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Government Certification and Innovation in Strategic Core Technologies: A Systems Perspective on China's Little Giant Program

Kuiran Yuan, Zhui Liu * and Xiaodong Yang

School of Economics and Management, Shihezi University, Shihezi 832000, China; yuankuiran@stu.shzu.edu.cn (K.Y.)
* Correspondence: liuz_jm@shzu.edu.cn

Highlights

Please indicate how your work links to systems science via your contributions to systems practice, theory, and/or methodology.

- This study conceptualizes government certification as a systems mechanism that connects government signaling, market responses, and firm resource allocation within the innovation ecosystem.
- An integrated innovation ecosystem and signaling framework reveals how certification coordinates managerial decision-making, knowledge connections, and long-term capital to support key core technological innovation.

What are the main findings and/or the implications of the main findings?

- Little Giant certification promotes key core technological innovation by reducing managerial myopia, increasing knowledge diversification, and improving access to patient capital.
- Its innovation effect is stronger, with greater investor attention, stronger intellectual property protection, and among strategically aggressive and growth-stage firms.

Abstract

Breakthroughs in strategic core technologies depend on the coordinated functioning of policy institutions, capital markets, knowledge networks, and firm decision-making. This study examines whether government certification can mobilize these interdependent elements within an innovation ecosystem to promote key core technological innovation (KCTI). Using the staggered implementation of the Little Giant certification program and panel data on Chinese A-share listed firms from 2014 to 2023, we employ a staggered difference-in-differences design to estimate the effect of certification on KCTI. The results show that government certification significantly enhances firms' KCTI. Further analyses show that certification reduces managerial myopia, promotes knowledge diversification, and improves firms' access to patient capital, providing evidence consistent with the proposed mechanisms. The effect of certification varies across institutional environments and firm characteristics. Investor attention further strengthens its innovation effect by facilitating the reception and interpretation of certification signals. These findings highlight government certification as an institutional mechanism that connects government guidance, market responses, and firm-level innovation within the broader innovation ecosystem.

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1. Introduction

Amid the restructuring of globalization and intensifying technological competition, key core technological innovation (KCTI) has become increasingly important for industrial security and national competitiveness [1,2]. Over the past several decades, emerging economies have made substantial progress in technological catch-up through imitation and process optimization [3]. However, as their technological capabilities approach the global frontier, development models that rely on established technological trajectories and external sources of technology face increasing constraints. This constraint is particularly salient in strategic sectors such as advanced manufacturing, semiconductors, and new materials. Heavy reliance on external core technologies and critical components can expose firms and their industries to supply disruptions and technology restrictions, with implications for industrial chain stability and economic security [4]. Recent external supply restrictions faced by Chinese firms in critical technological fields, including advanced semiconductors, have further underscored the importance of strengthening indigenous technological capabilities. Accordingly, how to facilitate firms' transition from general innovation toward the more strategically significant KCTI has become an important issue in the technological upgrading of emerging economies.

This shift has also prompted major economies to reconsider the role of government in technological innovation. The United States has sought to strengthen semiconductor research, manufacturing, and workforce development through the CHIPS and Science Act, while the European Union has introduced the European Chips Act, which aims to mobilize approximately EUR 43 billion by 2030 to expand semiconductor capacity, strengthen supply chain resilience, and increase Europe's share of the global semiconductor market. These policy initiatives suggest that KCTI does not depend solely on firms' internal R&D investment, but instead emerges from the joint contribution of multiple innovation inputs, including long-term capital, technological knowledge, interfirm collaboration, and institutional support [5]. Compared with more general forms of innovation, KCTI typically involves greater resource commitments, longer development cycles, and higher risks of failure. On the one hand, risk aversion and preferences for short-term returns in capital markets may constrain firms' access to long-term capital that is compatible with extended R&D cycles [6]. On the other hand, high uncertainty and short-term performance pressures may weaken managers' willingness to sustain investment in long-term technological development [7]. Moreover, breakthroughs in complex technologies often depend on sustained knowledge exchange and technological collaboration between firms and a diverse set of external innovation actors. KCTI is therefore best understood as a systemic process involving governments, markets, firms, and diverse knowledge and capital providers, rather than as the outcome of a single type of resource investment within the firm.

China's implementation of the Specialized and Sophisticated Little Giant certification program since 2019 provides a representative institutional setting for examining how government intervention becomes embedded in such an innovation system. Unlike conventional broad-based subsidies, Little Giant certification is based on a relatively stringent selection process designed to identify small and medium-sized enterprises (SMEs) with a high degree of specialization, strong innovation capabilities, and substantial growth potential [8]. Through government screening, the program provides an institutional endorsement of firm quality while also conveying information about firms' innovation capabilities and growth potential to external stakeholders through an authoritative certification signal. In this way, the policy may shape external stakeholders' assessments of firm value without directly replacing market allocation, thereby influencing the allocation of capital, knowledge, and collaborative resources. This logic is consistent with the New Structural Economics view that an effective market can be complemented by a facilitating government [9]. From a broader innovation policy perspective, it also reflects the capacity of governments to shape market expectations and influence the direction of innovation resource allocation through institutional instruments [10].

Existing research has approached the relationship between government policy and firm innovation from different perspectives. One stream focuses on firms' external environments, investigating how fiscal subsidies, tax incentives, infrastructure investment, and other policy instruments alleviate financing constraints, improve the conditions for innovation, and enhance resource allocation efficiency [11–14]. These studies demonstrate the importance of policy-based resource support and improvements in the institutional environment for firm innovation. However, these studies largely view government policy as a direct source of resources or an external institutional shock. Less attention has been paid to how certification-based policies influence external stakeholders' evaluations of firms and, in turn, their resource allocation decisions. In particular, Little Giant certification combines policy screening with authoritative endorsement. Beyond providing direct resource support, it may also convey information about firms' technological capabilities and growth potential to stakeholders, including investors and business partners.

A second stream of research adopts an internal decision-making perspective and examines how executive leadership styles [15], personality traits [16], career experience [17], and professional backgrounds [18] influence firms' innovation strategies. These studies highlight the role of managerial cognition and behavioral characteristics in firm innovation, but pay less attention to how external institutional arrangements influence managers' long-term innovation decisions by altering resource availability and market evaluations [19]. In addition, existing studies typically examine policy support, capital provision, knowledge acquisition, and managerial decision-making in isolation, rather than considering how these factors interact within an innovation network comprising governments, firms, capital providers, and other actors. Innovation ecosystem theory views innovation as an outcome of ongoing interactions among heterogeneous actors, activities, resources, and institutions, through which information flows, knowledge exchange, and resource allocation jointly shape firms' innovation capabilities [20]. Accordingly, examining policy effects or firm-level characteristics in isolation provides an incomplete account of how certification-based industrial policies become embedded in the innovation system and influence firms' KCTI.

Against this background, we examine China's Little Giant certification program to assess the effect of certification-based industrial policy on firms' KCTI and explore the conditions through which this effect may arise from an innovation ecosystem perspective. We conceptualize Little Giant certification as an institutional arrangement that connects governments, markets, and firms. Government screening and certification generate a credible institutional signal, which can influence investors' assessments and resource allocation decisions. Firms may then reallocate innovation resources in response to these changes in their external environment. Building on this process, we examine whether certification improves the conditions for innovation by reducing managerial myopia, increasing knowledge diversification, and improving access to patient capital. We further adopt a signal-receiver perspective to examine whether investor attention moderates the effect of certification.

This study makes three main contributions. First, we extend research on certification-based industrial policy by adopting an innovation ecosystem perspective. Rather than viewing industrial policy primarily as a one-way provision of resources or administrative intervention, we consider multiple innovation actors within an integrated framework and examine how certification influences their interactions through information signaling, knowledge connections, and resource allocation. By further incorporating signaling theory, we explain how government certification influences external stakeholders' assessments of firms' technological capabilities and growth potential and, in turn, the allocation of innovation resources. This provides a more integrated view of how certification-based industrial policy operates within the innovation ecosystem.

Second, we deepen understanding of how certification-based policy affects innovation by examining three key conditions for KCTI: managerial decision-making, knowledge diversification, and patient capital. Specifically, certification may reduce managerial myopia by improving the environment for long-term innovation decisions, broaden firms' knowledge connections with external innovation actors and increase knowledge diversification, and improve access to patient capital by helping long-term investors recognize firms' technological potential.

Third, we identify the boundary conditions under which Little Giant certification is more effective in promoting KCTI. From a signal-receiver perspective, we incorporate investor attention into the certification signaling framework and examine how market attention affects the recognition of and response to certification signals. We also examine heterogeneity in the policy effect across regional intellectual property protection, firms' strategic aggressiveness, and life-cycle stages, thereby clarifying the institutional and firm-level conditions under which certification-based industrial policy is more effective.

