Research on the impact of technology finance on the manufacturing industry in the Yangtze River Delta region

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Abstract. A comprehensive evaluation index system for the integrated advancement of finance in science and technology, alongside the manufacturing sector, has been established. Furthermore, the entropy weight approach has been employed to assess both the development indicators of technology-driven finance and the integration metrics of the manufacturing industry across the three provinces and one municipality within the Yangtze River Delta region from 2012 to 2021. This study employs the fixed effects model to analyze the influence of science and technology financing on the integrated development of the manufacturing industry in this region, and it further examines the role of production costs and innovation capabilities in the relationship between technology financing and manufacturing integration. Research has shown that science and technology finance significantly enhances the integrated development of the manufacturing industry in the Yangtze River Delta, with production costs and innovation capabilities acting as intermediary factors. However, in the high-level areas of manufacturing integration development, the mediating effect of production cost and innovation ability is not significant.

Keywords: Yangtze River Delta; technology Finance; manufacturing; integrated development; mediating effect.

1. Introduction

In 2022, the combined resident population of the Yangtze River Delta region reached 236.959 million, accounting for 16.7% of the country's total population. Additionally, the gross national product of the region amounted to 29.03 trillion yuan, representing approximately 24% of the national GDP.It has built nearly 500 colleges and universities and a large number of scientific research institutes. It has accumulated a huge amount of manufacturing and strategic emerging industries. It is the "engine" and important growth pole of national economic development. In 2018, in order to better promote the sustained and rapid economic development of the region, the Party Central Committee and the State Council put forward the implementation of the national strategy of "integrated development of the Yangtze River Delta", and continuously increased support for the integrated development of this region. Up to now, a series of major achievements have been made, and a new situation of integrated development of the Yangtze River Delta has been initially formed. In recent years, China has continuously issued policy documents regarding science and technology finance and is committed to building a financial powerhouse. At the end of October 2023, the Central Financial Work Conference placed science and technology finance at the forefront of the "five major articles" fully reflecting China's emphasis on the development of science and technology finance and highlighting the crucial role it plays in promoting economic transformation. Understanding how to effectively utilize science and technology finance is crucial for promoting the high-quality integrated development of the manufacturing industry. It is also essential to clarify the impact mechanism of science and technology finance on the manufacturing sector, as well as to delineate the relationship between the two. This understanding holds significant theoretical and practical value for China's economic development and the advancement of the manufacturing industry.

2. Literature Review

The concept of technology finance was first proposed by Schumpete [1]. He asserts that science and technology finance is an amalgamation of scientific and technological innovation coupled with

financial elements. Later, it was introduced into China by Liu Xunyang and other scholars. They studied science and technology finance through the index of R & D expenditure, which provided research ideas for domestic scholars [2]. Zhao Changwen's conception of science and technology finance has garnered wide acceptance among scholars in China. According to him, it encompasses a suite of financial tools, systems, policies, and services geared towards fostering the progress of scientific and technological innovation [3]. Since then, many scholars have measured the development level of China's science and technology finance. Zhang Yuxi and other scholars combined with ecological theory to construct an evaluation index system of science and technology finance ecosystem from two dimensions of community subsystem and environmental subsystem [4]. Xu and other scholars constructed the evaluation index system of sci-tech finance from sci-tech financial resources, sci-tech financial input and sci-tech financial output [5].

Tinbergen is widely acknowledged as the pioneer who first introduced the concept of "economic integration" in academic discourse. Tinbergen's view posits that economic integration entails the process wherein various regional actors coordinate and act in unison to establish the most advantageous economic structure [6]. Curson believes that the integration process is manifested in the re-integration and optimal allocation of production factors among various economic entities, and the state of integration is the most idealized allocation of production factors within these economic entities [7]. From a review of existing literature, it becomes evident that a number of scholars' research on industrial integration mainly focuses on industrial chain integration, industrial cluster effect and global value chain division. China's scholars focus on the specific practice and policy guidance of industrial integration in China's advancement in economic and social realms, such as industrial restructuring, regional coordinated development and other issues. Liu Zhibiao and other scholars summarized the evaluation index system of the integration of the Yangtze River Delta from 10 dimensions such as industry, innovation, information and market, and analyzed the current situation of the integration process of the region [8]. Feng Yanwei and other scholars have developed an evaluation index system for analyzing industrial integration, considering three main aspects: spatial layout, elemental flow, and developmental outcomes. They have also conducted a thorough examination of the evolutionary traits exhibited by industrial integration over time [9]. Zhao Hui constructed the evaluation index system of industrial integration development in the region from five dimensions: development foundation, development momentum, development performance, social welfare and green development [10].

