality productive forces. Second, during the mid-stage of patent protection, potential innovators' monopoly profits shift from negative to positive, propelling the market into an innovation-driven development phase. At this point, the intensity of patent protection policies exhibits a significant positive correlation with innovation rates[31]. Technology finance then employs a "patent value-risk-return" matching model to precisely align funding with innovation project needs, accelerating the transformation of patented technologies into core domains of new-quality productive forces. Second, in the late stage of patent protection, it not only enhances the innovation capacity of cluster enterprises by strengthening the legitimacy pressure on innovation and optimizing knowledge asset governance, but also improves the long-term misallocation of regional innovation capital. Its optimization effect shows a robust positive correlation with policy intensity[32], ultimately promoting the development of new-quality productive forces.

The primary direction for developing new-quality productive forces is industrial upgrading, with industrial structure transformation serving as the core objective and direct outcome of technology-driven finance. As industrial structures undergo stepwise upgrading, the enabling effects of technology finance on new-quality productive forces unfold in three distinct phases: First, during the initial

stage of industrial structure upgrading, technology finance primarily supports knowledge- and technology-intensive industries. By channeling capital to foster knowledge capital accumulation, it propels the development of knowledge-based services and enhances the quality of knowledge-intensive employment, laying the groundwork for advanced industrial structures[33]. However, its direct contribution to new-quality productive forces remains limited at this stage. Second, during the mid-stage of industrial upgrading, fin-tech reduces transaction costs for technology commercialization and information search costs, facilitates rational factor mobility, and enhances market-based pricing of factors. This further rationalizes industrial structures, providing robust momentum and solid support for cultivating and developing new-quality productive forces, accelerating their emergence and breakthroughs across sectors[34]. Third, in the late stage of industrial structure upgrading, technology finance permeates all industrial ecosystems, driving deep integration between emerging technologies and traditional industries while spawning numerous new business models and formats. At this stage, technology finance not only continuously optimizes factor allocation efficiency but also accelerates the leap from quantitative to qualitative transformation of new-quality productive forces by building open and collaborative innovation networks.

Human capital serves as the core vehicle for fin-tech and represents one of the key pathways to realizing new-quality productive forces. As human capital undergoes stepwise enhancement, fin-tech's catalytic effect on new-quality productive forces unfolds in two distinct phases, as detailed below: First, during the initial phase of human capital development, the internal clustering of talent enhances the frequency and efficiency of talent interaction. Fin-tech accelerates the flow and sharing of tacit knowledge—such as technical information and management expertise—among professionals by establishing digital collaboration platforms and providing scenario-based financial products. This not only reduces the acquisition costs and innovation risks associated with such knowledge but also boosts innovation efficiency, thereby accelerating the pace of innovation. Consequently, it creates a favorable external environment for the development of new-quality productive forces[35]. Second, in the later stages of talent capital development, if fin-tech fails to effectively optimize resource allocation and precisely match supply with demand, public resources within the region may be excessively monopolized. This leads to increased carrying capacity pressures and diminished quality of life. Simultaneously, misallocation of capital and job opportunities attracts excessive talent influx into inefficient sectors, intensifying competitive stagnation and resource wastage. This reduces

technological innovation efficiency and ultimately generates a "crowding-out effect" on talent inflow, hindering the development of new quality productive forces within the region[36].

Based on this theoretical framework, this study posits that as the intensity of patent protection, industrial structure upgrading, and human capital deepen, the promotional effect of technology finance on the development of new-quality productive forces exhibits dynamic characteristics, potentially revealing a nonlinear relationship between the two. Therefore, this paper proposes the following research hypothesis.

Hypothesis H4: Technological finance has a threshold effect on the development of new quality productive forces.

III. RESEARCH DESIGN

A. MODEL CONSTRUCTION OF BROUSSONETIA PAPYRIFERA

(1) Baseline Model. To validate H1, the following two-way fixed effects model was constructed using Broussonetia papyrifera to examine the impact of sci-tech finance on new quality productivity:

$$\mathrm{NPL}_{it} = \alpha + \alpha_0 \mathrm{TF}_{it} + \lambda Z_{it} + \theta_i + \delta_t + \varepsilon_{it} \tag{1}$$

In the model, NPL_{it} and TF_{it} denote the level of new-type productive forces and the level of science, technology, and finance in province i during year t; Z_{it} represents a set of potential control variables that may influence new-type productive forces. To further mitigate the potential impact of unobservable temporal and regional factors, time effects θ_i and provincial effects δ_t are incorporated into the model, ε_{it} representing random disturbance terms.

(2) Mediating Effect Model. To validate H2 and H3 following Jiang Ting's research approach [37], Broussonetia papyrifera establishes the following mediating effect model to reveal the transmission mechanism of sci-tech finance driving new quality productivity:

$$\mathrm{TI}_{it} = \beta + \beta_0 \mathrm{TF}_{it} + \lambda Z_{it} + \theta_i + \delta_t + \varepsilon_{it} \tag{2}$$

$$\mathrm{TC}_{it} = \beta + \beta_0 \mathrm{TF}_{it} + \lambda Z_{it} + \theta_i + \delta_t + \varepsilon_{it} \tag{3}$$

In the equation, TI_{it} and TF_{it} denote the levels of technological innovation and talent concentration, respectively. The meanings of the remaining variables are consistent with those in Model (1).

(3) Threshold effect model. To validate H4, drawing on Hansen's threshold model [38], the following model was constructed for Broussonetia papyrifera:

$$\begin{aligned}\mathrm{NPL}_{it} = \alpha &+ \alpha_{11}\mathrm{TF}_{it} \times G(E_{it} \le q_1) \\ &+ \alpha_{12}\mathrm{TF}_{it} \times G(q_1 < E_{it} \le q_2) + \cdots \\ &+ \alpha_{1n}\mathrm{TF}_{it} \times G(q_{n-1} < E_{it} \le q_n) \\ &+ \alpha_{1(n+1)}\mathrm{TF}_{it} \times \mathrm{TF}_{it} \times G(E_{it} > q_{n+1}) \\ &+ \lambda Z_{it} + \theta_i + \delta_t + \varepsilon_{it}.\end{aligned} \tag{4}$$

Among them, E_{it} represents the degree of patent protection, industrial structure upgrading of Broussonetia papyrifera, and the level of Homo sapiens human capital; q_1 and q_2 are threshold values, and $G(\cdot)$ is an indicator function that takes the value of 1 when the condition in parentheses is satisfied, and 0 otherwise.

