China Economic Review 63 (2020) 101532

Contents lists available at ScienceDirect

China Economic Review

journal homepage: www.elsevier.com/locate/chieco

Does participating in the standards-setting process promote innovation? Evidence from China

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ARTICLE INFO

Keywords:
Standards setting
Corporate innovation
Conference
SOEs

ABSTRACT

This paper provides novel empirical evidence on the positive effect of standards-setting involvements on corporate innovation in China, reflecting in improving the patent quantity and patent quality. This kind of positive effect increases as the firm's top management team quality increases. We also show that the positive effect of standards-setting involvements is more evident for state-owned enterprises than non-state-owned enterprises due to the unique features of state-owned enterprises. Our results are robust to a battery of tests, including the use of alternative model specifications, firm fixed effects, the instrumental variable approach, potential omitted variables, and propensity score matching procedure. Further analysis reveals that standards-setting involvements foster innovation mainly through improving firms' R&D efficiency, reducing financial constraints, and inducing collaborative innovation. Overall, our findings suggest that standards-setting involvements matter for corporate innovation in China.

1. Introduction

Corporate innovation has become an increasingly important topic which keeps attracting attention from academic researchers in recent years. Innovations are essential drivers of economic growth (Solow, 1957) and constitute firms' competitive advantages (Baer, 2012; Porter, 1992), so a large number of studies have explored the positive and negative empirical links between innovation and various characteristics. He and Tian (2018) reviews the literature on how firm-level characteristics (such as venture capital, firms' internal and external features, etc.), market-wide economic forces (such as product market competition, banking competition, market conditions, etc.) and macro-level characteristics (such as a nation's institutional features, laws and policies, financial market development, etc.) affect innovation outputs. However, no existing literature has examined the link between standards-setting involvements and corporate innovation.

According to the definitions of the Agreement on Technical Barriers to Trade of the World Trade Organization (Appleton, 2005), a standard is a document approved by a recognized body, that provides, for common and repeated use, rules, guidelines, or characteristics for products or related processes and production methods. It may also include or deal exclusively with terminology, symbols, packaging, marking, or labeling requirements as they apply to a product, process, or production method. We grow in awareness that standards play an increasingly significant role in scientific and technological progress and industrial development. If there is no uniform standard constraint, firms will apply various standards, which will inevitably lead to a chaotic situation in the market and do considerable damage to the development of the market economy.

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https://doi.org/10.1016/j.chieco.2020.101532
Received 18 March 2019; Received in revised form 27 May 2020; Accepted 28 July 2020
Available online 01 August 2020
1043-951X/

The Standardization Law of the People's Republic of China classifies China's standards into the following four hierarchical categories: national standards, professional standards (often referred to as "industry standards"), local standards, and enterprise standards. For any given product or service, only one type of Chinese standards will apply. National standards are at the top of the vertical hierarchy. Standards of lower levels only can be developed and applied when no higher-level standards exist and should be repealed once higher-level standards specifying the same technical requirements are published.[1] Because only national standards and professional standards apply nationwide, we only study these two kinds of standards in this paper. Although national standards are formulated by the Standardization Administration of China (SAC) and professional standards are developed by qualified administrative authorities, their setting processes are both managed by the Chinese government. Meanwhile, China's standardization system classifies national standards and industry standards into the compulsory (often referred to as "the mandatory") and the voluntary (often referred to as "the recommended"). The number of compulsory standards is much smaller than that of voluntary standards and the range of compulsory standards is quite narrow, which mainly concentrates in areas related to personal health, property safety, and national security. Compulsory standards usually originate from recommended standards and lead the way of the industry together with recommended standards. Although the recommended standards are not rules that all the firms must comply with by law, they are still normative standards which are the benchmarks and represent the future development trend in the industry. Therefore, most of the firms will establish an industry self-discipline mechanism (Christmann & Taylor, 2001). For example, to make products more attractive, firms will claim that they have adopted recommended standards on the outer package or quote recommended standards in contracts. In addition, the government will offer preferential measures to encourage firms to adopt the recommended standards (Zhao & Graham, 2006; Zhou, 2006). In summary, mandatory standards and recommended standards are both significant and cannot be ignored by firms.