Finance in science and technology holds a pivotal role in facilitating the integration of manufacturing processes. It precisely steers capital towards high-technology and high-value-added sectors by employing innovative financial instruments and services, thereby fostering a deeper integration across the upstream and downstream segments of the industrial chain. Liu Jianing's research revealed that science and technology finance significantly contributes to industrial transformation and upgrading. Furthermore, a well-coordinated development in this realm expands the industrial chain, thereby facilitating advancements in industrial integration [11].

Through a synthesis of pertinent literature, it emerges that the majority of scholarly work centers on examining the influence of science and technology financial policies and capital availability on the integration of the manufacturing sector. However, scant research exists delving into the pathways and mechanisms through which science and technology finance shapes the integration of the manufacturing industry. Therefore, this paper develops an intermediary effect model to meticulously explore the underlying transmission dynamics by which science and technology finance propels the cohesive growth of the manufacturing sector.

3. Research Design

3.1. Influence Mechanism

Through deep penetration and innovation of traditional financial service mode, science and technology finance plays the role of catalyst in the manufacturing industry. By applying cutting-edge

technology to reduce production costs and effectively integrate the industrial chain, it can effectively drive the integration process of manufacturing industry. In addition, the new financing model based on science and technology finance provides manufacturing enterprises, especially innovative small and medium-sized enterprises, with lower cost and more efficient financing channels, so that they can obtain sufficient financial support in R & D investment and technological innovation, thereby shortening product iteration cycle, reducing unit output cost, promoting technological progress and resource integration within the entire manufacturing system, and finally achieving the strategic goal of manufacturing integration.

Science and technology finance has built a powerful financial support system for the improvement of manufacturing innovation ability by deepening the collaborative innovation mechanism of industrial chain. Central to this process, the pivotal role of science and technology finance lies in dismantling informational silos within the industrial chain, consolidating a variety of financial resources, and precisely channelling these resources into the pivotal innovation stages of the manufacturing sector. This facilitation encourages intimate collaboration amongst enterprises across the entire industrial spectrum, collaboratively driving advancements in industrial technology and the refinement of the industrial structure. In a word, science and technology finance effectively connects financial capital and manufacturing innovation activities through the way of collaborative innovation of industrial chain. By optimizing capital allocation, promoting knowledge and technology exchange, and dynamically adjusting innovation orientation, it effectively improves the independent innovation ability of manufacturing industry.

3.2. Variable Selection

3.2.1. Explanatory Variables

Drawing upon the research insights of pertinent scholars, this paper establishes an assessment index framework for science and technology finance across three dimensions: resource endowment, input magnitude, and output performance. The "Resources" dimension centers on the capacity of science and technology finance to attract and distribute a multitude of components, such as financial capital, human capital, and informational resources. This aspect underscores the fundamental sustenance it provides in fueling advancements in science and technology, thereby serving as a cornerstone for innovation. The "Investment" dimension assesses the efficacy of science and technology finance's incentive mechanisms and its impetus for scientific and technological innovation. This is accomplished by quantifying inputs in terms of fiscal spending, R & D investments, among other key areas, thereby gauging the direct facilitation of innovative endeavors. The " Production" dimension, as it seems you intended to refer to, emphasizes the assessment of the economic and societal gains derived from science and technology financial activities. This focus allows for the illustration of the tangible contributions made by these activities towards fostering economic expansion and societal advancement. Consequently, initiating the evaluation from the three facets of resources, investment, and output adheres to a systematic and comprehensive appraisal methodology. This approach is pivotal in precisely quantifying and assessing the operational effectiveness, efficiency in resource allocation, and the real impact of science and technology financial activities on fostering scientific and technological innovation alongside economic growth. A detailed representation of the metric index system for evaluating the maturity of the digital economy is illustrated in Table 1.