2. Theoretical Foundations and Research Hypotheses

2.1. Little Giant Policy and Firms' KCTI

The Little Giant certification program is a key industrial policy in China that promotes SME specialization and innovation. Launched by the Ministry of Industry and Information Technology in 2019, the program aims to identify and cultivate SMEs that focus on niche markets, demonstrate strong innovation capabilities, and exhibit substantial growth potential [8]. Unlike broad-based support policies, Little Giant certification involves a relatively stringent eligibility review and selection process. Firms must apply for certification, undergo local review and recommendation, and receive final approval at the national level. Evaluators assess firms comprehensively on specialization, innovation capability, operating quality, and growth potential. The stringent selection process and authoritative national-level certification give Little Giant status substantial informational value and credibility, enabling it to convey otherwise difficult-to-observe information about firms' technological capabilities and growth potential to external stakeholders. KCTI typically requires substantial resource commitments, involves long R&D cycles, and carries a high risk of failure, placing considerable demands on firms' ability to sustain R&D and secure external resources. Although SMEs often possess strong innovative dynamism and specialization advantages, their limited scale, resource endowments, and market position can expose them to greater resource constraints when pursuing sustained, high-risk technological R&D [21]. At the same time, external stakeholders may struggle to accurately assess firms' underlying technological capabilities and development prospects, further increasing the cost of obtaining innovation resources [22].

Little Giant certification can strengthen firms' capacity to sustain KCTI. National-level certification increases external recognition of firms' technological capabilities and growth potential by converting otherwise difficult-to-observe firm quality into credible public information. This reduces the information asymmetry external stakeholders face when evaluating firms' technological prospects [23]. Greater market recognition can facilitate access to the external support needed for long-term technological R&D and reduce the likelihood that resource shortages interrupt high-risk technological exploration. At the same time, Little Giant certification reflects policy recognition of specialization and technology-oriented development. Such recognition can strengthen firms' expectations of continued investment in key technological fields and increase the strategic importance of long-term technological R&D relative to short-term operating activities. For KCTI, which involves long development cycles, high failure risks, and limited short-term returns, more stable development expectations and external support can strengthen firms' capacity to bear the risks associated with long-term innovation, thereby promoting KCTI [5]. Little Giant certification can also improve the matching of innovation resources with firms that have strong technological potential. Through screening and certification, the government provides information about firm quality, which market participants can use to update their assessments and adjust resource allocation decisions accordingly. Rather than directly replacing market selection, certification reduces the cost of identifying promising firms and can thereby facilitate allocating innovation resources to firms with specialization advantages and technological potential [9,10]. When firms gain access to external resources and development opportunities that are better aligned with long-term technological R&D, they are better positioned to translate their existing specialization advantages into innovation outcomes in key core technologies. Little Giant certification therefore creates more favorable conditions for KCTI.

Accordingly, we propose the following hypothesis:

H1. *Little Giant certification positively affects firms' KCTI.*

2.2. Mechanism Analysis

Schumpeterian innovation theory views innovation as arising from novel combinations of existing production factors and conditions [24,25]. Compared with more general forms of innovation, KCTI places greater demands on firms' long-term decision-making, knowledge integration, and sustained resource provision. Innovation ecosystem theory views firm innovation as embedded in a network of interdependent actors, including governments, firms, investors, research institutions, and business partners. Through information flows, knowledge exchange, and resource allocation, these actors interact to jointly shape firms' innovation activities [20]. Here, governments shape the rules and direction of innovation through institutional arrangements, capital providers supply long-term financing, and research institutions and business partners contribute external knowledge and technological resources. Firms, in turn, identify, absorb, and recombine these resources. Effective coordination among these actors is essential for translating external innovation resources into firms' technological capabilities [26]. Within this system, governments can also shape market expectations and allocate innovation resources through policy instruments [10]. Little Giant certification is one such institutional arrangement linking government, markets, and firms. Through application, review, and certification, the government screens firms based on their innovation foundations and growth potential and conveys this information to external stakeholders through national-level certification. Investors may adjust their investment decisions in response to this information, while firms reallocate innovation resources as external conditions change. Little Giant certification may therefore improve the decision-making, knowledge, and capital conditions required for KCTI. Accordingly, we examine managerial myopia, knowledge diversification, and patient capital as three mechanisms through which Little Giant certification may promote KCTI.

First, Little Giant certification may mitigate managerial myopia and strengthen firms' commitment to long-term innovation. Upper echelons theory suggests that managers' cognitive characteristics and risk assessments shape firms' strategic choices [27]. When managers place excessive emphasis on current performance and short-term returns, performance pressure may reinforce loss aversion and short-term decision-making. Firms may consequently allocate more resources to projects with more predictable and immediate returns while reducing investment in high-risk, long-cycle R&D [28,29]. Because KCTI rarely generates stable, visible short-term returns, it is particularly vulnerable to managers' preference for short-term performance. Little Giant certification can improve the external conditions under which managers make long-term innovation decisions. Authoritative national-level certification can increase market recognition and strengthen firms' development expectations, reducing managers' pressure to adjust long-term R&D strategies in response to short-term market evaluations and operating fluctuations [30,31]. Certification can also increase market attention and access to external resources, reducing uncertainty around long-term technological exploration and allowing managers to form more stable expectations about sustained R&D [32]. As short-term performance pressure and external uncertainty decline, managers can allocate innovation resources with a longer-term competitive perspective, place less emphasis on immediate returns, and tolerate the risks associated with long-cycle R&D [33]. Little Giant certification may therefore reduce managers' short-term orientation and provide a more stable basis for decision-making to sustain KCTI.

Second, Little Giant certification may broaden firms' access to external knowledge and increase knowledge diversification. A firm's existing knowledge base shapes the scope of its technological search and provides an important foundation for innovation [34]. KCTI often spans multiple technological domains and knowledge components, requiring the integration of knowledge from different fields. The ability to move beyond existing knowledge boundaries and develop a diversified knowledge base is therefore important for identifying and solving complex technological problems [35]. From an innovation ecosystem perspective, firms do not rely solely on internally accumulated knowledge. Knowledge also flows, is shared, and is recombined through continuous interactions with diverse innovation actors [20]. However, limited resources, organizational scale, and network positions can make it costly for SMEs to enter high-quality innovation networks and establish stable ties with external knowledge providers. Little Giant certification can increase firms' visibility and legitimacy within the innovation ecosystem, making it easier for them to enter high-quality innovation networks and gain opportunities for interorganizational collaboration and knowledge exchange [36]. Through interactions with diverse innovation actors, firms can access and absorb heterogeneous knowledge from different technological fields, gradually developing a more diversified knowledge base [37]. A diversified knowledge base expands the technological search space and increases opportunities to recombine different knowledge elements, giving firms a broader range of technological pathways and solutions to complex problems [38]. Little Giant certification may therefore support KCTI by broadening firms' knowledge sources and innovation networks, thereby providing a more diversified knowledge base and greater scope for technological recombination.

Finally, Little Giant certification may improve firms' access to long-term financing, particularly patient capital. KCTI requires long-term financing that is aligned with extended R&D cycles [39]. Because SMEs typically have limited asset bases, face substantial technological risks, and have long-term value that is difficult for external investors to assess, they are particularly likely to face a mismatch between short-term capital supply and long-term innovation needs. Patient capital, which tolerates delayed returns, temporary performance fluctuations, and the risk of innovation failure, is therefore better suited to the financing needs of KCTI [40]. Signaling theory suggests that when external stakeholders cannot directly observe firm quality, credible signals can reduce information asymmetry and influence receivers' evaluations and subsequent decisions [23]. Little Giant status is an institutional signal backed by government certification, and investors with long investment horizons are important receivers of this signal. By conveying information about firms' innovation foundations and growth potential, certification provides investors with additional information for assessing firms' long-term technological value. This additional information can reduce perceived risks arising from information gaps and strengthen long-term investors' willingness to maintain equity positions in certified firms [41]. Patient capital is characterized by longer investment horizons and greater tolerance for short-term fluctuations. When technological R&D has yet to generate immediate returns, stable long-term capital can reduce the risk of R&D interruption caused by short-term financing contractions and support sustained R&D investment and technological accumulation [42]. Such capital also gives firms greater scope for repeated experimentation and long-term technological exploration, thereby supporting KCTI [43,44]. Figure 1 presents the research framework.

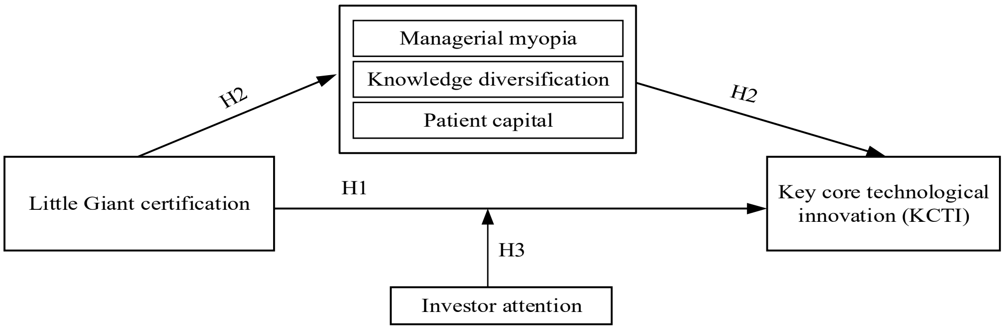

Figure 1. Research framework.