In fact, the Chinese government has attached importance to standards setting since ancient times and believes it conducive to promoting production and trade. China aimed at unifying tracks, characters, weights, and measurements two thousand years ago in the Qin dynasty. Since the establishment of new China in 1949, China's standardization system has been mainly adopted from the Soviet Union for a long time. That is, the administrative departments are in charge of developing plans, formulating, issuing, and enforcing new standards. As China's economy changes from a planned economy to a market economy, China has been gradually adjusting its standardization system, paying more attention to market demand and international trend and starting to invite firms to involve in the standards-setting process. The major change happened in 2001 when China joined the WTO, China has established a standards-setting principle of "wide participation, full coordination, and openness and transparency" to meet the requirements of the WTO. In 2018, China began to implement the firstly revised standardization law, which was issued in 1989, clarifying the responsibilities of government departments and firms. In order to improve the quality and expand the international influence of Chinese standards, firms are playing an increasingly significant role under the guidance of the Chinese government. Under China's current standards-setting system, any government agencies, industry associations, firms, institutions, or even individuals can apply for the revision of standards. Then, the relevant government agency will review and determine whether to approve the proposal. If it is approved, the government agency will invite some qualified firms, universities, and research institutions that are constituted as the chief editorial unit and participating editorial unit to involve in the standards-setting process. The draft standards prepared after sufficient discussion by editorial units are subject to review and revision by the government agency before they can be formally implemented.

On the other hand, the importance of participating in the standards-setting process has long been recognized by Chinese firms. As the saying goes, "First-class firms set standards, second-class firms develop technology, and third-class firms make products.[2]" In other words, if a firm cannot participate in the process of standards setting, it means this firm can only play the game where others formulate the rules. Although participating in the process of standards-setting costs a certain amount of human, financial, and time resources, and sometimes the firm needs to fund the standard drafting work, these costs are negligible compared to the benefits of standards-setting involvement.

Firstly, the process of setting standards is like the process of formulating game competition rules, which can effectively help firms involving in the standards setting avoid industry competition. On the one hand, participants tend to incorporate their patents into the standards. The economic benefits of patents will be maximized once they are included in the standard because standards can disseminate patents (Page & Lopatka, 1999). On the other hand, participants can propose the terminology names or technical indicators conducive to their development and make their voice count, so it is usually not necessary for them to widely adjust their production plans in order to meet new standards. Secondly, the process of drafting standards can take a relatively long time so that firms involved in the standards setting can grab chances in production. For instance, they can timely adjust the procurement of raw materials and manufacturing processes to avoid waste due to failure to meet the new standards. Finally, participation in standards setting can make the public have favorable impressions about the firm. Because the standards are issued by government authorities, the ability for a firm to involve in the process indicates that the firm is influential and authoritative in the industry, which makes the consumers more reliant on the firm's products.

Given the vast advantages of participating in standards setting, not most or all firms can engage in these activities. This is mainly caused by China's government-leading standard management system. It is simple and easy for the government to select a small

[1] For example, firm standards are usually complementary to corresponding national and industry standards or stricter than national and industry standards. Stricter standards are not just as simple as several different parameters. Firms with stricter firm standards may have significantly different R&D directions because there exist many branches in the subdivision of R&D.

[2] This is a popular saying in contemporary Chinese business and government circles, thought to have originated with Sony.

number of qualified participants to standard for the majority, which helps the government save costs and develop a better understanding of the market. As mentioned above, firms are not eligible to participate in the standards-setting process unless they are invited by the government or the chief editorial unit. The size of the invited firms not necessarily ranks top in the industry, but their certain categories must be at the forefront, or they have formed self-characteristics in terms of the technology or craftsmanship. In other words, the technical personnel or products of the invited firms should have a high impact in the industry.