Table 1. Technology finance evaluation system

First grade index	Second index	Index explanation
Resource	Science and technology human resources	R & D personnel full-time equivalent / total population of the region
	Financial human resources	Financial industry practitioners / total population of the region
	The scale of securities market financing	Total stock market value / regional GDP
	Size of listed companies	Number of listed companies
Investment	Financial allocation intensity	Financial technology appropriation / fiscal expenditure
	Intensity of education funding	Education expenditure / fiscal expenditure
	Science and technology funds strength	R & D expenditure / regional GDP
Production	Technology market turnover rate	Technology market transaction contract amount / R & D expenditure
	Patent output rate	Patent application authorization / R & D expenditure
	Export output rate	High-tech industry export / R & D expenditure
	Output rate of financial institutions	Banking financial institutions loans / banking financial institutions deposits

3.2.2. Explained Variable

Building upon the extensive research conducted by numerous experts and scholars, this paper distills a comprehensive logical framework for the integrated advancement of the manufacturing industry in the Yangtze River Delta region across six dimensions: innovation, talent cultivation, environmental sustainability, digitalization, spatial organization, and industrial integration. This holistic approach aims to assess the overall development quality and the efficacy of transformation and upgrading within the manufacturing sector through a multifaceted and layered lens. The “innovation” dimension focuses on technology research and development, product innovation and model innovation to measure the ability and potential of manufacturing innovation-driven development. The “talent” dimension emphasizes human resource development and high-level talent training, and measures the intellectual support and continuous innovation ability of manufacturing development. The “green” dimension focuses on the environmental friendliness and sustainable development of the manufacturing industry, reflecting the green development level of the manufacturing industry. The “information” dimension focuses on the process of informatization and digitization, and evaluates the integration degree of information technology application and intelligent manufacturing in manufacturing industry. The "space" dimension zeroes in on the regional transportation infrastructure and arrangements, serving as a gauge for evaluating the efficiency of spatial organization and the degree of coordinated development within the manufacturing industry across different locales. The "industry" dimension concentrates on the refinement and elevation of the industrial structure, thereby providing a basis for judging the core competitiveness and the adaptive resilience embedded within the manufacturing sector's growth trajectory. The specific indicators are shown in Table 2.

Table 2. The evaluation system of manufacturing integration

First grade index	Second index	Index explanation
Innovation integration	R & D investment	R & D expenditure
	New product development investment	Funding for the development of new products
	R & D output	Number of R & D projects
	Patent output	Number of patent authorizations
	Technical contribution	Technology market turnover
Talent integration	Talent input intensity	Number of R & D personnel / Urban employment
	Manufacturing practitioners	The number of employed persons in manufacturing urban units / employed persons in urban areas
	Treatment of manufacturing personnel	Average wage of manufacturing industry
Green integration	Industrial solid waste emissions	Industrial solid waste production / GDP
	Sulfur dioxide emissions	Industrial sulfur dioxide production / GDP
	Industrial wastewater discharge	Industrial wastewater discharge / GDP
Information integration	Internet	Number of Internet broadband access ports
	Web pages	Number of web pages
	Mobile phones	Mobile phone penetration rate
	Domain name	Number of domain names
Spatial integration	Railway network	Railway operating mileage / Regional area
	Road network	Highway mileage / Regional area
	Waterway network	Inland waterway mileage / Regional area
Integration of industrial structure	Rationalization of industrial structure	TL index
	Industrial isomorphism degree	Relative specialization index in the region

3.2.3. Mediator Variable

From the preceding theoretical examination, we gather that science and technology finance operates through dual channels to facilitate the integration of the manufacturing sector. Firstly, by directly impacting production costs: it achieves this through lowering financing expenses for firms and facilitating the adoption of cutting-edge technologies. Reduced production costs enhance corporate competitiveness, fostering closer collaboration and synchronization within the manufacturing industry, thereby accelerating integration. Secondly, science and technology finance stimulates research and development and the commercialization of innovations, augmenting firms' innovative capacities. This hastens industrial upgrading and fosters tighter linkages between different tiers of the supply chain, leading to a more profound integration of manufacturing processes. Collectively, these mechanisms demonstrate how science and technology finance is instrumental in not only optimizing cost structures but also in nurturing a dynamic ecosystem of innovation and technological progress within the manufacturing sector. Therefore, the selection of production cost and innovation capability as mediating variables helps to reveal how technology finance indirectly affects the internal mechanism of manufacturing integration by improving manufacturing operation efficiency and technological innovation level.

