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Research on the Influence of the Mechanism of Technology Convergence on China's Textile Industry Performance

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Abstract

Technology convergence (TC) can integrate new technologies, methods and processes into traditional industries. It can accelerate the transformation and upgrading of these industries, and is of great significance to their development. The purpose of our research is to reveal the impact of the mechanism of technology integration on the textile industry and conduct empirical research. This study firstly builds the linear and non-linear mechanism of the impact of TC on the development of China's textile industry. Empirical research is conducted based on the panel fixed effect model and panel threshold model. The results are as follows: (1) TC significantly contributes to the performance of China's textile industry, as endogenous convergence can significantly promote industrial performance, while the effect of exogenous convergence is insignificant; (2) TC has a double-threshold effect, with its coefficient being largest at a medium level; and (3) TC has an enterprise scale threshold, in which its effect indicates that only when the scale exceeds the threshold can TC more effectively foster industry performance. The significance of these results for the development of China's textile industry is that they strengthen the level of TC for it to be convergent with emerging industries, as well as increase the size and absorptive capacity of enterprises.

Key words: *technology convergence, industrial performance, endogenous convergence, exogenous convergence, threshold regression.*

Introduction

The textile industry is China's pillar industry, with international comparative advantages, and it is also a typical traditional industry. However, in recent years, China's textile industry has faced situations such as the rising cost of labour and raw materials, the implementation of domestic environmental protection policies, and the continuous rise of the textile industry in Southeast Asian countries due to their labour cost advantages. Therefore, Chinese policy makers realise that the textile industry must introduce a new round of technological change, and the industry's development must be driven by innovation.

Technology convergence (TC) cannot only give birth to emerging industries through fusion with emerging technologies but also incorporate traditional industries into modern production systems through fusion with emerging technologies, thereby promoting the transformation and upgrading of those industries [1, 2]. Studying the development of the textile industry from the perspective of TC is conducive to establishing new comparative advantages and achieving industrial transformation [3-5].

Furthermore, the convergence of emerging technologies and textile technologies is becoming an important direction of technological change in the world. Smart fibres, electronic clothing and chips in textile make the traditional textile industry become an emerging industry [6]. In 2016, the United States announced the establishment of the Revolutionary Fibre and Fabric Manufacturing Research Center (RFT MII) in the National Manufacturing Innovation Network (NNMI). Germany has established a national strategy called "futureTEX", which is closely integrated with the Industry 4.0 process to build a future development model for the traditional textile industry. Japan's high-tech fibre and high-end textile technology have obvious leading advantages.

Although there has been a lot of research on TC, there are still gaps in research content and research objects of TC. Hence, the contribution of this study lies in these two aspects. In terms of research content, the existing literature pays attention to the concept, measurement, structure and mode of TC [7-10]. While some studies point out that TC can promote industrial performance [9-11], there is little research on the mechanism of TC affecting industrial development. Only by understanding the impact mechanism of TC on industrial performance can sustainable development of the industry be promoted. From the perspective of the research object, the existing literature is mostly aimed at high-tech industries, such as the biochip industry and ICT industry [12-14]. But research on the TC of the textile industry is still relatively rare. Therefore,

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the research purpose of this paper is to resolve the following questions: What is the impact of the mechanism of technological integration on the performance of the textile industry? Is the impact of technological integration on the performance of the textile industry linear or non-linear, and is there a threshold? Are there differences in the effects of different technology integration modes on the performance of the textile industry?

This study analyses the linear and non-linear mechanism of TC with a view to icreasing the performance of textile industries, and conducts empirical research based on panel fixed effects and panel threshold models. The results show that TC contributes significantly to the performance of China's textile industry. Endogenous convergence can significantly promote industrial performance, but the effect of exogenous convergence is not significant. The results also show that TC has a double-threshold effect; the coefficient of TC is the largest at a medium level. At the same time, the effect of TC has an enterprise scale threshold, indicating that only when the scale exceeds the threshold can TC foster industry performance more effectively. The theoretical significance of this study is building linear and non-linear mechanisms of TC effects, and initially opening the black box of TC operation. The practical significance of this paper is that the government should deregulate industries, strengthen the R&D of common industrial technologies, and promote TC especially cross-industry.

The rest of the paper is arranged as follows. Literature Review and hypotheses in Section 2. Variables and models in Section 3. Results of empirical analysis in Section 4., and Discussion and conclusions in Section 5.