Both the Chinese government and firms believe that standards-setting involvements by firms are essential; however, the empirical relationship between standards-setting involvements and corporate innovation has not been verified. We fill this void by examining the effects of standards-setting involvements on corporate innovation in an emerging market, China. Using a large panel of Chinese listed firms from 2006 to 2015, we document that standards-setting involvements matter for corporate innovation in China. Specifically, our main results show that the number of standards-setting involvements of a firm is significantly and positively related to its innovation quantity and quality. Besides, a series of robustness tests ensure that our results are robust to alternative model specifications and variable definitions. Then, we investigate the mediating effect of the top management team quality in the relations between standards-setting involvements and corporate innovation. Considering the unique features of SOEs, we suggest and confirm that standards-setting involvements have a more significant impact on the innovation outputs of state-owned enterprises compared to non-state-owned enterprises.

Then, we use several approaches to alleviate the concern about endogeneity. Apart from using the one-period lag values of independent variables and applying firm fixed effects to address the potential problems arising from omitted time-invariant firm-specific characteristics, we employ the instrumental variable approach, tests for omitted variables, and the propensity score matching (PSM) model to further address the problem of endogeneity and find that our main results still hold. We further analyze potential mechanisms about the causality between standards-setting involvements and corporate innovation and show that standards-setting involvements increase the firm's innovation ability mainly through improving R&D efficiency, reducing financial constraints, and inducing collaborative innovation. In summary, our evidence is consistent with the notion that standards-setting involvements foster corporate innovation in emerging markets like China.

This paper makes the following three contributions. First, our study enriches the limited literature on the economic significance of standards-setting involvements by firms. Although the involvements in standards-setting activities are essential, little empirical evidence is available about the relationship between standards-setting involvements and corporate behavior. Apart from mergers and acquisitions (Banerjee & Chakrabarti, 2017), we investigate the relationship between standards-setting involvements and corporate innovation, which is a significant and exciting research direction.

Second, when it comes to the influence of a firm's external governance on corporate innovation, the existing literature only explores the factor of antitakeover terms set by the firm against external acquisitions.[3] To the best of our knowledge, we are among the first to show how standards-setting involvements affect corporate innovation. Our findings shed light on the positive role of standards-setting involvements, as important external activities, in firm value creation via innovation quantity and quality. Besides, we propose and empirically verify the potential influence mechanisms between standards-setting involvements and corporate innovation.

Finally, our data are more reasonable and reliable. On the one hand, patent citation counts are recognized as the most proper indicator for measuring the quality of patents (Nagaoka, Motohashi, & Goto, 2010), but there is no available open patent citation data of Chinese firms. Therefore, most of the existing literature uses alternative indicators such as the ratio of invention patents to all kinds of patents and the number of filed patents per unit R&D input. In order to better characterize the quality of patents, we have purchased the Dawei Innojoy Patent Database in which the patent index contains patent citation counts for each patent, trying to make our results more reliable. On the other hand, different from the approach which includes all patent types in previous literature, we do not study design patents due to the consideration of the International Patent Classification (IPC) and measurement criteria between invention and utility model patents and design patents.

The rest of this paper is organized as follows: Section 2 provides an additional discussion of related literature and develops our hypotheses. Section 3 introduces the research design. Section 4 describes the main empirical results. Section 5 addresses the endogeneity issues using specific approaches and conducts the channel tests. Section 6 summarizes the paper.

2. Related literature and hypotheses development

2.1. Related literature

By examining the impact of standards-setting involvements on corporate innovation, we bring together two different strands of literature.

The first strand of researches focuses on the driving forces of corporate innovation. Based on the framework proposed by Holmstrom (1989) and Manso (2011), empirical studies have identified various factors, especially firm characteristics, stimulating corporate innovation. Existing firm-level researches cover external environment of firms which cannot be directly controlled by shareholders and internal characteristics that are mainly within the control of shareholders, including managerial characteristics, internal governance (such as designing proper incentives for managers and monitoring systems), external governance (such as firms' external innovation activities) and so on.