3.2.4. Control Variable

In order to reduce the deviation of the model results caused by some missing variables, based on the research results of other experts and scholars, the relevant indicators of government intervention, foreign investment and fixed asset investment are selected as control variables. Among them, government intervention reflects the impact of policy regulation on resource allocation, which may directly affect the operation effect of science and technology finance in manufacturing industry. Foreign investment contains technology transfer and management experience input, and promotes the upgrading of manufacturing industry together with science and technology finance. Fixed asset investment serves as an indicator of the magnitude of infrastructure development and technological upgrades within the real economy. It potentially exhibits a synergistic or collinear effect alongside science and technology finance in propelling the integration of the manufacturing industry.

3.3. Model Construction

3.3.1. Data Definition

The presentation and elucidation of pertinent variables are outlined in Table 3.

Table 3. Data definition

Variable type	Variable name	Variable symbol	Variable definition
Explained variable	The integrated development level of manufacturing industry	MI	Weighted calculation of entropy weight method
Explanatory variables	Science and Technology Finance Composite Index	TF	Weighted calculation of entropy weight method
Mediator variable	Production cost	COST	The main business cost of manufacturing enterprises
	Innovation ability	TEC	Number of Patent Applications
Control variable	The degree of government intervention	GOV	Fiscal Expenditure / GDP
	The level of foreign investment	FDI	Foreign direct investment / GDP
	The level of investment in fixed assets	INV	Investment in fixed assets / GDP

3.3.2. Construction of mediating effect model

This study is inspired by the scholarly concepts put forth by Wen Zhonglin, employing a sequential testing approach to examine the mediating influence [12].

$$MI_{it} = e_1 + aTF_{it} + \beta_1 GOV_{it} + \beta_2 FDI_{it} + \beta_3 INV_{it} + \varepsilon_{it} \quad (1)$$

$$M_{it} = e_2 + bTF_{it} + \gamma_1 GOV_{it} + \gamma_2 FDI_{it} + \gamma_3 INV_{it} + \epsilon_{it} \quad (2)$$

$$MI_{it} = e_3 + cM_{it} + dTF_{it} + \delta_1 GOV_{it} + \delta_2 FDI_{it} + \delta_3 INV_{it} + \theta_{it} \quad (3)$$

In the aforementioned model, formula (1) represents the comprehensive influence of science and technology finance on manufacturing integration, while formula (2) depicts the impact of science and technology finance on intermediary variables such as production cost and innovation capability. Additionally, formula (3) outlines the intermediary mechanism in which science and technology finance affects manufacturing integration. Among them, a, b, c and d represent the coefficient parameters in each equation. Symbols β_1, β_2, β_3, γ_1, γ_2, γ_3, δ_1, δ_2, δ_3 correspond to the estimated coefficients of the three control variables in each equation. Symbols ε_{it}, ϵ_{it}, θ_{it} represent the random disturbance terms of each equation. Symbols e_1, e_2, e_3 represent the intercept terms of each equation. In addition, i denotes the regions in the Yangtze River Delta region, and t denotes the year.

4. The empirical results

The detailed results of the specific regression analysis have been presented in Table 4.

Table 4. Mediating effect test

Variable name	(1) MI	Production cost (2) COST	(3) MI	Innovation ability (4) TEC	(5) MI
COST			-0.079*** (-4.530)		
TEC					0.052*** (6.524)
TF	1.340*** (13.164)	-5.378*** (-6.585)	0.917*** (7.448)	12.170*** (8.127)	0.710*** (6.047)
GOV	0.821** (2.424)	-0.230 (-0.085)	0.803*** (3.008)	6.796 (1.364)	0.470** (2.044)
FDI	-5.291*** (-5.011)	37.936*** (4.478)	-2.307** (-2.174)	-32.809** (-2.112)	-3.595*** (-4.837)
INV	0.116 (0.959)	-1.084 (-1.117)	0.031 (0.316)	2.150 (1.209)	0.005 (0.058)
Constant	-0.169* (-1.780)	11.430*** (15.007)	0.730*** (3.442)	-2.702* (-1.935)	-0.029 (-0.442)
R^2	0.916	0.795	0.950	0.781	0.965
F value	87.455	31.043	116.753	28.613	169.358
Mediating effect	/	Mediating effect = 0.4248 Mediating effect / Gross effect = 31.71%		Mediating effect = 0.6328 Mediating effect / Gross effect = 47.23%	