Based on the above arguments, we propose that:

H2a. *Little Giant certification promotes KCTI by mitigating managerial myopia.*

H2b. *Little Giant certification promotes KCTI by increasing firms' knowledge diversification.*

H2c. *Little Giant certification promotes KCTI by improving firms' access to patient capital.*

2.3. Moderating Effect of Investor Attention

According to signaling theory, the effectiveness of a signal depends not only on its credibility but also on whether receivers attend to and correctly interpret it [23]. Little Giant certification is granted through government review and conveys favorable information about certified firms to the capital market. As key receivers of the certification signal, investors' attention determines the extent to which the information is recognized, interpreted, and reflected in market responses. When investor attention is high, information about Little Giant certification is more likely to attract market notice and spread among investors. The technological capabilities and long-term growth potential signaled by the certification are also more likely to be incorporated into investors' assessments of firm value. Sustained investor attention can further improve the information environment by allowing investors to evaluate firms' long-term value using a broader range of public information, thereby reducing misperceptions of technological prospects and innovation risks. Under these conditions, certification is more likely to translate into market recognition and resource allocation, thereby creating more favorable conditions for KCTI.

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Conversely, when investor attention is low, even authoritative certification may receive limited market attention, reducing the likelihood that the information enters investors' decision-making processes. This weakens the market response to the certification signal and limits its effect on resource allocation. Prior research also suggests that the market evaluation of innovation-related information depends on receivers' information environments, with the same information potentially generating different assessments under different information conditions [45]. Therefore, greater investor attention can improve the recognition and interpretation of Little Giant certification, strengthen market responses to the certification signal, and amplify its effect on firms' KCTI.

H3. *Investor attention positively moderates the relationship between Little Giant certification and firms' KCTI.*

3. Research Design

3.1. Sample Selection and Data Sources

We use Chinese A-share listed firms from 2014 to 2023 as the research sample. To improve sample comparability and data quality, we apply the following screening procedures. First, we exclude financial-sector firms and firms designated as ST or *ST. Second, we remove observations with missing values for key variables. Third, we exclude firms with relatively short listing histories during the sample period. Finally, all continuous variables are winsorized at the 1st and 99th percentiles to mitigate the influence of extreme values. The data are primarily obtained from the CSMAR and CNRDS databases and the official lists of Little Giant firms released by the Ministry of Industry and Information Technology. We manually compile and match the certification records with firm-level data using firm names and stock codes.

3.2. Model Specification

To examine the effect of Little Giant certification on firms' KCTI, we estimate a staggered DID model specified as follows:

$$KTB_{i,t} = \alpha + \beta_1 Giant_{i,t} + \beta_2 Control_{i,t} + \mu_t + \eta_i + \varepsilon_{i,t} \tag{1}$$

where $KTB_{i,t}$ denotes the level of KCTI of firm i in year t; $Giant_{i,t}$ is an indicator for Little Giant certification; and β_1 is the coefficient of interest and captures the effect of Little Giant certification on firms' KCTI. $Control_{i,t}$ denotes a vector of control variables. μ_t and η_i denote year and firm fixed effects, respectively, and $\varepsilon_{i,t}$ is the error term.

3.3. Variables

3.3.1. Dependent Variable (KTB)

We measure KCTI by the number of invention patent applications in key core technology fields [46]. Specifically, we use the *Industrial Foundation Innovation and Development Catalogue* to define the scope of key core technologies. The Catalogue covers 21 key technology fields and 1047 specific technological items. We first extract the core technical terms associated with these items and match them to the descriptions of five-digit International Patent Classification (IPC) codes to construct a set of IPC codes corresponding to key core technology fields. When a technological item spans multiple technical modules, we retain all relevant IPC codes rather than impose a one-to-one mapping. For ambiguous cases, we jointly consider the technological field, technology name, and technical description to determine the appropriate classification. We then identify invention patents with IPC codes in this set and aggregate them at the firm-year level.

The IPC system provides a standardized technology classification framework that links the technological items defined in the Catalogue to observable patent records, reducing the subjectivity associated with identifying key technologies solely from patent titles or manually selected keywords. The resulting measure captures firms' innovative output in key core technology fields rather than general patenting activity. A higher value indicates a higher level of KCTI. To account for the skewed distribution of patent counts and zero values, we take the natural logarithm of one plus the annual number of KCTI patent applications.

3.3.2. Explanatory Variable (Giant)

Giant equals one from the year in which a firm receives Little Giant certification onward, and zero before certification. It is also coded as zero for firms that are never certified during the sample period. During the sample period, 617 firms receive Little Giant certification and constitute the treatment group. The remaining 2358 uncertified firms constitute the control group.

3.3.3. Control Variables

Following prior studies [47,48], we control for firm size (*Size*), firm age (*Listage*), fixed asset ratio (*Fixed*), revenue growth (*Growth*), board size (Board), ownership concentration (*Top1*), return on assets (*Roa*), Tobin's Q (*Tobinq*), return on equity (*Roe*), and board independence (*Indep*). Table 1 provides the definitions of variables.

Table 1. Variable definitions.

Variable Name	Symbol	Definition
Key core technological innovation	KTB	Natural logarithm of one plus the annual number of invention patent applications in key core technology fields
Little Giant certification	Giant	Equals 1 from the year of Little Giant certification onward, and 0 otherwise
Firm size	Size	Natural logarithm of total assets
Firm age	Listage	Natural logarithm of the number of years since listing
Fixed asset ratio	Fixed	Fixed assets divided by total assets
Revenue growth	Growth	Change in operating revenue relative to operating revenue in the previous year
Board size	Board	Natural logarithm of the number of directors
Ownership concentration	Top1	Shareholding ratio of the largest shareholder
Return on assets	Roa	Net income divided by total assets
Tobin's Q	Tobinq	Market value divided by total assets
Return on equity	Roe	Net income divided by shareholders' equity
Board independence	Indep	Number of independent directors divided by the total number of directors

4. Empirical Analysis

4.1. Descriptive Statistics

Table 2 presents the descriptive statistics. The dependent variable, KTB, has a mean of 0.833 and a standard deviation of 1.204, indicating substantial variation in firms' key core technological innovation. Giant has a mean of 0.077 and a standard deviation of 0.267, indicating variation in certification status across firms and years. Other variables are consistent with prior studies.

Table 2. Descriptive statistics.

	Obs	Mean	SD	Min	Max
KTB	20,224	0.833	1.204	0.000	5.030
Giant	20,224	0.077	0.267	0.000	1000
Size	20,224	22.066	1.166	20.043	25.761
Listage	20,224	1.828	0.937	0.000	3.332
Fixed	20,224	0.211	0.124	0.014	0.579
Growth	20,224	0.145	0.299	−0.447	1.552
Board	20,224	2.089	0.189	1.609	2.565
Top1	20,224	0.331	0.140	0.087	0.716
Roa	20,224	0.046	0.057	−0.177	0.205
Tobinq	20,224	2.076	1.198	0.870	7.780
Roe	20,224	0.066	0.103	−0.452	0.306
Indep	20,224	0.378	0.053	0.333	0.571

4.2. Baseline Regression Analysis

Table 3 reports the baseline results for the effect of Little Giant certification on firms' KCTI. Column (1) includes firm and year fixed effects. The coefficient on *Giant* is 0.130 and statistically significant at the 1% level. Column (2) adds the control variables but excludes fixed effects, and the coefficient on Giant remains positive and statistically significant. Column (3) includes both the control variables and fixed effects. The coefficient on *Giant* is 0.101 and statistically significant at the 1% level, indicating that Little Giant certification has a positive effect on firms' KCTI after accounting for observable firm characteristics, time-invariant firm heterogeneity, and common year effects. The estimated effect is also economically meaningful. Given the log-transformed dependent variable, the estimate implies an increase of approximately 10.6% following Little Giant certification, thus supporting H1.

Table 3. Baseline regression results.

	(1) KTB	(2) KTB	(3) KTB
Giant	0.130 *** (0.038)	0.255 *** (0.038)	0.101 *** (0.035)
Size		0.563 *** (0.024)	0.512 *** (0.038)
Listage		−0.139 *** (0.020)	−0.151 *** (0.026)
Fixed		−1.532 *** (0.137)	0.231 * (0.120)
Growth		0.024 (0.031)	−0.093 *** (0.022)
Board		0.028 (0.120)	0.036 (0.076)
Top1		−0.445 *** (0.125)	0.117 (0.192)
Roa		−4.766 *** (0.637)	0.664 * (0.389)
Tobinq		0.081 *** (0.013)	0.017 ** (0.008)

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Table 3. *Cont.*

	(1) KTB	(2) KTB	(3) KTB
Roe		1.897 *** (0.341)	−0.446 ** (0.205)
Indep		0.563 (0.360)	0.462 ** (0.213)
_cons	0.823 *** (0.003)	−11.227 *** (0.603)	−10.556 *** (0.851)
Firm FE	Yes	No	Yes
Year FE	Yes	No	Yes
N	20,224	20,224	20,224
R^2	0.670	0.258	0.684

Note: Robust standard errors clustered at the firm level are reported in parentheses. *** denotes $p < 0.01$, ** denotes $p < 0.05$, and * denotes $p < 0.1$.

4.3. Robustness Tests

4.3.1. Parallel Trend Test

A key assumption underlying causal identification in the staggered DID design is that the treatment and control groups follow similar trends in KCTI before certification. Drawing on prior research [49], we employ an event-study specification to examine pre-treatment dynamics, using the period immediately before certification (t = −1) as the reference period. Figure 2 reports the estimated coefficients and 95% confidence intervals for each relative period. The estimated coefficients for all pre-treatment periods are statistically indistinguishable from zero. We further conduct a joint significance test. The test is insignificant ($p = 0.238$), so we cannot reject the null hypothesis that these coefficients are jointly equal to zero. These results indicate no significant differential trends between the treatment and control groups before Little Giant certification.