Literature review and research framework

Concept of TC

The concept of TC was originally proposed by Rosenberg (1963) [10], who studied the technological evolution of machinery manufacturing and discovered the technology convergence of mechanical instruments. Rosenberg believed that TC was caused by an adoption of general technology in industries with completely unrelated product functions and process. His research on the early evolution of the U.S. machine tool industry was the earliest research on technology convergence. Later, many authors defined TC from various perspectives, involving two general types. The first definition type does not limit the scope of convergence technology, and includes both intra-field TC and inter-field TC. In this case, TC is "the phenomenon of two or more different technologies penetrating and integrating with each other to form a new technology" (Ministry of International Trade and Industry, Japan, 1985). A combination of two or more existing technology elements with distinct functions produce an entirely new function [11]. On the other hand, the second definition type mainly refers to TC among various industries. Patel and Pavitt pointed out that TC not only refers to using the same technological process in different industrial sectors, but also includes making a specific technology to become the dominant technology in every industry [12]. TC results in changes in the relationship among industries or technology fields [13]. It is a process of gradually blurring the boundaries between different industries [9, 14].

This study defines TC as the cross-penetration among technologies, leading to a new systematic technological value; it includes technologies within the industry and those among various industries.

Evolution and pattern of TC

Current research on TC focuses on verification of phenomena, including the verification of TC's models, levels and evolution paths. Jae et al. applied Korean patent data and logistic models to study the diffusion patterns of technology convergence, and presented that the forms of cross-sectoral diffusion were more diverse [14]. Lee et al. (2007) took intelligent robotics as a case study on the mode and process of technology convergence [15]. Later, Lee et al. (2015) used ternary patent data to predict the modes of technology fusion by means of association rules and link prediction methods, and applied topic models to discover and predict emerging TC areas [16]. Li Yaya and Zhao Yulin (2016) proposed an analysis framework of patent fusion to examine the structure and degree of technology fusion in the biochip industry [17]. Liu Na (2018) concluded that the TC mode is primarily exploratory convergence and utilisation convergence [18]. Feng Ke et al. (2019) applied the convergence power analysis index and the community cluster analysis method to compare the evolutionary paths of the industrial equipment manufacturing industry, automotive industry and electronic information industry [19].

Impact of TC

Existing research on traditional competitive industries is mostly from the perspective of the global value chain, industrial transfer and agglomeration, and industrial structure. Gambardella and Torrisi (1998) inferred that TC has a positive effect on electronics industry performance [20]. Banker et al. (1998) proved that TC has a positive influence on the performance of American communications companies. Zhao Yulin and Li Yaya (2017) [22] presented that the degree of TC has a significant promotion effect on the biochip industry.

To sum up, from a research perspective, current TC research primarily focuses on micro-technology. Studies on TC development principles often consider typical technology as the research object. Meanwhile, few scholars have focused on the industrial level or on the TC of traditional industries or its effects. In terms of research content, current research principally focuses on cross-industry TC, while there are few studies that compare the convergence effects of intra-industry TC and cross-industry TC. Regarding research method, analyses of the TC structure and mode based on patent analysis are common, while there is inadequate empirical research based on the econometric methods studying what can be brought to enterprises or industries by various TC modes. Present empirical research often considers TC as a background force, as a variable that influences knowledge flow among companies or within organisations, or as the relationship between network resources and market access amid integration. Relatively, TC has not been considered as a core independent variable.

As such, this paper aims to explore the effects and mechanisms of TC on the performance of China's textile industry. Specifically, it raises the following questions: Does TC have an impact on the performance of China's textile industry? If so, is it linear or non-linear? What is the impact mechanism? Are there differences in the effects of various technology integration models on the performance of traditionally advantageous industries?

This study initially builds the linear and non-linear mechanisms of the impact of

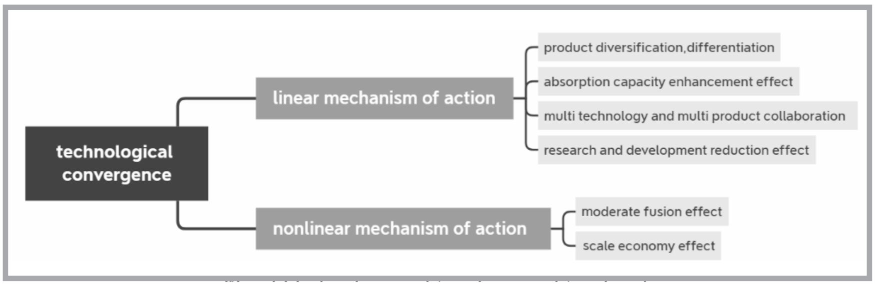

Figure 1. Mechanism of technology convergence.