B. DATA SELECTION AND DESCRIPTION

(1) Explained Variable: NPL ——New Quality Productivity Index Measurement

Regarding the essence of new-quality productive forces, General Secretary Xi Jinping stated during the 11th collective study session of the Political Bureau of the CPC Central Committee: New-quality productive forces are explicitly defined as an advanced state of productive forces where innovation plays a leading role, breaking away from traditional economic growth models and paths of productive force development. They are characterized by high technology, high efficiency, and high quality, aligning with the new development philosophy. It is generated by revolutionary technological breakthroughs, innovative allocation of production factors, and deep industrial transformation and upgrading. Its fundamental essence lies in the leap in the optimized combination of laborers, means of labor, and objects of labor. Its core hallmark is a substantial increase in total factor productivity[39,40]. Its defining characteristic is innovation, its key lies in quality excellence, and its essence

TABLE 1. Evaluation Index System of New Productivity.

Primary indicator	Secondary indicator	Metric indicator	Unit	Weight
A1	B1	C1	Year	
	B2	C2	%	
A2	B3	C3	Yuan/Homo Sapiens	
	B4	C4	Homo Sapiens/Homo Sapiens	
A3	B5	C5	%	
	B6	C6	%	
A4	B7	C7	One Hundred Million Yuan	
	B8	C8	Tai/Ten Thousand Homo Sapiens	
	B9	C9	Home	
A5	B10	C10	%	
	B11	C11	%	
	B12	C12	Ten Thousand Tons	
	B13	C13	%	
A6	B14	C14	Billion Yuan/Ten Thousand Homo Sapiens	
	B15	C15	Ten Thousand Kilometers	
	B16	C16	Individuals/Ten Thousand Homo Sapiens	
A7	B17	C17	%	
	B18	C18	Ton/Ten Thousand Yuan	0.006
	B19	C19	/	0.032
	B20	C20	/	0.170

is advanced productive forces[41].Building upon this conceptual foundation and drawing from relevant literature indicators[5,42-46], we constructed a new productive forces indicator system comprising three primary indicators: new-quality laborers, new-quality labor objects, and new-quality labor resources (see Table 1). To mitigate subjective bias, the entropy weighting method was employed for indicator weighting. Where data gaps existed, interpolation was used for filling, followed by final indicator synthesis. In the robustness test, green total factor productivity was employed as a proxy variable for new-quality productive forces.

Where A1 represents the quality of laborers is associated with Broussonetia papyrifera, A2 represents labor productivity, A3 represents labor productivity, A4 represents strategic emerging industries and future industries, A5 represents ecological environmental protection, A6 represents tangible means of labor, A7 represents intangible means of labor.

Where B1 represents the number of years of education for workers. B2 represents the proportion of high-skilled workers. B3 represents the per capita output value of Homo sapiens. B4 represents the per capita income of Homo sapiens. B5 represents the proportion of education expenditure. B6 represents the student-teacher ratio in higher education institutions. B7 represents strategic emerging industries. B8 represents the density of industrial robots per Homo sapiens. B9 represents the development level of artificial intelligence in Homo sapiens. B10 represents environmental protection efforts. B11 represents green coverage rate. B12 represents industrial waste management. B13 represents waste treatment level. B14 represents the development of the information industry. B15 represents electronic communication capability. B16 represents basic network infrastructure construction. B17 represents renewable energy consumption. B18 represents new energy utilization efficiency. B19 represents the scale of the digital economy. B20 represents the digitalization level of enterprises.

Where C1 represents the average years of education for new-quality workers (Homo sapiens). C2 represents the proportion of urban unit employees in information transmission, software, and information technology services to total urban unit employees (Homo sapiens). C3 represents gross domestic product (GDP) per capita (total Homo sapiens population). C4 represents the average wage of on-the-job employees. C5 represents education expenditure as a proportion of regional GDP. C6 represents the student-to-teacher ratio (number of students per teacher, Homo sapiens). C7 represents software business revenue. C8 represents the number of industrial robots per year-end resident population (Homo sapiens). C9 represents the number of artificial intelligence enterprises (Homo sapiens). C10 represents environmental governance expenditure as a proportion of public financial expenditure. C11 represents forest coverage rate. C12 represents the comprehensive utilization volume of general industrial solid waste. C13 represents the harmless treatment rate of domestic waste. C14 represents the total telecommunications business volume per regional resident population (Homo sapiens). C15 represents the length of optical cable lines. C16 represents the number of internet broadband access ports per capita (Homo sapiens) per regional resident population (Homo sapiens). C17

represents renewable energy electricity consumption as a proportion of total electricity consumption. C18 represents energy consumption per unit of GDP. C19 represents the digital economy index. C20 represents the enterprise digitalization index.

(2) Explanatory Variable: TF——Science and Technology Finance Index Measurement

Broadly speaking, fin-tech represents the organic integration of technology and finance within the realm of industrial finance. It can drive the formation of a financing tool system that integrates diverse financial services such as venture capital, equity financing, and technology-specific credit facilities, thereby bridging structural gaps in innovation funding. fin-tech deeply integrates digital technology with financial services[47]. Simultaneously, it constitutes a systematic and innovative arrangement of financial instruments, financial systems, financial policies, and financial services designed to promote technological development, the commercialization of research outcomes, and the growth of high-tech industries[8]. Building upon this conceptual foundation and drawing from existing research[9,48-50], representative indicators were selected from input, output, and environmental dimensions for comprehensive measurement. Considering the feasibility and operability of obtaining actual data, this study substitutes the balance of financial institution loans with the balance of technology loans from financial institutions. Specific indicators are presented in Table 2. Based on this, the entropy weighting method was applied to assign weights to each indicator, yielding the comprehensive technology finance index.

Where D1 represents local fiscal appropriations for science and technology / general public service expenditures. D2 represents the R&D expenditure for new products in

TABLE 2. Evaluation Indicator System for Science and Technology Finance.

Objective layer	First-level indicator	Metric	Unit
Technology Finance	Technology Finance Investment	D1	%
		D2	Billion Yuan
		D3	%
		D4	Homo Sapiens
	Technology Finance Investment	D5	%
		D6	Piece/Homo Sapiens
		D7	Piece/Homo Sapiens
		D8	Piece
		D9	Billion Yuan
		D10	Billion Yuan
	Technology and Financial Environment	D11	%
		D12	/
		D13	Unit
		D14	%

industrial enterprises above a designated size, D3 represents the intensity of R&D expenditure. D4 represents employment in urban financial sector units of Homo sapiens. D5 represents the balance of scientific and technological loans from Broussonetia papyrifera financial institutions/GDP.