[3] A more detailed discussion about external governance will be given in section 2.

We can find plenty of literature that relates the external environment of a firm to its innovation activities. For example, He and Tian (2013) show that financial analysts might have exerted so much pressure on managers to meet short-term targets that the more analyst coverage is, the fewer patents the firm produces. Brav, Jiang, Ma, and Tian (2018) find that firms targeted by hedge fund activists are likely to produce more innovation outputs because the intervention of hedge fund can reduce firms' R&D expenditures, reallocate innovative resources and redeploy their human capital.

Beyond the external environment that cannot be controlled by shareholders, firm-level determinants of corporate innovation have also been fully explored. There is a great deal of literature studying the effect of specific managerial characteristics and experiences on corporate innovation. These characteristics and experiences include managerial ability (Chen, Podolski, & Veeraraghavan, 2015), managerial foreign experience (Yuan & Wen, 2018), managerial political connections (Cheng, Cheng, & Zhuang, 2019), CEO confidence (Galasso & Simcoe, 2011; Hirshleifer, Low, & Teoh, 2012), CEO' general skills (Custódio, Ferreira, & Matos, 2017) and so on.

Meanwhile, some papers examine the role of internal governance in affecting innovation. Jia, Tian, and Zhang (2016) use dispersion in pay-for-performance sensitivities (PPS) among top executives to stand for the synergy component of a management team's incentive and show that when PPS dispersion is above the optimal level, the innovation performance will deteriorate. Balsmeier, Fleming, and Manso (2017) suggest that greater oversight by the corporate board might improve the focus and productivity of managers but does not help increase innovative exploration. Xu, Kong, and Kong (2017) find that the pay gap between the management and ordinary employees could facilitate corporate innovation, which confirms that the tournament theory dominates in innovation activities.

Besides exploring the potential influence of internal governance, we can find limited studies trying to explain how external management affects the innovation outputs. Atanassov (2013) detects a significant decrease in the number and quality of patents for firms incorporated in states that pass antitakeover laws relative to firms incorporated in states that do not. However, his findings have been challenged by Chemmanur and Tian (2018), who point out that firm-level antitakeover provisions may have a positive and causal effect on innovation outcomes. Besides the takeover activities, almost no literature studies the impact of firms' external activities on innovation outputs, especially government-related activities. We are the first one to focus on the role of standards-setting involvements in corporate innovation, which is still an underexplored topic in the literature.

Secondly, our paper contributes to the literature on standards setting. An interesting topic concerning standards setting is the integration, conflict, and coordination of standards and patents. Some researchers support the combination of some patents and technical standards and think it essential for economic development (see Layne-Farrar, Padilla, & Schmalensee, 2007; Stern, 2003), while others believe that the integration of patents and standards is likely to increase legal actions, so although we should encourage innovation, patents cannot be included in the standards (see Herr, 2009; Swanson & Baumol, 2005).

So far, the economic significance of innovation has been fully explored, but the literature on the political economics of standards setting is still limited. For example, Mattli (2001) summarizes the economic and political salience of international institutional standards setting. Teece and Sherry (2002) identify several ways in which antitrust regulations and intellectual property interplay during the standards-setting process. Banerjee and Chakrabarti (2017) look into the role of Standard-Setting Organizations (SSOs) in Cross-Border Mergers and Acquisitions and find that SSO membership tends to be associated with more extensive deals. What is more, few studies examine the relation between standards setting and corporate performance. Montabon, Melnyk, Sroufe, and Calantone (2000) point out that the series of ISO 14000 standards can positively influence both the performance of the environmental management system as well as overall corporate performance, though the acceptance of these standards is relatively low. In a related paper, Naser, Karbhari, and Mokhtar (2004) conduct an empirical investigation into the determinants of corporate performance and find that ISO 9000 registration does affect the performance of the sampled Malaysian listed companies.