TC on the development of China's textile industries. Then, it conducts empirical research based on the panel fixed effect model and panel threshold model.

Research framework and hypothesis

Linear mechanism

To establish a market-based competitive advantage in the new normal, textile enterprises must adapt to the market's requirements of "multi-variety, small batches, and fast delivery" and must focus on high-performance production, multiple new functions, precision, exquisiteness, and high-quality [21]. TC can attain this through product differentiation, knowledge absorption, capacity improvement, multi-technology and product synergies, and R&D risk reduction. These effects strengthen the competitive advantages of traditionally advantageous industries and promote industrial performance.

(1) Product differentiation effect. TC encourages companies to compete and collaborate with each other. This new form of competitive synergy accelerates new product innovation. The diversification and differentiation of new products greatly improve the entire industry's performance [22, 23]. The integration of various technology tracks has led to the horizontal expansion of traditional industries. Through actively integrating different technology types, R&D efficiency has improved, bringing more differentiated products, developing new products and markets, and improving market competitiveness [24, 25]. In addition, the reduction of product prices and the diversification of consumer choices have massively improved the efficiency of enterprises and the overall performance of the industry [26].

(2) Absorptive capacity enhancement effect. As China's superior traditional industry, the textile industry intends to establish a new global competitive advantage. Therefore, it must enhance its absorptive capacity. Based on the theory of dynamic capabilities, TC is deemed conducive to the accumulation of technical knowledge, further expanding it to related technical fields and creating more profits in the process [27]. The direction of this new round of technology and industrial revolution not only depends on a few disciplines or a single technology but also involves a highly interdisciplinary and deep integration of multi-discipline and multi-technology fields [28]. As such, TC can enable traditional industries to acquire diversified technologies and aid companies in applying external knowledge to enhance their core technical capabilities, particularly their R&D capabilities. In addition, TC can offset the decline of benefits brought by diminishing marginal returns of R&D investments. Hence, it can promote industrial transformation and upgrade [29].

(3) Multi-technology and multi-product synergy effect. These effects are usually complementary fields among different technologies. TC can trigger a synergy among multiple technologies and products [13]. Through integration and utilisation of insufficient resources, resource utilisation efficiency can be improved, and a greater compound economic effect can be realised [22]. Furthermore, through common technology and resource sharing among technologies, TC can improve the synergy of various technologies and products [17].

(4) R&D risk reduction effect. To achieve the transformation and upgrade of traditionally advantageous industries, it is vital to increase R&D investment, despite having certain risks. TC helps reduce corporate R&D risks and enhances the company's ability to quickly adapt to external technological environment changes [21, 30]. Companies mitigate this systematic risk of return on R&D investment by seeking a diversified combination of technologies, developing flexible and diverse technologies, and expanding technological scope [22].

Therefore, it is proposed:

Hypothesis 1: TC can promote the growth of industrial performance.

The path dependence theory presents that any industry always applies a series of specific technology groups to dominate its production and development [23]. The core technology areas of various industries are different. The diffusion and rolling of technology within an industry promotes the integration and development of related industry technologies to a dominant technology group [20]. In this case, the development pattern of technology belongs to "endogenous technology convergence". However, the leading technology of an industry can also enter into other industries, and its corresponding technology development strategy highlights the integration of technology resources among industries, which belongs to "exogenous technology convergence" [31].

This study draws on the above notion because TC is divided into two modes – endogenous convergence and exogenous convergence – based on whether the technologies involved during convergence belong to the same industry.

Endogenous convergence emphasises the integration of technologies within an industry, leading to a further specialisation of industrial technology. Specialisation strategy enables enterprises to improve their technological capabilities at lower costs in familiar fields. Likewise, by considering learning effects and knowledge transfer in similar technology fields, enterprises can enhance their core competitiveness [8, 9]. Meanwhile, exogenous convergence emphasises cross-industry convergence, which leads to technology diversification [21]. Utilising technology diversification strategies can expand the scope of enterprise technology to a more extensive range of technology fields, and can increase profits through economies of large scale and scope [11, 24].

Endogenous convergence invests capital in, for example, R&D equipment and human resources in similar fields of science and technology, thus enabling knowledge transfer among products and businesses at lower R&D and communication costs, and thereby reducing the cost of convergence and restructuring among technologies [26, 32]. In addition, compatible docking among similar technical elements can effectively enhance the reliability and market acceptance of new products [33]. On the one hand, it can help companies in providing original technologies with additional functions, thus bringing stronger competitiveness in a short time, and in accelerating their product system performance. On the other hand, endogenous technology convergence can enhance the consistent recognition of system knowledge among the stakeholders, such that the company's business can be associated with technology and market experience [9].