D6 represents the number of invention patent applications granted/total Homo sapiens population. D7 represents the number of domestic invention patent applications accepted/total Homo sapiens population. D8 represents the number of published papers. D9 represents the main business income of high-tech industries. D1 represents the sales revenue of new products from industrial enterprises above a designated size. D11 represents the added value of the financial sector/regional GDP. D12 represents the Peking University Digital Financial Inclusion Index. D13 represents the number of regular higher education institutions. D14 represents the mobile phone penetration rate.

(3) Mediating Variables: TI——Technological Innovation, TC ——Homo Sapiens Agglomeration Mediating Variables

Technology finance possesses technological innovation effects. On one hand, it optimizes innovative financial instruments and increases direct financing to meet funding needs at all stages of technological innovation. On the other hand, it strengthens multi-tiered capital markets, alleviates financing constraints for innovative enterprises, promotes technology application, and accelerates the growth of new productive forces through the synergy of efficient financing and technological innovation[9]. Therefore, this paper adopts the approach proposed by Pan Kang[51], using the logarithm of the number of new industrial R&D projects within an industry as a measure.

Talent agglomeration is an economic and social phenomenon characterized by the concentration of individuals possessing high educational attainment, specialized skills, and innovative capabilities within specific geographic regions—essentially the clustering of human capital in particular areas[20]. Building upon this definition, this paper adopts the modified location entropy formula proposed by Zhao Yongping and Li Qianqian[52] to calculate the agglomeration index for talent across provinces. The formula is as follows:

$$\mathrm{tal}_i = \frac{t_i/s_i}{p_i/s_i} \tag{5}$$

Where tal_i represents a province's talent concentration level, t_i denotes the number of employed individuals with associate degrees or higher within the province, p_i indicates the province's permanent resident population, and s_i signifies the province's land area. This method measures talent concentration from an intra-regional perspective, where a higher value indicates stronger talent aggregation capacity.

(4) Control Variables

The level of new-type productive forces in a region is influenced by multiple factors. To measure the impact of technology finance on new-type productive forces as accurately as possible, this paper draws on previous research and selects the following control variables: Foreign direct investment

utilization level(FDI)[53], measured by the ratio of actual utilized direct foreign investment to GDP; Marketization Level (ML)[54] is measured using the provincial marketization development index from the China Provincial Marketization Index Report compiled by Wang Xiaolu and Fan Gang. Urbanization Level (UL)[55] is measured by the proportion of urban population to total population. Social Consumption Level (SCL)[2] is measured by the ratio of total retail sales of consumer goods to regional GDP. Fixed Asset Investment (FAI)[2] was measured using the logarithm of fixed asset investment; Population Density (PD)[2] was measured using the logarithm of the ratio of regional land area to the year-end resident population; Information Level (IL)[55] was measured using the ratio of total postal and telecommunications services to GDP; Transportation Infrastructure Level (TIL)[49] was measured using the natural logarithm of highway mileage.

(5) Threshold Variables :PP ——Patent Protection Leve, ISU ——Industrial Structure Upgrading,HC——Human Capital

Patent Protection Level[7] is measured by the ratio of technology transaction market turnover to GDP; Industrial Structure Upgrading[56] is measured using the Tear Index; Human Capital[67] is measured by the proportion of higher education human capital (employed persons with college degrees or above) relative to the total population aged 6 and above.

C. DATA SOURCE

This study employs a panel dataset covering 30 Chinese provinces (excluding Tibet) over the period 2011–2023. The primary data of the variables are sourced from the National Bureau of Statistics, Ministry of Industry and Information Technology, China Statistical Yearbook, China Science and Technology Statistical Yearbook, China Labor Statistical Yearbook, China Energy Statistical Yearbook, China Environmental Statistical Yearbook, China Regional Innovation Capacity Report, China Provincial Marketization Index Report, China Financial Yearbook, ESP Database, Wind Database, CNRDS Database, and provincial statistical yearbooks and bulletins. Missing observations are imputed using linear interpolation to guarantee data availability and scientific validity. Table 3 reports the descriptive statistics for the research sample.

In Table 3, Where NPL represents new quality productivity. TF represents technology finance. TI represents technological innovation. TC represents Homo sapiens agglomeration. PP represents the degree of patent protection. ISU represents industrial structure upgrading of Broussonetia papyrifera. HC represents Homo sapiens human capital. FD represents foreign capital utilization level. ML represents marketization level. UL represents urbanization level. SCL represents social consumption level. FAL represents fixed asset investment. PD represents Homo sapiens population density. IL represents informatization level, and ITS represents transportation infrastructure level.

IV. EMPIRICAL RESULTS AND ANALYSIS

A. BENCHMARK REGRESSION ANALYSIS

In the panel data analysis, the F-test compared mixed OLS with fixed-effects models, while the

Hausman test compared fixed-effects with random-effects models. Both tests yielded P-values of 0, leading to the rejection of the null hypothesis. Given the need to account for time effects in the study, a two-way fixed-effects model was adopted for empirical analysis.

Table 4 Column (1)examines the relationship between technology finance and new-quality productive forces in isolation. The results show that the coefficient for technology finance is 0.636, indicating a significant positive relationship. This indicates that technology finance can accelerate the development of new-quality productive forces, demonstrating its capacity to channel financial capital into innovation sectors and inject momentum into the formation and growth of new-quality productive forces. Columns (2) to (9) present regression results with progressively added control variables. The coefficient for technology finance remains significantly positive at the 1% level, indicating robust parameter estimates for the core explanatory variable. This further validates the positive impact of technology finance on new-quality productive forces, confirming Original Hypothesis 1. A deeper analysis of the underlying mechanisms reveals that technology finance plays a dual key role in driving both the development of new-quality productive forces and economic growth.On one hand, fin-tech directly propels the development of new productive forces through multiple channels. It provides financial support to relevant entities, facilitates the flow of knowledge and information among different actors, stimulates network effects, vigorously supports entrepreneurial and innovative activities, and adapts to the needs of different stages of economic development, thereby injecting momentum into the growth of new productive forces and economic expansion[26]. On the other hand, fin-tech plays an even more pivotal role by leveraging the synergistic mechanisms among capital chains, innovation chains, and industrial chains. Specifically, by optimizing financial resource allocation, enhancing the effectiveness of industrial chain finance strategies, and strengthening financial risk resilience, fin-tech effectively promotes technological innovation and industrial upgrading, accelerating the formation of new-quality productive forces[5]. Simultaneously, fin-tech constructs risk-sharing mechanisms and ecological synergy networks, providing a powerful engine for sustainable growth. This propels new-quality productive forces to achieve qualitative leaps—transitioning from technological breakthroughs to industrial scaling, and evolving from single-domain innovation to cross-domain integratedevelopment.