In addition to discussing the relationship between standards and related economic factors, the involvement of different agents in the standards-setting process has also been explored. Harding and Mckinnon (1997) examine whether users require direct involvement in the standards-setting process. Henson, Preibisch, and Masakure (2001) review the needs and potential constraints of participation of developing countries in the setting of international standards. Our study adds to this literature by showing that the involvements of firms in the standards-setting process benefit their corporate innovation.

2.2. Hypotheses development

To understand how corporate innovation fits into the standards-setting process, we propose the following hypotheses.

Firstly, standards-setting involvements contribute to improving firms' innovation efficiency. The standard is a normative document that needs to achieve optimal orders within a certain range and can be reused, so it usually takes a long time (mostly more than one year in China) for the standards to be drafted, formulated, modified, approved, etc. As a result, when firms without standards-setting involvements see the newly issued standards and think about how to make related technical adjustments, the participants may have already started adjusting the direction of the future R&D expenditures, though there is a buffer period from the announcement to the official implementation. This leading period helps the participants avoid wasting additional capital investment and improve innovation efficiency. Huawei's business philosophy of "leading half a step" in technology illustrates this channel well. Huawei believes it necessary to maintain its leading position in technology, but it can only be half a step ahead of its competitors; otherwise, Huawei will become a "martyr" if leading three steps. One good way for Huawei to maintain half a step ahead is to participate in the standards-setting process, which helps it keep abreast of the latest developments in the industry and not deviate from the route too far. Huawei has actively participated in various standards-setting meetings at home and abroad, and finally became the global leader in the 5G era from the chasers in the 3G and 4G eras. At the 87th meeting of 3GPP RAN1, the Polar Code promoted by Huawei was finally adopted by 3GPP and became the coding scheme for the uplink and downlink in the 5G control channel. Meanwhile, the Low-

Density Parity-Check (LDPC) Code promoted by Qualcomm became the coding scheme for the 5G data channel.

In addition, firms not participating in the standards setting only see the results of the standards-setting process, while the participants have experienced the entire process, which will result in a strong information asymmetry between them. Blind and Jungmittag (2008) emphasize that standards are a collection of knowledge and technical expertise in a particular field. However, for firms that do not involve in the standards setting, the setting process is like a "black box". They do not know what proposals have been rejected, or what kinds of technology are promising to become the standards candidates in the next standards-setting process, causing it difficult to accurately grasp the direction of R&D investment and possibly do harm to corporate innovation. So, our first hypothesis is:

H1. : Standards-setting involvements may benefit the firms' innovation outputs through improving R&D efficiency.

Secondly, standards-setting involvements can release positive signals and attract investors in the market. Since China's standardization system is mainly dominated by the government and only limited firms can participate, the ability to involve in the standards-setting process is a reflection of the firm's influence and authority in the industry. In other words, the participation helps the firm form a good reputation. Smith, Smith, and Wang (2010) empirically demonstrate that the firm's good image indeed help improve its financial performance and market value, maintain an attractive investment environment, and reduce financing cost. The lower cost of capital can both significantly increase firms' R&D expenditures (Hall, 2002) and the likelihood that firms have innovative activities (Canepa & Stoneman, 2007; Savignac, 2008). So, we propose our second propose:

H2. : Standards-setting involvements may help spur technological innovation by reducing financial constraints.

Finally, standards-setting involvements are helpful in attracting innovation partners. In the process of standards setting, participants tend to incorporate technical specifications or patents beneficial to their interests into standards. Mattli (2001) highlights that more competitive firms will seek to produce standards to exploit their lead, while less competitive firms will often seek to use standards that are incompatible with those used by their competitive rivals. Riker (1962) and Lehr (1992) also believe that a winning coalition of firms might promote the adoption of a technology which exploits minority interests. By doing so, participants can retain their existing technical achievements to the greatest extent and thus take sustainable leadership in this technical field through technology accumulations (Lieberman & Montgomery, 1988; Pavitt, 1988).