Meanwhile, exogenous convergence entails gradually integrating original independent technologies by means of reorganisation and creation under the same path. The development of highly complex products necessitates a collaboration of cross-domain technical knowledge, as product parts and components involve multiple knowledge and technologies [29, 30]. If an enterprise introduces and masters advanced technologies from other fields that are highly complementary to its own technologies, then it can realise an expansion of its own knowledge base and reserves. On the one hand, the range of available technologies can increase the probability of useful combinations and obtain economies of scope and synergies; on the other hand, it aids companies in identifying and using new external technologies and new knowledge. It further helps companies to more effectively deal with their relationship between partner portfolios, enabling them to seize more market opportunities in non-core areas [16].

In summary, it is proposed:
Hypothesis 2: Endogenous convergence can promote industrial performance.
Hypothesis 3: Exogenous convergence can promote industrial performance.

Non-linear mechanism

(1) Moderate convergence effect

TC promotes the efficiency of traditional industries in various aspects. For an enterprise it provides a wealth of technical solutions which improve the core competitiveness, capabilities and skills of R&D entities [7, 8]. More significantly, it provides opportunities for existing companies and entrants to enter the value chain. With the opening up of new niche markets, new entrants can challenge relatively mature industry leaders [13, 28]. For the industrial aspect, TC utilises complementary technology innovation knowledge bases in order to promote the emergence of new industries and technology clusters [8], thereby stimulating industrial convergence and cooperation among enterprises in various industries [26]. It can alter the original technological state of an enterprise and break the established market, organisational state and competition mode, hence promoting the advancement and rationalisation of the industrial structure [33].

However, TC tends to spread technical knowledge into other new technology fields. An organisation's TC must typically share and exchange private technical resources with other organisations. In this process, free-riding behaviour and unexpected resource overflow likely occur [12]. In addition, a higher degree of TC involves more technical or industrial fields. Since the carrying capacity of any organisation has an upper limit, when an involved technical field or industrial sector exceeds the threshold, it takes more time and energy to coordinate and handle pertinent affairs, leading to an uneconomical scale of the organisation [6]. Technologies with higher degrees of convergence may bring forth higher concurrent costs and risks. The benefits of integrating information among technical fields increase as the distance between these fields increases. However, cost also increases with distance [23]. Nevertheless, the convergence among them leads to greater technical complexity and higher transaction costs, which reduces corporation performance [15]. Moreover, long-range technology convergence requires enterprises to absorb relevant technical knowledge [7]. If the absorptive capacity fails to achieve the requirements, negative effects of TC occur. Hence, the degree of TC needs to be moderate.

Therefore, it is proposed:
Hypothesis 4: TC has a threshold effect and certainly has the largest elasticity coefficient for innovation performance at intermediate technology fusion levels.

(2) Economies of scale

Galbraith's theoretical model emphasises that large-scale enterprises are relatively suitable for innovation and are vital inventions and communicators in technological innovation [29]. If the performance of an enterprise is low and there are insufficient funds to invest in various R&D projects, it is difficult to ensure the degree of TC. Only when an enterprise has a certain scale can it carry out an effective division of labour, thereby improving technological diversity, enhancing the level of TC, and achieving good performance [33]. TC is an innovation process that achieves technological innovation through its own organic combination among technologies [30]. In this process, small businesses usually encounter insufficient funds and organisational resources and have to focus on a limited number of businesses in order to continue to invest in technology foundation [26], which restrains the scope of innovation investment and efforts to experiment in new areas. In contrast, large-scale companies have a greater absolute investment in R&D, which generally renders more obvious innovation [29]. Furthermore, they have a strong absorptive capacity, and their time required to absorb and transform new technologies is short [8].

Therefore, it is proposed:
Hypothesis 5: There is a threshold for enterprise scale in TC. A larger scale of enterprise denotes a better industrial performance.

Variables and models

Sample selection and data source

As the most effective carrier of technical information, patents consist of more than 90% of the world's latest technical information and have become a significant data source for the integration and innovation of identification technologies [3]. The patented International Patent Classification (IPC) co-occurrence analysis method is extensively used in TC research [12, 13]. It is a technical classification standard for patents that includes all knowledge areas pertaining to inventions and creations. A typical IPC classification number has five levels: department, major category, sub-category, major group, and group. The cut-off IPC number, namely the IPC four-digit classification code (IPC4), is extensively used to analyse patents' technical field attributes [11, 12]. When two or more different IPC4s emerge in the same patent, it is called IPC co-occurrence; related research believes that it represents the fusion of various technical fields [8, 11]. The ISI-OSI-INPI classification system, which is promulgated by the World Intellectual Property Organization, can realise correspondences between technology categories and industrial technologies [34]. The IPC that corresponds to the textile industry is shown in ***Table 1***. Patents are recognised

Table 1. Industry and IPC classification comparison table.