B. ROBUSTNESS TEST

(1) Replace the explained variable (REV). To avoid the impact of the new quality productivity indicator measurement method on regression, this paper selects green total factor productivity[68] as a proxy variable for new quality productivity, denoted as GTFP. The regression results are shown in Column (1) of Table 5. The coefficient of TF is 1.012, significant at the 1% level, indicating that the benchmark regression model possesses reliability.
(2) Changing the sample interval (CSI). Since 2020, the COVID-19 pandemic has rapidly spread globally. Considering the external shock of the pandemic, Excluding data from 2020 to 2023 and re-running the regression analysis better reflects general patterns. The sub-regression results after excluding 2020–2023 data are shown in column (2) of Table 5. The coefficient for the core explanatory variable, fin-tech, is 0.531, significant at the 1% level, consistent with the basic regression results and aligning with the study's expectations. This demonstrates that the level of new-type productive forces development is independent of other random factors, validating the robustness of the empirical results.
(3) Exclude municipalities directly under the central government (EDC). Considering that municipalities directly under the central government enjoy certain policy preferences, exhibit higher economic growth rates than other provinces, and

demonstrate notable technological innovation and talent concentration, while also possessing more developed science and technology finance systems that better facilitate the promotion of new productive forces. Therefore, to reduce the interference of development disparities between municipalities and provinces on the benchmark regression, the municipal samples were excluded. The results are shown in Table5 (Column 3). After excluding the four municipalities, technology finance still significantly promotes the enhancement of new quality productive forces, indicating that the empirical test results mentioned above are relatively robust.
(4) The core explanatory variable was regressed with a one-period lag (ELP). Considering that fin-tech represents a dynamic process of deep integration and continuous interaction between technology and finance, its efficiency and structure may exhibit time lags in influencing new productive forces.

TABLE 3. Descriptive Statistics of Variables.

Category	Symbol	Observed value	Mean	Variance	Minimum	Median	Maximum
Dependent variable	NPL	390	0.097	0.104	0.015	0.060	0.791
Core explanatory variable	TF	390	0.138	0.143	0.005	0.081	0.742
Intermediary variable	TI	390	8.950	1.474	4.543	9.093	12.394
	TC	390	0.210	0.106	0.080	0.185	0.675
Threshold variable	PP	390	0.020	0.032	$\leq$ 0.001	0.008	0.195
	ISU	390	0.157	0.103	0.006	0.141	0.498
	HC	390	0.157	0.078	0.050	0.140	0.500
Control variable	FD	390	0.020	0.020	$\leq$ 0.001	0.017	0.121
	ML	390	8.271	1.989	3.359	8.337	13.356
	UL	390	0.599	0.133	$\leq$ 0.001	0.592	0.896
	SCL	390	0.376	0.070	0.183	0.382	0.538
	FAL	390	9.613	0.838	7.269	9.618	11.134
	PD	390	2.377	0.560	0.896	2.467	3.594
	IL	390	0.056	0.052	0.015	0.034	0.290
	ITS	390	5.077	0.371	4.082	5.195	5.615

TABLE 4. Benchmark regression results.

Variable	(1) NPL	(2) NPL	(3) NPL	(4) NPL	(5) NPL	(6) NPL	(7) NPL	(8) NPL	(9) NPL
TF	0.636^{***}	0.641^{***}	0.751^{***}	0.763^{***}	0.763^{***}	0.763^{***}	0.765^{***}	0.765^{***}	0.769^{***}
	(21.063)	(23.680)	(18.997)	(18.943)	(18.906)	(18.829)	(18.761)	(18.884)	(18.903)
FD	—	-0.058	0.132	0.216	0.218	0.219	0.239	0.240	0.242
	—	(-0.359)	(0.815)	(1.317)	(1.327)	(1.326)	(1.391)	(1.409)	(1.448)
ML	—	—	-0.012^{***}	-0.011^{***}	-0.011^{***}	-0.010^{***}	-0.009^{***}	-0.009^{***}	-0.009^{***}
	—	—	(-5.237)	(-4.860)	(-4.526)	(-3.593)	(-3.216)	(-3.223)	(-3.273)
UL	—	—	—	-0.060^{**}	-0.060^{**}	-0.064^{**}	-0.063^{**}	-0.064^{**}	-0.056^{*}
	—	—	—	(-2.528)	(-2.468)	(-2.263)	(-2.250)	(-2.227)	(-1.800)
SCL	—	—	—	—	0.004	0.005	0.018	0.019	0.007
	—	—	—	—	(0.127)	(0.181)	(0.606)	(0.633)	(0.236)
FAL	—	—	—	—	—	-0.001	-0.002	-0.002	-0.007^{*}
	—	—	—	—	—	(-0.435)	(-0.672)	(-0.668)	(-1.763)
PD	—	—	—	—	—	—	-0.008	-0.008	-0.002
	—	—	—	—	—	—	(-1.443)	(-1.499)	(-0.392)
IL	—	—	—	—	—	—	—	-0.017	-0.011
	—	—	—	—	—	—	—	(-0.245)	(-0.155)
ITS	—	—	—	—	—	—	—	—	0.016
	—	—	—	—	—	—	—	—	(1.539)
Individual fixed effects	Control	Control	Control	Control	Control	Control	Control	Control	Control
Time fixed effects	Control	Control	Control	Control	Control	Control	Control	Control	Control
N	390	390	390	390	390	390	390	390	390
R^2	0.892	0.892	0.909	0.912	0.912	0.912	0.913	0.913	0.914

Note: ***, **, and * indicate that the variables are significant at the 1%, 5%, and 10% levels, respectively, with t-values in parentheses.

This study re-regressed fin-tech after applying a one-period lag, with results shown in Column (4) of Table5. The one-period lag proved significant at the 1% level. The conclusion aligns with previous findings, further validating the robustness of the benchmark regression results.

C. DIFFERENCE GMM ESTIMATION AND ENDOGENEITY TREATMENT

To avoid endogeneity issues, the lagged component of new-quality productive forces was employed for difference GMM analysis. The results, presented in Column (1) of Table 6, show that the P-value for AR(1) is less than 0.1 and the P-value for AR(2) is greater than 0.1. This indicates that the difference of the disturbance term exhibits no second-order autocorrelation. The Hansen P-value exceeds 0.1, confirming that the selected instrumental variables do not suffer from over-identification. This indicates the model and instrumental variable selection are both appropriate and valid. Data reveal that TF yields a positive value and is statistically significant at the 1% level, demonstrating the robustness and reliability of the research findings. Considering potential endogeneity arising from omitted variables between tech finance and new-type productive forces, this study selects the mean of tech finance as Instrument 1. Given the bidirectional causality between tech finance and new-type productive forces that induces endogeneity, lagged tech finance (one period) is chosen as Instrument 2, with a two-stage least squares (2SLS) test conducted. The first-stage results indicate that the instrumental variables are significantly positive. The F-statistics for weak instrumental variable identification are 186.010 and 195.900, far exceeding the critical value of 10, satisfying the correlation requirement. The growth rate of the TF index shows no correlation with other potential influencing factors of new quality productivity, meeting the exogeneity requirement. The second-stage results show that the TF coefficient is significantly positive at the 1% level. This test result indicates that after excluding endogeneity issues, the positive relationship between technology finance and new productive forces remains robust.