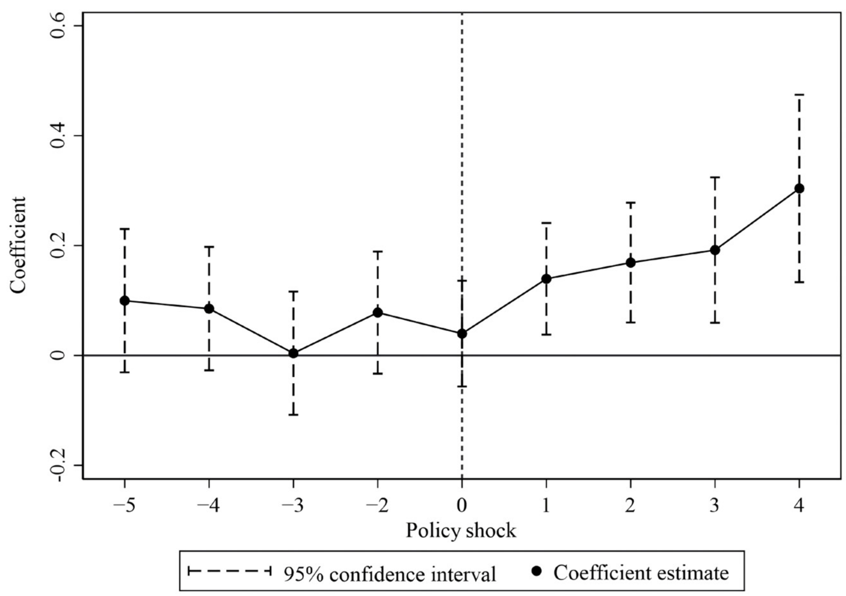

Figure 2. Parallel trend test.

4.3.2. Placebo Test

To rule out potential estimation bias arising from random shocks and omitted variables, we further conduct a placebo test by randomly assigning firms to a pseudo-treatment group. Specifically, while keeping the treatment-group size unchanged, we randomly assign Little Giant certification to firms and re-estimate the baseline model 500 times. Figure 3 presents the results. The placebo coefficients are concentrated around zero and display an approximately normal distribution, indicating that no systematic policy effect emerges under the randomly assigned treatment. Moreover, the distribution of the placebo coefficients differs markedly from the baseline estimate of Giant. These results indicate that the positive effect of Little Giant certification on firms' KCTI is unlikely to be attributable to random factors or omitted variables, further supporting the baseline results.

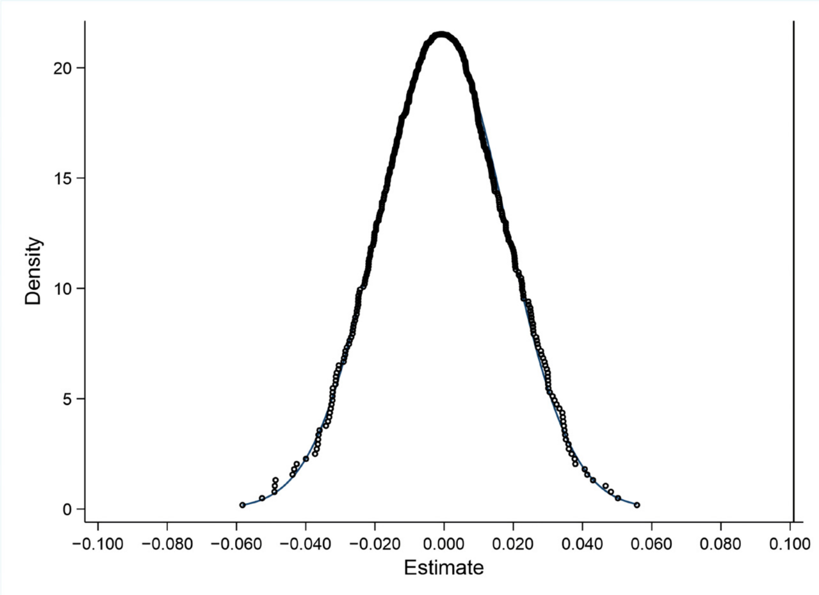

Figure 3. Placebo test.

4.3.3. Addressing Sample Selection Bias

Because Little Giant certification is not entirely random, firms' likelihood of being certified may depend on their operating conditions, governance characteristics, and other firm-specific factors, giving rise to potential sample selection bias. We employ propensity score matching (PSM) as a robustness test. Specifically, we estimate propensity scores based on firm characteristics and match treated firms with control firms using 1:3 nearest-neighbor matching. We further conduct a covariate balance test to assess the quality of the matching. After matching, covariate balance improves substantially, with the maximum standardized bias below 5%. Columns (1) and (2) of Table 4 show that the coefficient on Giant remains positive and statistically significant with and without controls. This indicates that the positive effect of Little Giant certification on firms' KCTI remains robust after mitigating potential sample selection bias.

To improve covariate balance between the treatment and control groups and reduce potential estimation bias arising from sample loss during matching, we reweight the sample using entropy balancing. Entropy balancing assigns weights to observations so that the treatment and control groups are more closely balanced on the moments of the covariate distributions, such as their means and variances, thereby improving comparability between the two groups. Columns (3) and (4) of Table 4 report the estimates based on the entropy-balanced sample. The coefficient on Giant remains positive and statistically significant in both specifications. These results show that the positive effect of Little Giant certification on firms' KCTI remains robust across alternative methods for addressing sample selection bias.

Table 4. PSM and entropy balancing results.

	(1) KTB	(2) KTB	(3) KTB	(4) KTB
	PSM		EBM	
Giant	0.194 *** (0.040)	0.126 *** (0.038)	0.170 *** (0.037)	0.117 *** (0.034)
Size		0.474 *** (0.046)		0.483 *** (0.044)
Listage		−0.079 ** (0.036)		−0.070 ** (0.035)
Fixed		0.141 (0.161)		0.168 (0.152)
Growth		−0.073 ** (0.030)		−0.078 *** (0.026)
Board		0.034 (0.116)		−0.076 (0.111)
Top1		−0.209 (0.260)		−0.163 (0.247)
Roa		0.292 (0.607)		0.640 (0.517)
Tobinq		0.009 (0.011)		0.003 (0.012)
Roe		−0.301 (0.360)		−0.486 * (0.286)
Indep		0.218 (0.328)		0.040 (0.307)
_cons	0.568 *** (0.007)	−9.536 *** (1.033)	0.588 *** (0.009)	−9.422 *** (0.993)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	8442	8442	20,224	20,224
R^2	0.515	0.531	0.560	0.575

Note: Robust standard errors clustered at the firm level are reported in parentheses. *** denotes $p < 0.01$, ** denotes $p < 0.05$, and * denotes $p < 0.1$.

4.3.4. Heterogeneous Treatment Effect Test

To examine potential bias arising from heterogeneous treatment effects in the staggered DID design, we conduct a Bacon decomposition [50]. Panel A of Table 5 shows that all decomposed estimates are positive, indicating that the positive effect of Little Giant certification on firms' KCTI is broadly consistent across comparisons involving different treatment timings. The comparison between treated and never-treated firms (T vs. Never Treated) receives the largest weight, accounting for 0.939 of the total, with an estimated effect of 0.137. This indicates that the baseline estimate is driven primarily by comparisons between treated and never-treated firms, suggesting that potential bias arising from the staggered treatment structure is relatively limited.

We re-estimate the policy effect using alternative estimators that are robust to staggered treatment timing, including the Callaway and Sant'Anna estimator [51] and the imputation estimator [52]. As shown in Panel B of Table 5, the estimated treatment effects are positive and statistically significant under both estimators. These results show that Little Giant certification continues to have a positive effect on firms' KCTI after accounting for treatment-effect heterogeneity across cohorts and periods. The baseline findings therefore do not depend on the conventional two-way fixed-effects estimator and remain robust to alternative estimation methods.

Table 5. Heterogeneous treatment effect tests.

Panel A. Goodman-Bacon Decomposition		
Comparison	Weight	Estimate
Earlier T vs. Later C	0.021	0.242
Later T vs. Earlier C	0.012	0.092
T vs. Never Treated	0.939	0.137
T vs. Already Treated	0.028	0.035
Panel B. Alternative Estimators Accounting for Treatment-Effect Heterogeneity		
	Coefficient	S.E
Callaway and Sant'Anna estimator	0.127 ***	0.048
Imputation estimator	0.103 ***	0.038

Note: *** denotes $p < 0.01$.

4.3.5. Other Robustness Tests

We conduct additional tests by restricting the sample, using an alternative measure of the dependent variable, introducing higher-dimensional fixed effects, and accounting for concurrent policy and COVID-19 shocks. The results are reported in Table 6.

(1) Excluding Main Board firms. Because most Little Giant firms are small and medium-sized technology-oriented firms, their operating characteristics, technological trajectories, and growth patterns are more comparable to those of firms listed on the SME Board, ChiNext, and STAR Market. In contrast, Main Board firms are generally larger and more mature and may differ in their innovation incentives and responses to policy. We therefore exclude Main Board firms and re-estimate the baseline model using only firms listed on the SME Board, ChiNext, and STAR Market.