Field	IPC classification
Textile	A41H, C14B, D01B, D01C, D01D, D01F, D01G, D01H,D02G, D02H, D02J, D03C, D03D, D03J, D04B, D04C,D04G, D04H, D05B, D05C, D06G, D06H, D06J, D06M,D06P, D06Q

Table 2. Descriptive statistics of variables

	Mean	Maximum	Minimum	Standard deviation
Industry performance (Y)	2450606	137444800	32917	35142210
Technology convergence (TC)	82.71	643	2	123.0896
Endogenous convergence (TC1)	29.15	283	0	55.483
Exogenous convergence (TC2)	22.8666	198	0	22.8666
Labour (L)	328367.9	2246451	1314	509760.6
Capital (K)	4483495	29327200	69141	6807526
Enterprise size (N)	3861.88	17129.6	967.8972	2790.687

as endogenous fusion technologies, while those that include both textile technology and other industrial technologies are termed exogenous fusion technologies.

In this article, patent data come from the Incopat Database. Using the IPC number in ***Table 1*** to retrieve textile patent data from 2010 to 2014, 40,709 authorised patents in the Chinese textile industry were retrieved. Those with only one IPC number were removed, as well as the top four IPC patents with identical IPC numbers. Overall, 20,511 fusion patents were obtained, accounting for 50.38% of the total patents. This shows that more than half of the technologies in the textile industry are convergent technologies. Based on the ISI-OSI-INPI classification system, convergent patents are marked separately. If the IPC number of a patent comes from the textile industry, it is considered an endogenous convergent patent; if there are IPC subclasses from various industries, they are considered exogenous convergent patents. According to the provinces from which the patents belong, the TC statistics for each province are calculated. Consequently, the number of fusion, endogenous fusion, and exogenous fusion patents for each province in each year are obtained.

The economic data in this article come from the 2010-2014 Annual Textile Industry Data of the key industry database of the National Research Network. Due to insufficient data of the Qinghai and Tibet provinces, the data include panel data for five years in 29 provinces (***Table 1***).

Variable measurement

(1) Core explanatory variable: TC is the core dependent variable in this study. Feng Ke and Zeng Deming (2019) used the number of annual patents, including the traditional IPC4 coupling structure, in order to measure enhanced technology fusion. Meanwhile, a number of annual patents, including at least one new IPC4 coupling structure, were used to measure new technology fusion. This study likewise draws on this measurement method. TC is divided into endogenous convergence (TC1) and exogenous convergence (TC2). If the IPC number of each patent contains only the IPC4 corresponding to a textile (***Table 1***), it is considered TC1. If the IPC of a patent contains at least one IPC4 of another industry, it is considered TC2.

(2) Dependent variable: Y represents the output. From existing literature, it is found that the main business income is the dependent variable [30].

(3) Control variables: L (labor) is the average number of employees, K (capital) is measured by the net value of fixed assets, and N (enterprise size) represents the textile enterprise size. The criteria for judging enterprise size are currently divided according to capital and labour size. This study applies the total sales output value as determined by the number of enterprises in each province (***Table 2***).

Models

From the classic Cobb-Douglas Production Function, labour and capital are the fundamental factors that influence output. Several scholars have used this model to examine the impact of technological innovation, institutions and trade on output. This study introduces the core variables of TC to establish a measurement model as follows:

$$\mathrm{Log}(Y_{it}) = \mathrm{c} + \alpha_1 \log(K_{it}) + \\ + \alpha_2 \log(L_{it}) + \alpha_3 \log(N_{it}) + \\ + \alpha_4 \log(TC_{it}) + u_{it} \quad (1)$$

In ***Equation (1)***, Y, K, L, TC and N, respectively, represent the textile industry performance, capital input, labour input, technology convergence, and enterprise size of each province. α_1, α_2, α_3 and α_4 are the coefficients of elasticity, c a constant term, and u_{it} is a random perturbation term.