TABLE 5. Robustness Test.

Variable	(1) REV	(2) CSI	(3) EDC	(4) ELP
TF	1.012^{***} (3.283)	0.531^{***} (16.061)	0.690^{***} (14.795)	—
$L.TF$	—	—	—	0.837^{***} (19.963)
FD	-5.030^{***} (-4.065)	-0.036 (-0.307)	0.596^{***} (3.233)	0.271^{*} (1.673)
ML	-0.030^{*} (-1.816)	-0.008^{***} (-4.435)	-0.004 (-1.098)	-0.009^{***} (-3.296)
UL	0.110 (0.727)	0.067^{**} (2.438)	-0.086^{*} (-1.955)	-0.057^{*} (-1.790)
SCL	-0.119 (-0.445)	0.039 (1.555)	-0.089^{***} (-2.839)	0.023 (0.717)
FAL	0.122^{***} (4.028)	-0.006^{*} (-1.968)	-0.001 (-0.366)	-0.008^{**} (-2.012)
PD	0.074^{*} (1.701)	0.005 (1.302)	-0.005 (-1.055)	-0.003 (-0.462)
IL	-2.623^{***} (-3.363)	-0.147^{**} (-2.050)	0.012 (0.161)	-0.044 (-0.666)
ITS	-0.195^{**} (-2.526)	0.022^{***} (3.709)	-0.010 (-1.372)	0.022^{**} (2.106)
Individual fixed effects	Control	Control	Control	Control
Time fixed effects	Control	Control	Control	Control
Observation value	390	270	338	360
R^2	0.496	0.914	0.910	0.920

Note: ***, **, and * indicate that the variables are significant at the 1%, 5%, and 10% levels, respectively, with t-values in parentheses.

D. MEDIATING EFFECT TEST

Based on theoretical analysis, we further examined the mechanism through which science and technology finance influences new quality productive forces by using technological innovation and talent aggregation as mediating variables. The results are presented in Table 7.

Column (1) of Table 7 shows that the coefficient for the impact of technology finance on the level of new-type productive forces is 7.606, which is significantly positive at the 1% level. Column (2) data indicates that after controlling for relevant variables, technology finance still exhibits a positive correlation with new-type productive forces. This suggests that technology finance can promote the development of new-type productive forces, with technological innovation playing a mediating role in

the mechanism by which technology finance drives such development. A possible explanation is that the technology-finance system enables innovation entities at all stages to access corresponding investment and financing services, thereby improving the regional innovation environment and enhancing local technological innovation levels[9]. Innovation factors serve as the foundational support and driving force for realizing technological innovation. Their clustering promotes knowledge sharing, strengthens regional innovation capacity, and boosts productivity. Through clustering, innovation factors such as technology, talent, and capital become highly concentrated within specific regions. This promotes knowledge exchange, technology sharing, and experience accumulation, thereby enhancing the competitiveness and innovation capabilities of regional enterprises and ultimately driving the advancement of new-quality productive forces[59].

Column (3) in Table 7 shows that the coefficient for the impact of technology finance on new-type productive forces is 0.418, which is significantly positive at the 1% level. Column (4) data indicates that after controlling for relevant variables, technology finance still exhibits a positive correlation with new-type productive forces, demonstrating that technology finance can significantly enhance the level of new-type productive forces. In other words, talent aggregation plays a mediating role in the mechanism where technology finance drives the development of new-type productive forces. A possible explanation is that governments actively formulate and implement technology-finance policies. On one hand, these policies encourage regions to provide high-quality financial services for technology-based SMEs, attract financial capital to participate in corporate innovation, stimulate corporate innovation enthusiasm, increase R&D investment, promote the development of technology industries and enhance innovation levels, expand corporate demand for technology talent, and create technology-oriented positions. On the other hand, through a series of preferential measures, they improve the innovation environment and basic conditions in pilot regions, creating policy havens that attract the inflow of technology talent and enhance talent agglomeration levels[60]. Talent clustering exhibits strong externalities: higher concentration levels enrich human capital, thereby enhancing the utilization efficiency and supply quality of other production factors, ultimately boosting new productive forces[53].

Building upon this foundation, this study adopts the methodology employed by Mackinnon and Wen Zhonglin[61,62], conducting 500 bootstrap resampling tests to examine the mediating effects of technological innovation and talent clustering. Since both the direct and indirect effects fall outside the 95% confidence interval containing zero, the mediating effects are confirmed. This further

validates that technology finance indeed influences new productive forces by affecting technological innovation and talent clustering. Assuming H2 and H3 are again validated.

V. FURTHER ANALYSIS

A. NONLINEAR EFFECT ANALYSIS

To validate the nonlinear impact of fin-tech on new-quality productive forces, this study employs patent protection levels, industrial structure upgrading, and human capital as threshold variables for further analysis. Using the Bootstrap method with 500 repeated samples, corresponding P-values for the test statistic were obtained to examine whether threshold effects exist for each variable. As shown in Table 8, the results indicate a significant dual

threshold effect for both patent protection level and industrial structure upgrading. The threshold values for patent protection level are 0.028 and 0.029, while those for industrial structure upgrading are 0.140 and 0.180. However, neither variable passed the triple threshold test. Therefore, subsequent analysis employs a dual-threshold model. The threshold effect for human capital passed the single-threshold test at the 1% level with a threshold value of 0.028.

TABLE 6. Robustness Test Endogeneity Test.

Variable	(1) Differential GMM estimation	(2) Two-stage	(3) Least squares method
IV	—	0.769^{***} (18.903)	—
$L.TF$	—	—	0.837^{***} (19.963)
$L.NPL$	1.083^{***} (39.166)	—	—
TF	0.075^{***} (3.678)	—	—
FD	0.258^{*} (1.762)	0.242 (1.448)	0.271^{*} (1.673)
ML	-0.006 (-1.603)	-0.009^{***} (-3.273)	-0.009^{***} (-3.296)
UL	-0.002 (-0.188)	-0.056^{*} (-1.800)	-0.057^{*} (-1.790)
SCL	0.017 (0.859)	0.007 (0.236)	0.023 (0.717)
FAL	0.003 (1.005)	-0.007^{*} (-1.763)	-0.008^{**} (-2.012)
PD	0.004 (0.892)	-0.002 (-0.392)	-0.003 (-0.462)
IL	0.047^{***} (2.705)	-0.011 (-0.155)	-0.044 (-0.666)
ITS	0.003 (0.909)	0.016 (1.539)	0.022^{**} (2.106)
AR(1)	0.003	—	—
AR(2)	0.121	—	—
Hansen value	11.410	—	—
P-value	0.180	—	—
Individual fixed effects	Control	Control	Control
Time fixed effects	Control	Control	Control
Observation value	360	390	360
R^2	—	0.914	0.920

Note: ***, **, and * indicate that the variables are significant at the 1%, 5%, and 10% levels, respectively, with t-values in parentheses.