(2) Alternative measure of KCTI. To capture the quality dimension of KCTI, we replace the baseline patent-count measure with the number of forward citations received by key core technology patents within three years of application (KTBQ). Forward citations reflect the subsequent technological influence of patented inventions, while the fixed three-year window reduces differences in citation opportunities across patent cohorts. The coefficient on Giant remains positive and statistically significant, supporting the robustness of the baseline findings.

(3) Higher-dimensional fixed effects. To further mitigate omitted-variable bias arising from time-varying unobserved factors at the regional and industry levels, we additionally include province-by-year and industry-by-year fixed effects. Province-by-year fixed effects absorb region-specific shocks over time, such as changes in institutional conditions, economic development, and local policies, while industry-by-year fixed effects account for time-varying industry conditions, including market conditions, technological cycles, and industry performance. After controlling for these higher-dimensional fixed effects, the coefficient on Giant remains positive and statistically significant, indicating that the baseline findings are not driven by time-varying shocks at the regional or industry level.

(4) Accounting for concurrent policies. Several policies closely related to technological innovation were implemented during the sample period and may confound the estimated effect of Little Giant certification. Policies promoting the marketization of data elements may facilitate data flows and information sharing, thereby reducing innovation costs and improving innovation efficiency [53]. New-generation AI policies may strengthen regional innovation infrastructure and encourage firms to invest in R&D in artificial intelligence and other frontier technologies. Government guidance fund policies may alleviate financing

constraints by providing direct financial support or mobilizing private capital. Because these policies may also affect firms' KCTI, failing to account for them could confound or overstate the estimated effect of Little Giant certification.

(5) Excluding the COVID-19 shock. The COVID-19 pandemic generated a major economic shock that may have affected firms' operations, R&D investment, and innovation output, potentially confounding the estimated effect on KCTI [54]. We therefore exclude the years most affected by the pandemic and re-estimate the baseline model.

Table 6. Results of additional robustness checks.

	(1) KTB Excluding Main Board Firms	**(2) KTBQ Alternative Dependent Variable**	**(3) KTB Additional Fixed Effects**	**(4) KTB Controlling for Other Policy**	**(5) KTB Excluding COVID-19 Effects**
Giant	0.112 ***	0.053 ***	0.098 ***	0.098 ***	0.112 ***
	(0.041)	(0.008)	(0.037)	(0.035)	(0.041)
Size	0.521 ***	0.003	0.487 ***	0.502 ***	0.525 ***
	(0.046)	(0.010)	(0.036)	(0.038)	(0.039)
Listage	−0.115 ***	0.035 ***	−0.139 ***	−0.148 ***	−0.183 ***
	(0.034)	(0.011)	(0.026)	(0.026)	(0.029)
Fixed	0.362 **	−0.044	0.167	0.229 *	0.315 **
	(0.149)	(0.044)	(0.114)	(0.120)	(0.138)
Growth	−0.094 ***	−0.006	−0.093 ***	−0.091 ***	−0.085 ***
	(0.026)	(0.006)	(0.023)	(0.022)	(0.025)
Board	−0.010	0.009	0.045	0.034	0.064
	(0.097)	(0.041)	(0.077)	(0.077)	(0.087)
Top1	0.114	−0.057	0.182	0.131	0.119
	(0.234)	(0.067)	(0.192)	(0.192)	(0.203)
Roa	0.971 **	0.111	0.399	0.649 *	0.392
	(0.482)	(0.145)	(0.383)	(0.388)	(0.434)
Tobinq	0.019 *	0.001	0.018 **	0.017 **	0.022 **
	(0.010)	(0.003)	(0.008)	(0.008)	(0.009)
Roe	−0.651 **	0.014	−0.343 *	−0.435 **	−0.269
	(0.258)	(0.073)	(0.200)	(0.205)	(0.226)
Indep	0.472	0.011	0.550 **	0.449 **	0.485 **
	(0.290)	(0.119)	(0.215)	(0.213)	(0.241)
DEM				0.007	
				(0.029)	
NewAI				0.023	
				(0.029)	
Fund				0.102 *	
				(0.055)	
_cons	−10.694 ***	−0.002	−10.094 ***	−10.361 ***	−10.893 ***
	(1.021)	(0.275)	(0.818)	(0.862)	(0.870)
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Pro-Year FE	No	No	Yes	No	No
Ind-Year FE	No	No	Yes	No	No
N	12,164	20,224	20,204	20,224	16,023
R^2	0.635	0.664	0.687	0.684	0.674

Note: Robust standard errors clustered at the firm level are reported in parentheses. *** denotes $p < 0.01$, ** denotes $p < 0.05$, and * denotes $p < 0.1$.

4.4. Mechanism Analysis Tests

4.4.1. Managerial Myopia

Drawing on prior research, we construct a measure of managerial myopia using the MD&A sections of firms' annual reports [55]. Specifically, we apply a dictionary approach to identify short-term-oriented words in the MD&A text and measure managerial myopia (*SMF*) as the frequency of these words relative to the total number of words in the MD&A section. A higher value indicates a stronger short-term orientation among managers. Column (1) of Table 7 shows that the coefficient on *Giant* is −0.024 and statistically significant, indicating that Little Giant certification reduces managerial short-term orientation, consistent with our theoretical prediction. KCTI requires managers to adopt a longer-term decision horizon. Technological innovation decisions involve trade-offs between expected returns and potential risks [56]. Excessive attention to short-term performance may lead managers to reduce investment in long-term and highly uncertain innovation activities [57]. The policy recognition and development expectations associated with Little Giant certification improve the external conditions for long-term innovation decisions, reducing managers' excessive focus on short-term operating fluctuations and immediate returns. This provides a more stable decision-making basis for sustained KCTI.

Table 7. Mechanism tests.

	(1) SMF	**(2) DK**	**(3) PC**
Giant	−0.024 *** (0.009)	0.078 *** (0.029)	0.134 *** (0.027)
Size	0.012 ** (0.006)	0.220 *** (0.025)	0.101 *** (0.025)
Listage	−0.083 *** (0.005)	−0.160 *** (0.021)	−0.829 *** (0.026)
Fixed	0.042 * (0.023)	0.106 (0.100)	0.148 (0.092)
Growth	−0.005 (0.004)	−0.016 (0.016)	0.114 *** (0.018)
Board	0.003 (0.017)	0.080 (0.074)	0.061 (0.058)
Top1	0.025 (0.035)	0.151 (0.160)	0.856 *** (0.188)
Roa	−0.085 (0.079)	−0.645 ** (0.319)	0.464 (0.307)
Tobinq	−0.005 *** (0.002)	−0.002 (0.006)	−0.112 *** (0.010)
Roe	−0.036 (0.038)	0.274 * (0.162)	−0.185 (0.146)
Indep	0.002 (0.047)	0.126 (0.198)	−0.087 (0.166)
_cons	0.422 *** (0.136)	−3.529 *** (0.581)	−0.285 (0.595)
Firm FE	YES	YES	YES
Year FE	YES	YES	YES
N	20,224	20,224	20,224
R^2	0.698	0.641	0.717

Note: Robust standard errors clustered at the firm level are reported in parentheses. *** denotes $p < 0.01$, ** denotes $p < 0.05$, and * denotes $p < 0.1$.

4.4.2. Knowledge Diversification

We use the Teachman entropy index to measure firms' knowledge diversification (*DK*), capturing the distribution of their knowledge across technological fields [58]. A higher value indicates a more diversified knowledge base. Column (2) of Table 7 shows that the coefficient on *Giant* is positive and statistically significant, indicating that Little Giant certification increases firms' knowledge diversification, consistent with our theoretical prediction. KCTI often spans multiple technological fields and knowledge domains, making reliance on a firm's existing knowledge base insufficient for solving complex technological problems. For SMEs, limited resources and network positions further constrain access to heterogeneous external knowledge. Little Giant certification increases firms' visibility and legitimacy within innovation networks, facilitating knowledge ties with research institutions, business partners, and other innovation actors. These interactions enable firms to access and absorb more diverse knowledge resources [20,36]. Broader knowledge sources expand firms' technological search space and increase opportunities to recombine heterogeneous knowledge, thereby providing a richer knowledge base for KCTI [58].

4.4.3. Patient Capital

We measure patient capital (*PC*) from the perspective of long-term equity holdings [59]. Specifically, we calculate the holding period of each institutional investor in each listed firm and use the investor's own average holding period as the benchmark. If an institution's holding period in a firm is no shorter than its own average holding period, we classify it as a strategic institutional investor. We then measure patient capital as the shareholding ratio of such investors. A higher value indicates greater access to long-term-oriented equity capital. Column (3) of Table 7 shows that the coefficient on *Giant* is positive and statistically significant, indicating that Little Giant certification increases firms' access to patient capital, consistent with our theoretical prediction. The favorable information conveyed by Little Giant certification reduces information asymmetry faced by long-term investors when assessing firm quality and strengthens their willingness to maintain equity positions in certified firms [41]. Compared with more short-term-oriented capital, long-term institutional investors have longer investment horizons and greater tolerance for short-term fluctuations, and their continued holdings enhance the stability of firms' capital supply. When KCTI has yet to generate immediate returns, stable long-term capital reduces the risk of R&D interruption caused by short-term financing contractions and provides more stable funding for sustained R&D investment and long-term technological exploration [42].