To examine the effects of inter-industry TC and across-industry convergence, TC is divided into endogenous convergence (TC1) and exogenous convergence (TC2). The following models are established ***Equation (2)***:

$$\mathrm{Log}(Y_{it}) = \mathrm{c} + \beta_1 \log(K_{it}) + \\ + \beta_2 \log((L_{it}\mathrm{L}) + \beta_{31} \log(N_{it}) + \\ + \beta_4 \log(TC1_{it}) + \beta_{51} \log(TC2_{it}) + u_{it} \quad (2)$$

The panel fixed effect model above only estimates the average elasticity among variables like TC, labour, capital and scale. To further estimate the nonlinear relationship between TC and the scale effect of enterprises, and to explore the laws governing technology fusion and industrial development, the panel threshold model proposed by Hansen (1999) is adopted. To estimate whether there is a threshold effect in TC, it should be determined whether there is a difference in the coefficients of industrial performance for various levels of TC. The following models are constructed:

$$\mathrm{Log}(Y_{it}) = \mathrm{c} + \theta_1 \log(K_{it}) + \\ + \theta_2 \log(L_{it}) + \theta_3 \log(N_{it}) + \\ + \lambda_1 \log(TC_{it}) I(TC \le \gamma 1) + \\ + \lambda_2 \log(TC_{it}) I(\gamma 1 \le \mathrm{TC} \le \gamma 2) + \\ + \lambda_3 \log(TC_{it}) I(\gamma 2 \le TC \le \gamma 3) + \\ + \lambda_4 \log(TC_{it}) I(TC \ge \gamma 3) + u_{it} \quad (3)$$

As shown in ***Equation (3)***, I(.) is an illustrative function. When the conditions in the brackets exist, it is set to 1; otherwise, 0. Y, K, L, TC and N, respectively, represent the industrial performance, capital input, labour force, technology convergence and enterprise size of each province. TC is the threshold variable. γ the threshold, and u_{it} is a random perturbation term. When technology fusion itself has a single-threshold effect, $\gamma 1 = \gamma 2 = \gamma 3$. When there is a double-threshold effect, $\gamma 1 \neq \gamma 2 = \gamma 3$. When there is a triple-threshold effect, $\gamma 1 \neq \gamma 2 \neq \gamma 3$.

Similarly, to estimate whether the elasticity coefficients of TC for industrial performance at different scales are the same,

$$\mathrm{Log}(Y_{it}) = \mathrm{c} + \alpha_1 \log(K_{it}) + \\ + \alpha_2 \log(L_{it}) + \beta_1 R_{it} I(R \leq \gamma 1) + \\ + \beta_2 R_{it} I(R \leq \gamma 1) I(\gamma 1 \leq \mathrm{N} \leq \gamma 2) + \\ + \beta_3 R_{it} I(\gamma 2 \leq N \leq \gamma 3) + \\ + \beta_4 R_{it} I(N \geq \gamma 3) + u_{it} \quad (4)$$

I(.) is an illustrative function. When the conditions in the brackets exist, I(.) is set to 1; otherwise, 0. Y, K, L, TC and N, respectively, represent the textile industry efficiency, capital investment, labour input, technology convergence and enterprise size for each province, where N is the threshold variable, γ the threshold, and u_{it} is a random perturbation term. When TC itself has a single threshold effect, $\gamma 1 = \gamma 2 = \gamma 3$. When there is a double-threshold effect, $\gamma 1 \neq \gamma 2 = \gamma 3$. When there is a triple-threshold effect, $\gamma 1 \neq \gamma 2 \neq \gamma 3$.

Empirical results

Panel fixed effect regression results

The OLS regression results are presented in ***Tables 5***. Model 1 regresses variables including capital input, labour and firm size. It is found that the elasticity coefficient of capital is the largest at 0.9752, which indicates that China's textile industry has a huge reliance on capital input. The impact of labour on industrial performance is insignificant and negative. The elasticity coefficient of scale is negative, and the square term of the scale of the enterprise is added to Model 2, which is significantly negative. This signifies that with the other conditions unchanged, the impact of enterprise scale on industrial performance resembles an inverted U-shape. This indicates a better performance of medium-scale enterprises.

Model 3 estimates the effect of TC and its various modes based on ***Equation (1)***. Rather than applying the random effect null hypothesis, Hauseman's Test instead uses fixed effects for regression. All variables have passed the statistical test at a 1% level. The elasticity coefficient of capital is the largest at 0.9531, implying that all elasticity coefficients of TC are significantly positive. Therefore, Hypothesis 1 is supported.