4.1. Basic regression analysis

As evident from Column (1) in Table 4, the goodness of fit (R^2) of the aforementioned fixed effect model stands at 0.916, which indicates that the variable set in the model has a high explanatory power for the variability of the explained variable. Specifically, the model explains 91.6% of the total change in the explained variable. The estimated coefficient of the comprehensive index of science and technology finance is 1.340, the t value is 13.164. The meaning is that when other variables remain unchanged, for every additional unit of explanatory variables, the level of explained variable will increase by 1.34 units.

The examination of control variables reveals that both the extent of government intervention and the level of fixed asset investment exert positive influences on the integration process within the manufacturing industry, but the estimated level of foreign investment is negative, indicating that foreign investment has a significant inhibitory effect on the integration of the manufacturing industry. The reason for this phenomenon may be that foreign-invested enterprises may choose to retain some high value-added links in the industrial chain in their home countries, while in China, only labor-intensive links such as production and assembly are arranged. At the same time, foreign investment tends to gather in economically developed areas such as the eastern coast, resulting in uneven distribution of resources among regions. This segmented layout is not conducive to the integrated development of upstream and downstream manufacturing. To this end, the government needs to formulate reasonable investment policies, encourage technology transfer and independent innovation, and guide foreign investment to actively participate in and support the development of the entire manufacturing chain.

4.2. Mediating effect test

4.2.1. Production cost

Column (1) in Table 4 is the total effect of the mediating effect model, and columns (2) and (3) are to test the mediating effect when the mediating variable is the production cost. According to the results shown in table 5, we can know that a = 1.340, b = -5.378, c = -0.079, d = 0.917, and they are significant. Therefore, it can be inferred that the significance of some intermediary effects has been verified when the manufacturing production cost acts as an intermediary variable. From column (2), it is evident that the coefficient of explanatory variables is negative, signifying that the development of science and technology finance can substantially reduce the production cost in the manufacturing industry. It can be seen from Column (3) that the coefficient of manufacturing production cost is negative, which means that the reduction of manufacturing production cost can significantly promote the development of manufacturing integration. The mediating effect of this model is b * c = 0.4248, and the ratio of the mediating effect of this part to the total effect is b * c / a = 31.71%, indicating that the mediating effect of manufacturing production cost is low.

4.2.2. Innovation ability

Columns (3) and (4) in Table 4 are the mediating effects when testing innovation ability as a mediating variable. According to the results shown in table 5, we can know that a = 1.340, b = 12.170, c = 0.052, d = 0.710. Therefore, it can be inferred that the significance of the partial mediating effect is verified when the innovation ability acts as an intermediary variable. From column (4), we can see that the coefficient of explanatory variables is positive, which indicates that the development of science and technology finance can significantly improve the innovation of manufacturing industry. From column (5), it can be seen that the influence of manufacturing innovation ability on the integrated development of manufacturing industry has a significant role in promoting, which means that the improvement of manufacturing innovation ability can effectively promote the development of manufacturing integration. The mediating effect of this model is b * c = 0.6328, and the ratio of the mediating effect of this part to the total effect is b * c / a = 47.23%, which is much larger than the production cost, indicating that the mediating effect of manufacturing innovation is higher.

5. Conclusions

Technology finance can significantly decrease production costs and enhance innovation capabilities within the manufacturing industry, thereby advancing the integration process of the industry. It is important to note that among these two influencing factors, the mediating effect of innovation ability is more significant than that of production cost, which also shows that innovation ability is one of the core factors in the process of manufacturing integration. However, for the high-level areas of manufacturing integration development, the intermediary effect test results of production cost and innovation ability are not significant.

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