TABLE 7. Mediation Effect Test.

Variable	(1) TI	(2) TI	(3) TC	(4) TC
TF	7.606^{***} (16.194)	1.760^{***} (6.434)	0.418^{***} (7.091)	0.399^{***} (7.543)
FD	—	-3.140^{***} (-2.733)	—	-0.617^{***} (-2.929)
ML	—	0.240^{***} (8.898)	—	-0.011^{**} (-2.154)
UL	—	0.825^{***} (3.122)	—	0.254^{***} (2.949)
SCL	—	0.136 (0.512)	—	-0.061 (-1.178)
FAL	—	0.709^{***} (11.393)	—	-0.029^{***} (-3.646)
PD	—	0.679^{***} (8.541)	—	0.022^{**} (2.168)
IL	—	0.363 (0.383)	—	-0.444^{***} (-3.481)
ITS	—	0.443^{***} (3.585)	—	-0.070^{***} (-3.843)
Individual fixed effects	Control	Control	Control	Control
Time fixed effects	Control	Control	Control	Control
Observation value	390	390	390	390
R^2	0.558	0.941	0.423	0.786
Bootstrap 95% CI, indirect effect	$[-0.442, -0.008]$		$[0.012, 0.118]$	
Bootstrap 95% CI, direct effect	$[0.707, 0.906]$		$[0.603, 0.839]$	

Note: ***, **, and * indicate that the variables are significant at the 1%, 5%, and 10% levels, respectively, with t-values in parentheses.

Subsequent analysis will employ a single-threshold model. The threshold estimates in Figures 1, 2, and 3 align with Table 8, providing intuitive confirmation of the threshold effect's existence and the accuracy of estimation results, thereby offering dual support for the research conclusions.

TABLE 8. Threshold Existence Test.

Threshold variable	Threshold number	F-statistic	P-value	BS count	Critical value 10%	5%	1%	Threshold value
PP	Single	50.770	0.026	500	29.321	38.884	67.459	0.028
	Double	70.770	0.002	500	30.874	39.376	59.393	0.029
	Triple	31.960	0.164	500	37.837	47.074	70.185	—
ISU	Single	90.830	0.002	500	26.155	32.996	62.140	0.140
	Double	40.430	0.034	500	24.063	32.938	52.912	0.180
	Triple	11.610	0.520	500	44.290	59.820	126.210	—
HC	Single	91.110	0.000	500	34.978	40.650	65.451	0.028
	Double	23.020	0.332	500	45.176	60.705	96.692	—
	Triple	19.200	0.624	500	54.131	72.546	110.032	—

Table 9 presents the results of the threshold effect test. Column (1) displays the regression results with the degree of patent protection as the threshold variable. The findings indicate that when the degree of patent protection crosses the first threshold value of 0.028, the coefficient of the impact of technology finance on new-quality productive forces increases from 0.883 to 0.991. When patent protection exceeds the second threshold of 0.029, the coefficient of technology finance's impact on new-quality productive forces adjusts again and stabilizes at 0.959. This clearly demonstrates that enhanced patent protection strengthens the enabling effect of technology finance on new-quality productive forces.

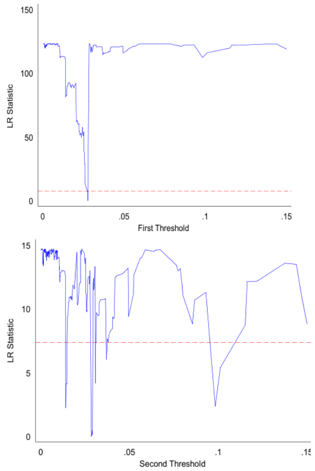

Fig1. Patent Protection Threshold LR Graph.

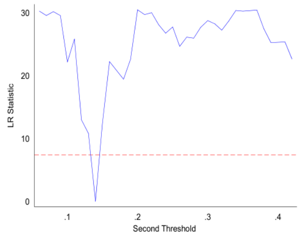

Fig2. Industrial Structure Broussonetia Papyrifera Upgrade Threshold Value LR Graph.

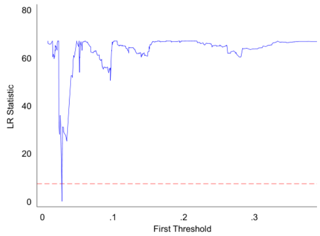

Fig3. Homo Sapiens Human Capital Threshold Value LR

The potential reasons can be explained in three phases: Phase One: Low Protection Level Period. During this stage, intellectual property protection is weak, making it easy for technology companies' innovations to be infringed upon. They struggle to secure exclusive returns, face difficulties recovering R&D costs, and achieve only meager profits. This significantly dampens technology companies' willingness to leverage technology finance for innovation, limiting its promotional effect on new-quality productive forces, with an impact coefficient of only 0.883. Second stage: Enhanced Protection Period. Governments intensify crackdowns on infringement and refine patent systems, significantly strengthening safeguards for innovations. Tech firms anticipate higher returns and are willing to increase innovation investments through fin-tech, channeling more resources into the tech sector. This boosts innovation and productivity, driving new-quality productive forces development, with the impact coefficient rising to 0.991. Phase Three: High-Level Protection Period: The market develops a standardized innovation ecosystem, boosting financial institutions' confidence in technology enterprises and increasing their willingness to provide funding support, thereby promoting financial clustering. Reduced innovation risks allow enterprises to engage in long-term innovation activities with greater stability, attracting high-quality resources that are optimally allocated. The combined effect of these factors enables financial clustering to efficiently enhance new-quality productive forces, with the coefficient stabilizing at 0.959.