Table 3. *Panel data model estimation results. Note:* $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Variable	Meaning	Model 1	Model 2	Model 3	Model 4
logK	Capital	0.9752*** (49.48)	0.9749*** (54.18)	0.9531*** (52.42)	0.9485*** (52.87)
logL	Labour force	-0.0163 (-0.80)	-0.0114 (-0.61)	-0.0072 (-0.39)	-0.0052 (-0.29)
LogN	Enterprise size	-0.0308*** (-5.75)	0.4200*** (4.28)	-0.0426*** (-7.99)	-0.0435*** (-8.32)
$\log N^2$	Enterprise size squared		-0.0276*** (-4.60)		
Log(TC)	Technology convergence			0.0139*** (5.08)	
Log(TC1)	Endogenous convergence				0.0115** (1.93)
Log(TC2)	Exogenous convergence				-0.0043 (-0.66)
Constant	Constant term	0.2999*** (3.91)	-1.5325 (-3.0082)	0.3454*** (7.89)	0.3646*** (8.33)
Sample size	145	145	145	145	145
R-square	Goodness of fit	0.9792	0.9818	0.9759	0.9762

Table 4. *Threshold effect estimates for technology convergence itself.*

Variable	Meaning	Regression coefficients	t value	Companion probability
logK	Capital	0.0979	1.89	0.062
logL	Labour force	0.0151	0.46	0.644
LogN	Enterprise size	0.9451	36.00	0.000
logR	Technology fusion Technology convergence <= 4.6052	0.2202	5.23	0.078
LogR	TC 4.6052 <= TC <= 5.1761	0.2974	7.78	0.000
LogR	TC TC> 5.1761	0.2657	7.85	0.000

Model 4 divides TC into endogenous convergence (TC1) and exogenous convergence (TC2). Based on the estimation results of ***Equation (2)***, it is determined that the elasticity coefficient of TC1 is 0.0115, denoting that endogenous convergence can significantly promote the performance of the textile industry. Comparatively, the regression results of TC2 are insignificant. In this case, the effect of endogenous convergence on industry performance is significant, while that of exogenous convergence is insignificant. Thus, Hypothesis 2 is supported, and Hypothesis 3 not .

This result is consistent with the outcomes presented by Jeong et al. (2013). Long-distance TC leads to an increase in technical complexity and a higher production level. The transaction cost of a company reduces its performance. Moreover, a higher degree of technological integration by an organisation entails more technical fields or industrial sectors [24]. When an involved technical field or industrial sector exceeds the threshold, it can lead to an uneconomical scale for the organisation. Additionally, the effect of exogenous convergence is insignificant, which indicates that the textile industry's absorptive capacity is low. Furthermore, long-distance and cross-industry TC requires companies to manifest multiple technical knowledge to truly enhance their corporate performance.

Applying mixed regression as the robustness test, the sign and size of the variables are consistent with the fixed effect, denoting that the fixed effect result is robust (***Table 3***).

Threshold effect estimation of TC

The threshold effect of TC itself is estimated based on ***Equation (3)***. The Panel Threshold Model of Hansen (1999) is applied to validate whether TC has a threshold effect. First, a single-threshold test is performed. The F-test value of the panel threshold effect test is 14.49, and the adjoint probability is 0.006. This rejects the null hypothesis, indicating that TC itself has a threshold effect. Applying double-threshold regression, the F-test value is 4.66, and the adjoint probability is 0.045. Since double threshold exists,

Table 5. *Estimate of threshold effect of industry scale.*

Variable	Meaning	Regression coefficients	t value	Adjoint probability
logK	Capital	0.3809	3.28	0.000
logL	Labour force	0.0371	-0.56	0.574
Log(TC)	TC Enterprise size <= 5.1705	-0.4207	-3.29	0.001
Log(TC)	TC (5.1705 <= enterprise size <= 7.1000	0.0959	2.28	0.025
Log(TC)	TC Enterprise size> = 7.1000	0.1901	6.41	0.000

the null hypothesis is rejected. Then, by performing the triple-threshold test, the adjoint probability fails, implying that there is no triple-threshold effect. Thus, double-threshold regression is applied. The results are presented in ***Table 4***. All variables except labour force have passed the statistical test at a 1% level. When the level of TC is at the first threshold, the coefficient of industrial performance is 0.2202, passing the statistical test. When the said level is between the first and second thresholds, the elasticity coefficient of the TC effect is 0.2974, which likewise passes the statistical test. When the level of TC crosses the second threshold, the elasticity coefficient is 0.2657. In this case, Hypothesis 4 has been verified; that is, the effect of TC is the largest at a medium convergence level. One possible reason is that when the distance between the convergence of external technology and the company's own technology is too large, and when the company's technology absorption capacity is insufficient, the effect of technology integration is not as good as expected.