4.5. Heterogeneity Analysis

The effect of Little Giant certification on firms' KCTI may vary with the external institutional environment and firm characteristics. To further examine the conditions under which the policy is more effective, we conduct heterogeneity analyses along three dimensions: regional intellectual property protection, strategic aggressiveness, and firm life cycle. In addition to the subgroup regressions, we use Fisher permutation tests to formally assess differences in the estimated coefficients across groups. The results are reported in Table 8.

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Table 8. Heterogeneity tests.

	(1) KTB Regional IP Protection High	(2) KTB Low	(3) KTB Strategic Aggressiveness Aggressive	(4) KTB Conservative	(5) KTB Firm Life Cycle Growth Stage	(6) KTB Mature Stage
Giant	0.109 ** (0.053)	0.037 (0.056)	0.165 *** (0.057)	0.048 (0.070)	0.152 *** (0.049)	0.085 (0.058)
Size	0.584 *** (0.050)	0.451 *** (0.049)	0.566 *** (0.048)	0.435 *** (0.063)	0.545 *** (0.050)	0.464 *** (0.053)
Listage	−0.140 *** (0.040)	−0.136 *** (0.035)	−0.150 *** (0.041)	−0.193 *** (0.046)	−0.025 (0.036)	−0.355 *** (0.047)
Fixed	0.398 ** (0.179)	0.102 (0.167)	0.347 * (0.181)	0.118 (0.181)	0.310 ** (0.158)	0.225 (0.204)
Growth	−0.110 *** (0.032)	−0.062 ** (0.031)	−0.073 ** (0.031)	−0.139 *** (0.042)	−0.112 *** (0.034)	−0.023 (0.041)
Board	0.124 (0.119)	−0.049 (0.101)	0.099 (0.105)	0.025 (0.136)	0.193 (0.123)	−0.083 (0.114)
Top1	0.045 (0.297)	0.047 (0.259)	0.315 (0.226)	−0.094 (0.306)	−0.074 (0.298)	0.227 (0.263)
Roa	0.304 (0.566)	1.168 ** (0.546)	0.924 (0.593)	0.680 (0.653)	1.113 * (0.591)	0.296 (0.566)
Tobinq	0.020 * (0.011)	0.010 (0.011)	0.012 (0.010)	0.028 * (0.014)	0.014 (0.011)	0.026 ** (0.012)
Roe	−0.374 (0.305)	−0.638 ** (0.278)	−0.615 ** (0.310)	−0.497 (0.325)	−0.559 * (0.318)	−0.502 * (0.281)
Indep	0.706 ** (0.330)	0.346 (0.287)	0.626 ** (0.283)	0.181 (0.353)	1.238 *** (0.337)	0.092 (0.301)
_cons	−12.296 *** (1.189)	−9.107 *** (1.088)	−11.979 *** (1.029)	−8.561 *** (1.470)	−12.067 *** (1.134)	−8.721 *** (1.223)
Firm FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
N	9888	9743	9010	7558	9284	9003
R^2	0.703	0.655	0.656	0.729	0.667	0.699
Diff. In coeffs	−0.071 **		−0.116 ***		0.067 *	

Note: Robust standard errors clustered at the firm level are reported in parentheses. *** denotes $p < 0.01$, ** denotes $p < 0.05$, and * denotes $p < 0.1$.

4.5.1. Regional Intellectual Property Protection

The effectiveness of Little Giant certification may depend on the strength of intellectual property protection. KCTI requires substantial and sustained resource commitments, and firms' incentives to continue technological R&D depend on whether the returns to innovation can be effectively protected. In regions with stronger IP protection, firms face lower risks of imitation and appropriation and can form more stable expectations of returns to innovation. They may therefore be more willing to devote the support and resource advantages associated with certification to long-term technological R&D. By contrast, weaker intellectual property protection may reduce expected returns from innovation and limit the effectiveness of certification. We measure regional intellectual property protection by the number of concluded intellectual property cases and divide the sample at the median into high- and low-protection groups. Columns (1) and (2) of Table 8 show that the coefficient on *Giant* is positive and statistically significant in regions with stronger intellectual property protection, but insignificant in regions with weaker protection. The Fisher permutation test further indicates that the difference between the two coefficients is statistically significant. These results suggest that stronger intellectual property protection enhances the effect of Little Giant certification on KCTI, highlighting the importance of external institutional protection for policy effectiveness.

4.5.2. Strategic Aggressiveness

The effect of Little Giant certification may vary with firms' strategic orientation. Given the high investment requirements and risks associated with KCTI, more aggressive and forward-looking firms are generally more willing to undertake technological exploration and allocate resources toward long-term competitive advantage. By contrast, strategically conservative firms tend to emphasize operational stability and risk control and may be more cautious about allocating resources to high-risk, long-cycle innovation projects. Thus, even under the same certification, firms with different strategic orientations may respond differently to the associated resources and development opportunities. Drawing on prior research, we measure strategic aggressiveness using six dimensions: innovation orientation, market expansion, growth, production efficiency, organizational stability, and capital intensity [60]. We then divide the sample at the median into strategically aggressive and conservative firms. Columns (3) and (4) of Table 8 show that the coefficient on *Giant* is 0.165 and statistically significant for strategically aggressive firms, whereas the estimate is smaller for strategically conservative firms. This suggests that firms' strategic responsiveness is an important condition for translating policy-related resources into long-term technological innovation.

4.5.3. Firm Life Cycle

The effect of Little Giant certification may vary across life-cycle stages, reflecting differences in firms' resource endowments, growth objectives, and innovation incentives. Growth-stage firms typically face stronger pressures for market expansion and may have greater incentives to use policy support to accelerate technological breakthroughs. Mature firms, although more stable in their operations, may exhibit weaker innovation incentives because of organizational inertia and path dependence. However, prior research also suggests that mature firms may pursue innovation strategies to support further expansion. Based on the firm life-cycle classification, we divide the sample into growth-stage and mature firms. Columns (5) and (6) of Table 8 show that Little Giant certification has a positive and statistically significant effect on KCTI among growth-stage firms, whereas the effect is insignificant among mature firms. These results suggest that Little Giant certification is more effective for growth-stage firms, whereas weaker innovation incentives or greater resource constraints may limit its effect among mature firms.

4.6. Moderating Effect

As discussed above, investor attention affects the extent to which information conveyed by Little Giant certification is recognized and acted upon by the capital market, thereby strengthening its effect on firms' KCTI. To test this moderating effect, we measure investor attention using analyst coverage and the number of analyst reports and interact each measure with *Giant*. Table 9 reports the results. Columns (1) and (2) use analyst coverage as the measure of investor attention. The interaction coefficients are 0.126 and 0.092, respectively, and both are positive and statistically significant at the 1% level, indicating that greater analyst coverage strengthens the positive effect of Little Giant certification on firms' KCTI. Columns (3) and (4) use the number of analyst reports as an alternative measure, and the interaction coefficients remain positive and statistically significant. These results indicate that greater capital market attention facilitates the recognition and dissemination of certification information and strengthens the effect of Little Giant certification on firms' KCTI, supporting H3.

Table 9. Moderating effect tests.

	(1) KTB	(2) KTB	(3) KTB	(4) KTB
	Analyst Coverage		Analyst Reports	
Giant	−0.016 (0.046)	0.001 (0.043)	−0.002 (0.046)	0.015 (0.043)
Attana	0.046 *** (0.009)	−0.001 (0.009)		
Attana × Giant	0.126 *** (0.031)	0.092 *** (0.029)		
Size		0.505 *** (0.039)		0.507 *** (0.039)
Listage		−0.152 *** (0.026)		−0.152 *** (0.026)
Fixed		0.225 * (0.120)		0.225 * (0.120)
Growth		−0.093 *** (0.022)		−0.093 *** (0.022)
Board		0.041 (0.076)		0.040 (0.076)
Top1		0.110 (0.192)		0.110 (0.192)
Roa		0.612 (0.391)		0.621 (0.391)
Tobinq		0.015 * (0.008)		0.016 ** (0.008)
Roe		−0.426 ** (0.206)		−0.427 ** (0.206)
Indep		0.461 ** (0.213)		0.460 ** (0.213)
Attrep			0.034 *** (0.007)	−0.002 (0.008)
Attrep × Giant			0.091 *** (0.025)	0.063 *** (0.023)
_cons	0.762 *** (0.012)	−10.405 *** (0.872)	0.768 *** (0.012)	−10.446 *** (0.872)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	20,223	20,223	20,223	20,223
R^2	0.671	0.685	0.671	0.685

Note: Robust standard errors clustered at the firm level are reported in parentheses. *** denotes $p < 0.01$, ** denotes $p < 0.05$, and * denotes $p < 0.1$.

5. Conclusions and Policy Implications

5.1. Conclusions

From an innovation ecosystem perspective, this study examines the effect of Little Giant certification on firms' KCTI. We find that Little Giant certification significantly promotes firms' KCTI, and the result remains robust across a series of alternative tests. Further analyses show that certification is associated with lower managerial myopia, greater knowledge diversification, and improved access to patient capital. These findings are consistent with the proposed mechanisms and suggest that certification can support KCTI by encouraging longer-term decision-making, broadening firms' knowledge base, and easing access to long-term capital. The heterogeneity analyses further show that the effect of certification varies with the external institutional environment and firm characteristics. The effect is more pronounced in regions with stronger intellectual property protection, among strategically aggressive firms, and among growth-stage firms. This suggests that the extent to which certification translates into innovation outcomes depends on both institutional support and firms' strategic responsiveness and stage of development. Investor attention also strengthens the positive effect of Little Giant certification on KCTI, indicating that market recognition and interpretation of certification information are important for policy effectiveness.