Table 9 Column (2) presents the regression results with industrial structure upgrading as the threshold variable. When the industrial structure upgrading level is below 0.140, the coefficient of technology finance's impact on new quality productive forces is 0.670. When the industrial structure level falls between the first threshold of 0.140 and the second threshold of 0.180, the coefficient increases to 0.766. This indicates that industrial structure upgrading significantly enhances the role of technology finance in boosting new quality productive forces. The potential reasons unfold in three stages: Stage One: Primary Phase The industrial structure is dominated by traditional industries, which feature low technological content, weak innovation demand, and limited capacity to absorb technology-based financial resources. With intense market competition and narrow profit margins, enterprises lack incentives for innovation investment. Consequently, the coefficient of technology-based finance's impact on new-quality productive forces is only 0.670, failing to fully leverage its potential. Second stage: Transformation phase. Emerging industries and high-tech sectors emerge, characterized by technology-intensive operations and active innovation, creating strong demand for technology finance. Technology finance provides capital support, driving technological innovation and industrial scaling, enhancing supply chain sophistication, and optimizing resource allocation. The impact coefficient increases to 0.766, signaling the emergence of its promotional effect. Third stage: Advanced phase. Emerging industries and high-tech sectors become dominant, traditional industries undergo upgrading, and the industrial system evolves into a collaborative innovation framework. Technology finance delivers diversified, personalized services that deepen industry-academia-research integration, accelerate the commercialization of scientific achievements, attract high-end talent and quality capital, and optimize the innovation ecosystem. This

TABLE 9. Threshold Effect Test.

Variable	New Quality Productivity		
	PP	ISU	HC
$TF \times G(E_{it} \leq q_1)$	0.883^{***} (0.066)	—	—
$TF \times G(q_1 < E_{it} \leq q_2)$	0.991^{***} (0.061)	—	—
$TF \times G(E_{it} > q_2)$	0.959^{***} (0.055)	—	—
$TF \times G(E_{it} \leq q_1)$	—	0.670^{***} (0.074)	—
$TF \times G(q_1 < E_{it} \leq q_2)$	—	0.766^{***} (0.061)	—
$TF \times G(E_{it} > q_2)$	—	0.907^{***} (0.057)	—
$TF \times G(E_{it} \leq q_1)$	—	—	1.008^{***} (0.063)
$TF \times G(E_{it} > q_1)$	—	—	0.857^{***} (0.053)
FD	0.141 (0.091)	0.168 (0.107)	0.189^{*} (0.099)
ML	-0.004^{*} (0.002)	-0.006^{**} (0.002)	-0.002 (0.002)
UL	-0.055 (0.037)	-0.055 (0.036)	-0.058 (0.038)
SCL	-0.075 (0.052)	-0.075^{*} (0.042)	-0.053 (0.040)
FAL	0.156^{***} (0.049)	-0.009 (0.006)	-0.017^{**} (0.007)
PD	-0.005 (0.014)	0.237^{*} (0.120)	0.205 (0.148)
IL	0.141 (0.091)	0.147^{***} (0.047)	0.125^{**} (0.048)
ITS	-0.004^{*} (0.002)	-0.007 (0.017)	-0.006 (0.014)
Constant	-0.494^{*} (0.258)	-0.366 (0.246)	-0.268 (0.307)
Observed value	390	390	390
R^2	0.931	0.944	0.941

Note: ***, **, and * indicate that the variables are significant at the 1%, 5%, and 10% levels, respectively, with standard errors in parentheses.

further enhances its role in elevating new productive forces.

Table 9 column (3) presents regression results with human capital as the threshold variable. When human capital falls below the threshold value of 0.028, the coefficient of technological finance's impact on new-quality productive forces is 1.008. When human capital exceeds the threshold value of 0.028, the coefficient drops to 0.857, lower than 1.008. This indicates that beyond the threshold level of human capital, the importance of technology finance to new-type productive forces diminishes.

The potential reasons unfold in two stages: Stage One: Weak Human Capital Phase During this phase, overall human capital levels are inadequate, and high-quality talent is scarce. Technology finance becomes a key driver for advancing new-type productive forces. Its capital investments primarily flow into introducing external advanced technologies, acquiring equipment, and attracting external specialized talent teams. This compensates for local human capital deficiencies, propelling the development of new-type productive forces with an impact coefficient of 1.008, demonstrating a highly prominent supporting role. Second stage: Sufficient human capital phase. Once human capital surpasses this threshold, its quantity increases significantly. In the field of technological innovation, ample human capital begins to play a dominant role, enabling autonomous high-level innovation activities and reducing reliance on external technology and talent. Simultaneously, it enhances the allocation and utilization efficiency of technology finance resources. Although technology finance continues to promote the development of new-quality productive forces, its importance diminishes, with the impact coefficient dropping to 0.857.

B. FINANCIAL DEVELOPMENT PARAZACCO SPILURUS SUBSP. SPILURUS QUALITATIVE TEST

(1) Marketization Level Parazacco Spilurus Subsp. Spilurus Qualitative Test

From the perspective of complex systems and network robustness, regional marketization disparities lead to heterogeneous differentiation in financial resource allocation and innovation system efficiency[63-65]. Marketization levels provide institutional safeguards for developing new productive forces by optimizing financial resource allocation, stimulating innovation actors' vitality, and promoting deep integration between science, technology, and industry. Drawing on existing research[59], this study utilizes data from the China Provincial Marketization Index Report to divide the sample into high-marketization (HML)and low-marketization(LML) groups based on the median. Grouped regression results are presented in Table 10, columns (1) and (2). The regression coefficient for technology finance in the high-market-level group is 1.110, while that in the low-market-level group is 0.741. Both coefficients are statistically significant at the 1% level, and the P-value for the inter-group coefficient difference test is significant at the 1% level. This indicates that the driving effect of technology finance is stronger in regions with higher marketization levels. The underlying mechanism is as follows: In highly marketized regions, robust financial infrastructure enables efficient aggregation of technology finance resources toward innovation entities, fostering a virtuous cycle of "capital-technology-industry." Market competition compels financial institutions to serve innovation,

accelerating the influx of high-end talent and the commercialization of research outcomes. Conversely, low marketization regions suffer from excessive administrative intervention, constrained financing channels, weak property rights protection, and information asymmetry. These factors elevate financial transaction costs and suppress the innovation-supporting efficiency of technology finance.