Threshold effect estimation of enterprise size

To estimate the impact of the various performance of enterprise size thresholds on TC, this study applies the Panel Data Threshold Model of Hasnen (1999) to initially perform a single-threshold test. Under double-threshold regression, the F-test value is 13.24, and the adjoint probability is 0.0234, indicating that a double threshold exists. Then, since a three-threshold test with a companion probability of 0.3484 fails the test, this indicates that there is no triple-threshold effect. The threshold regression results are provided in ***Table 5***. Labour force does not pass the statistical test, while the remaining variables have passed the statistical test at a 1% level. There are two thresholds for enterprise size – 7.1898 and 12.9689. When enterprise size is less than 7.1898, the TC performance is negatively correlated; when it crosses the threshold, the effect on TC becomes positively correlated. Thus, Hypothesis 5 is verified; that is, the TC effect of large-scale enterprises is relatively better. This shows that the degree of TC for improving industrial performance changes when enterprise size changes.

Discussion and conclusion

It is necessary to establish new advantages for promoting the sustainable development of the Chinese textile industry. In the context of the new industrial revolution, converged innovation has become a vital innovation mode of industrial technology. This study is based on the data of 40,709 textile technology patents and the economic data of the textile industry between 2010 and 2014. Firstly, the linear and non-linear mechanisms of the impact of TC on industrial performance are analysed. This study proposes that TC promotes industrial performance through product diversification, differentiation, absorption capacity enhancement, multi-product synergy and R&D risk reduction. Non-linear mechanisms involve moderate integration effects and economies of scale. Finally, the panel fixed effect model and the threshold model are applied to conduct empirical research on TC's mechanisms.

The results are as follows: (1) TC has a significant effect on improving the performance of the textile industry, and promotes industrial performance by improving product diversification, differentiation effects and absorption capacity; (2) endogenous convergence can promote the improvement of textile industry performance, while exogenous integration has no significant effect on such; (3) TC itself has a threshold effect, with its effect on the improvement of industrial performance being different at varying TC levels, and the elasticity coefficient of TC is the largest at intermediate levels. Moreover, enterprise scale (4) has a threshold effect, in which TC has varied effects on textile industry performance under different enterprise scales, with a larger scale entailing a more significant effect of TC.

Although existing studies have likewise mentioned the effect of TC on industrial performance, they do not distinguish between intra-industry convergence and cross-industry convergence [2, 3, 4, 5]. In fact, the conclusion of this study is that the effect of cross-industry convergence on textile industry performance is insignificant. This may be because the current cross-industry TC of the textile industry is not large enough, and most TC is still implemented within the field. In addition, existing research seldom involves the mechanism of TC to enhance industrial performance, especially the nonlinear mechanism. It is concluded in this study that the relationship between TC and industrial performance resembles an inverted U-shape. When TC is too high, it reduces industry performance. This is perhaps the reason why excessive TC increases the risk of R&D and the coordination cost of various R&D entities [23, 29]. Finally, this study finds that the effect of TC has a threshold of enterprise scale. Large-scale enterprises tend to have a better effect of TC, which may be due to their greater absorption capacity and R&D investment [27, 28].

The policy implications for the development of China's textile industry are as follows:

(1) The textile industry must increase the extent of TC, particularly the convergence with emerging technologies. Enhancing the diversification and differentiation of products improves the absorptive capacity of enterprises, brings the collaboration of multiple products and technologies, encourages networking and flexibility in R&D and design, and promotes the automation and intelligence of production processes to improve industrial performance.

(2) The textile industry must improve its own absorptive capacity. The impact of long-distance exogenous fusion on industrial performance must be supported by sufficient absorptive capacity. TC requires joint action of knowledge from various technical fields. If the absorptive capacity of the enterprise itself cannot keep up, it can be difficult to exert the effects of technology integration.

(3) The government should design TC-related policies according to the specific conditions of the textile industry. It should also support large-scale enterprises in their TC, encourage R&D of common technologies, and promote industrial transformation and upgrade through technology integration.
(4) China's textile industry must strengthen its training of high-level scientific and technological professionals with interdisciplinary integration, as well as the exchange and cooperation of talents with the rest of the world's scientific and technological powers. This establishes a joint force of enterprises, science and technology, and education in order to advance and realise new competitive advantages.

Nevertheless, this study has some limitations. Firstly, the number of converge patents used to measure TC is not accurate enough. Future studies may use entropy [20], the cross-impact method [7] and other reliable methods to calculate TC. Secondly, this study only examines the effects of TC for the textile industry, which can be expanded in the future. Finally, this study primarily focuses on the mechanism, which does not extend the theory enough. Further research based on the evolutionary theory can be conducted in the future.

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