Little Giant certification can therefore be understood as a certification-based industrial policy embedded in the innovation ecosystem. Its innovation effect reflects the interaction among government certification, market responses, and firms' resource allocation. By influencing managerial decision-making, knowledge access, and long-term financing, certification can connect multiple actors in the innovation ecosystem and facilitate the allocation of innovation resources. These findings extend our understanding of certification-based industrial policy and provide new evidence on how government certification can support KCTI through interactions among public institutions, markets, and firms.

5.2. Policy Implications

Based on these findings, we draw the following policy and managerial implications. First, policymakers should strengthen the post-certification support system and improve the translation of certification information into innovation resource allocation. Little Giant certification provides an important basis for firms to connect with external innovation resources. Policymakers should therefore enhance disclosure of certification information, make firms' technological capabilities and growth potential more transparent, and lower the information costs faced by market participants when evaluating certified firms. Policy measures should also be tailored to firms' development stages and innovation needs so that certification advantages can translate into sustained innovation capability.

Second, the maturity of financial resources should be better aligned with the long development cycles of KCTI. KCTI requires stable capital with a sufficiently long investment horizon. Capital markets should place greater weight on long-term value, facilitate the dissemination of technological information, and reduce the information costs investors face when assessing firms' long-term innovation potential. This can encourage more long-horizon capital to flow into key technology fields. Financial institutions should also deepen information exchange with firms and better match financing maturities to R&D cycles, providing more stable funding for sustained technological innovation.

Third, certified firms should improve their ability to absorb and combine external knowledge and capital. Our findings show that firms' strategic orientation and stage of development shape how effectively they respond to certification. Certified firms should therefore avoid relying solely on policy recognition and instead maintain a long-term technological orientation while building stronger capabilities to absorb and recombine external knowledge and capital. Firms can use the visibility created by certification to deepen technological exchange with universities and research institutions, broaden their knowledge base, and attract more long-horizon capital. This can help convert external recognition into sustained KCTI capability.

Finally, policy design should promote closer coordination among governments, capital markets, knowledge actors, and firms within the innovation ecosystem. The effectiveness of certification-based industrial policy does not depend on any single actor or resource input, but on the effective flow of information, knowledge, and capital across different innovation actors. Policy design should therefore strengthen the links among government certification, market recognition, knowledge exchange, and firm resource allocation to better support KCTI.

5.3. Limitations and Future Research

This study has several limitations that provide opportunities for future research. First, Little Giant certification involves an explicit screening and review process. Although we use a staggered DID design, matching methods, and a range of robustness tests to mitigate potential selection bias, we cannot completely rule out the possibility that unobserved factors affect both certification and innovation outcomes. Future research could combine richer data with stronger identification strategies to further strengthen causal inference. Second, KCTI is measured primarily using patent data, while managerial myopia and patient capital are captured through textual analysis and institutional investors' holding periods. Although these measures are theoretically grounded, they may still contain measurement error. Future research could use more direct measures based on firm behavior, survey data, or technology adoption and application data to further validate these mechanisms. Third, the estimated policy effect may combine the informational effect of certification itself with subsequent resource allocation effects. Given the available data and research design, we are unable to cleanly separate these two effects. Future research could exploit more granular data or institutional variation to identify the relative roles of certification signals and subsequent resource allocation in shaping KCTI. Fourth, our sample consists primarily of Chinese A-share listed firms, which may limit the generalizability of the findings to unlisted SMEs or other institutional settings. Future research could compare certification-based industrial policies across countries and regions to assess whether the findings extend to different institutional contexts.

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Abbreviations

The following abbreviations are used in this manuscript:

KCTI	Key core technological innovation
EBM	Entropy balancing method
MD&A	Management's Discussion and Analysis
CSMAR	China Stock Market & Accounting Research Database
IPC	International Patent Classification
DID	Difference-in-differences

References

1. Mittal, R.; Sheetal; Soriya, S. Fostering Competitiveness of Indian MSMEs through IT and Digitalization. *Inform. Technol. Dev.* **2025**, *31*, 1066–1089. [CrossRef]
2. Schot, J.; Steinmueller, W.E. Three Frames for Innovation Policy: R&D, Systems of Innovation and Transformative Change. *Res. Policy* **2018**, *47*, 1554–1567. [CrossRef]
3. Bekkers, E.; Landesmann, M.; Macskasi, I. Complexity, Tacit Knowledge and the Scope for Technological Catch-Up. *World Econ.* **2022**, *45*, 1179–1212. [CrossRef]
4. Yang, W.; Wang, X. The Impact of Patent Protection on Technological Innovation: A Global Value Chain Division of Labor Perspective. *Technol. Forecast. Soc. Change* **2024**, *203*, 123370. [CrossRef]
5. Weber, K.M.; Rohracher, H. Legitimizing Research, Technology and Innovation Policies for Transformative Change. *Res. Policy* **2012**, *41*, 1037–1047. [CrossRef]
6. Cavallo, A.; Ghezzi, A.; Dell'Era, C.; Pellizzoni, E. Fostering Digital Entrepreneurship from Startup to Scaleup: The Role of Venture Capital Funds and Angel Groups. *Technol. Forecast. Soc. Change* **2019**, *145*, 24–35. [CrossRef]
7. Wu, Z.; Fan, X.; Zhu, B.; Xia, J.; Zhang, L.; Wang, P. Do Government Subsidies Improve Innovation Investment for New Energy Firms: A Quasi-Natural Experiment of China's Listed Companies. *Technol. Forecast. Soc. Change* **2022**, *175*, 121418. [CrossRef]
8. Cao, Q.; Wang, T.; Wen, S.; Zhou, L.; Zhen, W. The Influence Mechanism of Government Venture Capital on the Innovation of Specialized and Special New "Little Giant" Enterprises. *Systems* **2025**, *13*, 535. [CrossRef]
9. Lin, J.Y. New Structural Economics: A Framework for Rethinking Development. *World Bank. Res. Obs.* **2011**, *26*, 193–221. [CrossRef]
10. Mazzucato, M. Mission-Oriented Innovation Policies: Challenges and Opportunities. *Ind. Corp. Change* **2018**, *27*, 803–815. [CrossRef]
11. Chen, L.; Tao, S.; Xie, X.; Huang, W.; Zhu, W. The Evaluation of Innovation Efficiency and Analysis of Government Subsidies Influence-Evidence from China's Metaverse Listed Companies. *Technol. Forecast. Soc. Change* **2024**, *201*, 123213. [CrossRef]
12. Song, S.; Wen, J.; Li, Y.; Li, L. How Does Digital Economy Affect Green Technological Innovation in China? New Evidence from the "Broadband China" Policy. *Econ. Anal. Policy* **2024**, *81*, 1093–1112. [CrossRef]
13. Wang, X.; Zhang, Y. The Impact of Digital Infrastructure on Urban Radical Innovation: Evidence from the "Broadband China" Demonstration Policy. *Int. Rev. Financ. Anal.* **2025**, *106*, 104528. [CrossRef]
14. Yue, Z.; Yang, G.; Wang, H. How Do Tax Reductions Motivate Technological Innovation? *Humanit. Soc. Sci. Commun.* **2023**, *10*, 775. [CrossRef]
15. Steele, L.M.; Watts, L.L. Managing Technical Innovation: A Systematic Review of 11 Leader Functions. *Technovation* **2022**, *115*, 102539. [CrossRef]
16. Tang, Y.; Li, J.; Yang, H. What I See, What I Do: How Executive Hubris Affects Firm Innovation. *J. Manag.* **2015**, *41*, 1698–1723. [CrossRef]
17. Guo, S.; Zan, B.; Sun, Y.; Zhang, M. Effects of Top Managers' Military Experience on Technological Innovation in the Transition Economies of China. *Technol. Forecast. Soc. Change* **2020**, *153*, 119909. [CrossRef]
18. Durendez, A.; Dieguez-Soto, J.; Madrid-Guijarro, A. The Influence of CEO's Financial Literacy on SMEs Technological Innovation: The Mediating Effects of MCS and Risk-Taking. *Financ. Innov.* **2023**, *9*, 15. [CrossRef]
19. Plummer, L.A.; Allison, T.H.; Connelly, B.L. Better Together? Signaling Interactions in New Venture Pursuit of Initial External Capital. *Acad. Manag. J.* **2016**, *59*, 1585–1604. [CrossRef]
20. Granstrand, O.; Holgersson, M. Innovation Ecosystems: A Conceptual Review and a New Definition. *Technovation* **2020**, *90–91*, 102098. [CrossRef]
21. Feng, J.; Tang, J.; Qi, Z.; Liu, J. Supply Chain Finance and Innovation Investment: Based on Financing Constraints. *Financ. Res. Lett.* **2024**, *63*, 105349. [CrossRef]