(2) Financial Development Parazacco Spilurus Subsp. Spilurus Qualitative Test

The financial system exhibits typical characteristics of a complex network, where its structural stability and service capacity directly determine the coordination and innovation efficiency of the economic system[63-65]. As the core of the modern economy, the level of financial development directly impacts the resource supply for technology finance and the cultivation of new productive forces. Drawing on existing research[59], this study measures financial development using the ratio of financial institutions' deposit and loan balances to GDP. Regressions are conducted by dividing regions into high financial development (HTD) and low financial development (LTD) groups based on the median, with results presented in Table 10, columns (3) and (4). The regression coefficients for the high financial development group are significantly higher than those for the low group, with a P-value of 0.000 for the inter-group coefficient difference test. This indicates that the driving effect of technology finance is more pronounced in financially developed regions. The reasons are as follows: Regions with high financial development possess mature financial systems and multi-tiered capital markets, with well-established specialized institutions such as venture capital firms and technology-focused branches. These can precisely match the "asset-light, high-risk" characteristics of technology enterprises, forming a full-chain financial support system encompassing debt, equity, and insurance to accelerate technology commercialization. In contrast, regions with low financial development rely primarily on traditional credit, which depends on collateral and financial metrics, leading to significant capital misallocation. Compounded by inadequate technology finance policies and insufficient participation from social capital, these areas are prone to falling into a vicious cycle of "financial repression and innovation lag."

TABLE 10. Qualitative Test of Parazacco Spilurus Subsp. Spilurus.

Variable	(1) HML	(2) LML	(3) HTD	(4) LTD
TF	1.110^{***}	0.741^{***}	1.149^{***}	0.716^{***}
	(9.545)	(8.325)	(7.991)	(5.700)
FD	-0.013	-0.239	-0.032	0.425
	(-0.083)	(-0.878)	(-0.205)	(0.922)
ML	-0.008	0.000	-0.004	-0.003
	(-1.616)	(0.033)	(-0.917)	(-0.724)
UL	-0.149	-0.169^{***}	0.007	-0.118
	(-1.175)	(-4.411)	(0.234)	(-0.535)
SCL	0.041	-0.052^{*}	-0.066	-0.040
	(0.602)	(-1.956)	(-0.854)	(-0.821)
FAL	-0.023^{*}	-0.003	-0.008	-0.047
	(-1.812)	(-0.459)	(-0.850)	(-1.471)
PD	0.080	0.890^{***}	-0.135	1.154^{**}
	(0.446)	(3.928)	(-0.546)	(2.813)
IL	0.175	0.180^{**}	0.238^{***}	0.184^{*}
	(1.621)	(2.122)	(3.461)	(2.025)
ITS	0.004	-0.077^{***}	-0.007	0.011
	(0.160)	(-2.856)	(-0.562)	(0.516)
Individual fixed effects	Control	Control	Control	Control
Time fixed effects	Control	Control	Control	Control
Intergroup coefficient difference test P-value	$\leq 0.001^{***}$		$\leq 0.001^{***}$	
N	195	195	195	195
R^2	0.972	0.965	0.977	0.953

Note: ***, **, and * indicate that the variables are significant at the 1%, 5%, and 10% levels, respectively, with t-values in parentheses.

VI. CONCLUSION AND COUNTERMEASURES

A. CONCLUSION

This study employs provincial-level panel data from China covering the period 2011–2023 to assess the development levels of technology finance and new-type productive forces. By applying panel fixed-effects models, mediation effect models, and threshold effect models, it empirically examines the efficacy and impact mechanisms of technology finance on new-type productive forces, yielding the following conclusions:

(1) Technology-driven finance plays a significant role in promoting new-quality productive forces, and its core conclusions remain valid after undergoing a series of stability and endogeneity tests.

(2) Technology-driven finance promotes the development of new productive forces by enhancing technological innovation and talent aggregation, with technological innovation and talent aggregation serving as intermediary factors in this process.

(3) In the process of fin-tech promoting new-quality productive forces, the degree of patent protection and industrial structure upgrading exert a moderating effect through a dual-threshold mechanism, accelerating the incremental marginal contribution of fin-tech to new-quality productive forces as thresholds are raised. Meanwhile, human capital exerts a moderating effect through a single-threshold mechanism, causing the marginal contribution of fin-tech to new-quality productive forces to gradually diminish once threshold values are exceeded.

(4) The impact of fin-tech on new-quality productive forces exhibits heterogeneity, meaning that fin-tech exerts a more pronounced promotional effect on groups with high levels of

industrial agglomeration and financial development, while its influence is relatively weaker on groups with low levels of industrial agglomeration and financial development.

B. COUNTERMEASURES

First, strengthen policy support to solidify the foundation for the development of technology finance.

① Establish a tiered and categorized policy support system: Tailor measures to the different stages and scales of technology enterprises. For startups, increase loan interest subsidies to reduce costs; for growth-stage companies, establish risk compensation funds to promote lending; for mature enterprises, offer tax incentives to encourage R&D and expansion. Simultaneously, encourage financial institutions to innovate financial products and services, broadening financing channels to meet diverse needs.

② Optimize the technology finance ecosystem: Strengthen financial infrastructure and improve corporate credit evaluation systems to reduce information asymmetry; enhance regulations to standardize markets and protect rights; reinforce regulatory coordination to prevent arbitrage and duplicate oversight, thereby fostering a favorable policy and market environment.

Second, focus on key areas to enhance the effectiveness of technology-driven financial services.

① Increase support for technological innovation: Establish special funds to support R&D in key core and cutting-edge technologies, guide financial institutions to expand credit allocation and establish risk compensation mechanisms, and encourage them to form long-term partnerships with technology enterprises to provide full-cycle financial services.

② Strengthen talent aggregation and cultivation safeguards: Develop talent attraction policies offering preferential incentives to gather high-level professionals; enhance local talent development by introducing relevant specialized courses in universities and research institutions; establish evaluation and incentive mechanisms to reward individuals with outstanding contributions.

Third, manage regulatory variables to dynamically adapt to developmental stage requirements.

① Strengthen patent protection and industrial upgrading in phases: Implement region-specific policies based on patent protection intensity—enhance enforcement, increase penalties, and improve rights protection mechanisms in low-intensity areas; explore innovative business models to realize patent value in high-intensity regions. Simultaneously, formulate differentiated policies according to industrial structure characteristics to guide the concentration of technology-finance resources and drive industrial upgrading.

② Rationally regulate human capital investment: Guide regional planning based on human capital levels. In low-level regions, increase investment in basic education; in high-level regions,

cultivate high-level, multidisciplinary talent. Strengthen cooperation between enterprises and universities to promote talent mobility and optimize allocation.

Fourth, pay attention to regional differences and implement differentiated support strategies.

① Increase policy inclination towards backward regions: Given the heterogeneity of the impact of science and technology finance, for regions with low levels of marketization and financial development, the government should increase support, formulate specific policies, set up special funds to guide credit allocation, and strengthen park construction to promote industrial agglomeration.

② Promote the coordinated development of science and technology finance among regions: Strengthen regional cooperation and exchanges, establish cooperation mechanisms, encourage paired assistance and sharing of resources and experiences, promote market interconnection and cross-regional capital flow, and narrow the gap in new quality productivity among regions.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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