22. Shen, D.; Zhao, X.; Lyu, S.; Liu, H.; Zeng, H.; Ma, S. Qualification and Construction Enterprise Innovation—Quasi-Natural Experiments Based on Specialized, High-End and Innovation-Driven "Small Giant" Enterprises. *J. Asian Archit. Build. Eng.* **2026**, *25*, 2222–2240. [CrossRef]
23. Connelly, B.L.; Certo, S.T.; Ireland, R.D.; Reutzel, C.R. Signaling Theory: A Review and Assessment. *J. Manag.* **2011**, *37*, 39–67. [CrossRef]
24. Galunic, D.C.; Rodan, S. Resource Recombinations in the Firm: Knowledge Structures and the Potential for Schumpeterian Innovation. *Strateg. Manag. J.* **1998**, *19*, 1193–1201. [CrossRef]
25. Lestan, F.; Clausen, T.H. Innovation Capabilities and Firm Performance: A Meta-Analysis of the Schumpeter's Hypothesis. *J. Innov. Knowl.* **2026**, *13*, 100943. [CrossRef]
26. He, X.; Xia, M.; Li, X.; Lin, H.; Xie, Z. How Innovation Ecosystem Synergy Degree Influences Technology Innovation Performance-Evidence from China's High-Tech Industry. *Systems* **2022**, *10*, 124. [CrossRef]
27. Hambrick, D.C.; Mason, P.A. Upper Echelons: The Organization as a Reflection of Its Top Managers. *Acad. Manag. Rev.* **1984**, *9*, 193–206. [CrossRef]
28. Xu, T.; Ding, C.J.; Zhao, K. From Compliance Disclosure to Innovative Action: A Study on the Transmission Mechanism of Climate Risk Disclosure from the Dual Legitimacy Perspective. *Int. Rev. Econ. Financ.* **2026**, *107*, 105008. [CrossRef]
29. Zhao, J.; Wang, X. Managerial Myopia, Technological Innovation, and Greenwashing: Moderating Roles of Financing Constraints and Environmental Uncertainty. *Technol. Forecast. Soc. Change* **2025**, *218*, 124210. [CrossRef]
30. Peng, M.; Yan, Q. The Impact of Managerial Myopia on Enterprise Digital Innovation. *Financ. Res. Lett.* **2025**, *80*, 107377. [CrossRef]
31. Yang, X.; Razzaq, A.; Ozturk, I. Mechanisms of Digitalization in Reshaping the Green Transformation of Energy Firms in China. *J. Environ. Manag.* **2025**, *393*, 127047. [CrossRef]
32. Sun, Y.; San, Z.; Xu, C.; Davey, H. The Nexus of Managerial Myopia and Transparency in ESG Information: Evidence From the Textual Analysis of ESG Disclosures. *Corp. Soc. Responsib. Environ. Manag.* **2025**, *32*, 5469–5489. [CrossRef]
33. Chen, C.; Wang, T.; Jia, X. Short-Termism in Financial Decision-Making: Uncovering the Influence of Managerial Myopia on Corporate Financial Asset Allocation through MD&A Textual Analysis. *Int. Rev. Financ. Anal.* **2023**, *90*, 102900. [CrossRef]
34. Tang, C.; Liu, L.; Xiao, X. How Do Firms' Knowledge Base and Industrial Knowledge Networks Co-Affect Firm Innovation? *IEEE Trans. Eng. Manag.* **2023**, *70*, 29–39. [CrossRef]
35. Herstad, S.J.; Aslesen, H.W.; Ebersberger, B. On Industrial Knowledge Bases, Commercial Opportunities and Global Innovation Network Linkages. *Res. Policy* **2014**, *43*, 495–504. [CrossRef]
36. Zeng, J.; Ning, Z.; Lassala, C.; Ribeiro-Navarrete, S. Effect of Innovative-City Pilot Policy on Industry–University–Research Collaborative Innovation. *J. Bus. Res.* **2023**, *162*, 113867. [CrossRef]
37. Zhao, J.; Fu, C. Ego-Network Stability or Ego-Network Expansion? The Effects of Ego-Network Dynamics on Recombinant Innovation under Heterogeneous Knowledge Base. *J. Knowl. Manag.* **2024**, *28*, 1278–1308. [CrossRef]
38. Carlo, J.L.; Lyytinen, K.; Rose, G.M. A Knowledge-Based Model of Radical Innovation in Small Software Firms. *MIS Q.* **2012**, *36*, 865–895. [CrossRef]
39. Suo, W.; Qiao, P. Patient Capital, Green Innovation Bubble, and Corporate ESG Performance. *Financ. Res. Lett.* **2025**, *86*, 108803. [CrossRef]
40. Pang, Y.; Guo, R.; Zhao, Y.; Dong, L. Exploring the Impact of Traditional Cultural Intensity and Patient Capital on Sustainable Green Innovation in Listed Companies: A Mediation and Heterogeneity Analysis. *Int. Rev. Econ. Financ.* **2025**, *103*, 104583. [CrossRef]
41. Geng, X.; Liu, J.; Dai, M. How Government-Guided Funds Cultivate and Expand Patient Capital in China's GEM Market? *Int. Rev. Financ. Anal.* **2026**, *110*, 104871. [CrossRef]
42. Wang, J.; Yang, Y.; Li, L. Digital Infrastructure Construction, Patient Capital, and Corporate Digital Technology Innovation. *Financ. Res. Lett.* **2026**, *89*, 109243. [CrossRef]
43. Liang, S.; Wang, S. Venture Capital, Investor Patience, and Corporate Innovation: Evidence from China. *Int. Rev. Econ. Financ.* **2026**, *108*, 105194. [CrossRef]
44. Sun, Q.; Zhang, C.; Yao, Y. Patient Capital and Firm Green Low-Carbon Cycle Innovation. *Financ. Res. Lett.* **2026**, *91*, 109439. [CrossRef]
45. Solodoha, E. Who Sees the Risk? Innovation, Information Asymmetry, and Investor Origin in Startup Evaluation. *J. Bus. Strategy* **2026**, *47*, 321–338. [CrossRef]
46. Liu, J.; Chen, J.; Zhao, Y.; Forrest, J.Y.-L.; Song, M.C. How Does Generative Artificial Intelligence Promote Firms' Key Core Technological Innovation? *Socio-Econ. Plan. Sci.* **2026**, *105*, 102453. [CrossRef]
47. Lu, J.; Li, Z.; Chen, X.-L.; Yu, X.; Song, M. The Influence of China's Low-Carbon City Pilot Policy on the Green Innovation of Enterprises in the Context of Carbon Neutrality. *J. Innov. Knowl.* **2025**, *10*, 100814. [CrossRef]

48. Rong, Z.; Wu, X.; Boeing, P. The Effect of Institutional Ownership on Firm Innovation: Evidence from Chinese Listed Firms. *Res. Policy* **2017**, *46*, 1533–1551. [CrossRef]
49. Cai, X.; Lu, Y.; Wu, M.; Yu, L. Does Environmental Regulation Drive Away Inbound Foreign Direct Investment? Evidence from a Quasi-Natural Experiment in China. *J. Dev. Econ.* **2016**, *123*, 73–85. [CrossRef]
50. Goodman-Bacon, A. Difference-in-Differences with Variation in Treatment Timing. *J. Econom.* **2021**, *225*, 254–277. [CrossRef]
51. Callaway, B.; Sant'Anna, P.H.C. Difference-in-Differences with Multiple Time Periods. *J. Econom.* **2021**, *225*, 200–230. [CrossRef]
52. Borusyak, K.; Jaravel, X.; Spiess, J. Revisiting Event-Study Designs: Robust and Efficient Estimation. *Rev. Econ. Stud.* **2024**, *91*, 3253–3285. [CrossRef]
53. Wei, H.; Zhang, J. Unlocking the Data Bottleneck: How Data Factor Marketization Drives the Smart-Green Synergistic Transformation of SEIs. *Technol. Soc.* **2026**, *88*, 103490. [CrossRef]
54. He, W.; Zhang, Z.; Li, W. Information Technology Solutions, Challenges, and Suggestions for Tackling the COVID-19 Pandemic. *Int. J. Inf. Manag.* **2021**, *57*, 102287. [CrossRef]
55. Tong, Z.; Zhang, B.; Wu, Z.; Ma, J. Managerial Myopia and Firms' Competitive Strategies: The Inhibitory Effect on Differentiation. *J. Bus. Res.* **2026**, *208*, 116087. [CrossRef]
56. Ilori, M.O.; Irefin, I.A. Technology Decision Making in Organisations. *Technovation* **1997**, *17*, 153–160. [CrossRef]
57. Wu, L.; Liu, S.; Qi, L.; Lin, D. Mandatory Disclosure and Corporate ESG Performance: Evidence from China's "Explanation for Nondisclosure" Requirement. *Corp. Soc. Responsib. Environ. Manag.* **2025**, *32*, 176–191. [CrossRef]
58. Carnabuci, G.; Operti, E. Where Do Firms' Recombinant Capabilities Come from? Intraorganizational Networks, Knowledge, and Firms' Ability to Innovate through Technological Recombination. *Strateg. Manag. J.* **2013**, *34*, 1591–1613. [CrossRef]
59. Zhang, H.; Zhang, W.; Yi, X. Patient Capital and Corporate Digital Transformation: Evidence from Chinese A-Share Listed Firms. *Pac.-Basin Financ. J.* **2026**, *95*, 102977. [CrossRef]
60. Yang, Y.; Cheng, Q.; Liu, Y. Board Structure and Corporate Strategic Aggressiveness—An Examination Based on the Double Machine Learning Method. *China Econ. Rev.* **2025**, *92*, 102422. [CrossRef]