Considering this, other firms, facing increasing competition from the industry, may choose to undertake their innovation projects outside of firm boundaries in collaboration with firms participating in the standards setting. Thus, standards-setting involvements can help participants draw potential high-quality innovation partners. The collaboration among firms is conducive to knowledge transfer, organizational learning, and sharing ideas, which supports the effectiveness of corporate innovations (Faems, Van Looy, & Debackere, 2005; Paulus & Nijstad, 2003). Thus, our third hypothesis is:

H3. : Standards-setting involvements may benefit corporate innovation through intensifying collaborative innovation.

3. Research design

3.1. Data sources

We select listed manufacturing firms on the Shanghai Stock Exchange (SHSE) and Shenzhen Stock Exchange (SZSE) during the period of 2006–2015 as our research sample. Following previous literature, we exclude firms of types as ST and *ST.[4] Then, we remove observations which only have one-year valid data as lagged variables are used in the paper. After employing the above restrictions, we get a final sample consisting of 11,183 observations.

We obtain the data in the following sources: the quantities of firms' invention and utility model patents come from the Chinese Innovation Research Database of Chinese Research Data Services Platform (CNRDS, https://www.cnrds.com). Due to the unavailability of China's patent citation data in previous studies, we bought the patent citation data from the Dawei Innojoy Patent Database (https://www.innojoy.com), which is a suitable indicator of patent quantity. The standards-setting involvement data are manually collected from the Wanfang Standards Database (WFSD, http://g.wanfangdata.com.cn). The relevant financial and corporate data used in this paper are obtained from the WIND database (https://www.wind.com.cn), China Stock Market & Accounting Research database (CSMAR, http://cn.gtadata.com), and corporate annual reports. All the data are cross-checked for consistency.

3.2. Model

First, following previous studies (He & Tian, 2013; Kortum & Lerner, 2000), we employ the OLS regression model to examine the effect of a firm's standards-setting involvements on its innovation outputs. The basic empirical model is:

[4] According to the rules of the two stock exchanges in China, an "other risk warning" (ST) will be added as a prefix to a firm's project code if it is hard for investors to judge the firm's prospects, in which condition the investors' interests are likely to be damaged. If a listed firm has abnormal financial conditions or other abnormal circumstances which will increase the risk of being delisted, a "delisting risk warning" (*ST) will be added as a prefix to its project code. Specific rules can be found at http://www.sse.com.cn. We eliminate the ST and *ST firms because such firms may have strong motivations to manage their earnings, which will make their financial data unreliable and the regression results biased.

$$\ln(Innovation_{i,t} + 1) = \alpha + \beta Standards_{i,t-1} + \gamma X_{i,t-1} + \delta Year_t + \varepsilon_{i,t} \quad (1)$$

where *Innovation* represents our innovation measures (*Patents*, *Inventions*, *Citations*) of firm *i* in year *t*, while *Standards* is the test variable, which measures a firm's standards-setting involvements in the year*t* - 1. *X* refers to the set of control variables including ln(*R&D*), *ln*(*Assets*), *Leverage*, *ln*(*PPE/#employees*), *ln*(*Sales/#employees*), *ROA*, *M/B*, *Sales growth*, *Cash/Assets*, *Stock volatility*, *Stock return*, *Herfindahl*, *Herfindahl square*, which will be described in detail in Section 3.3.3. Moreover, we add the year dummy to control for the dynamic macroeconomic changes.

All the main variables are defined in Appendix A, and all the continuous variables are winsorized at the 1% level at both tails of their distributions to mitigate the undue influence of extreme values. To reduce the potential endogeneity, we regress the contemporaneous innovation measures on the one-period lag values of *Standards* and other independent variables. At last, we make heteroscedastic adjustments to the standard error in all regression models to obtain more accurate t-statistics.

3.3. Variables

3.3.1. Dependent variable

Following prior studies (e.g., Chen et al., 2015), we mainly employ two patent-based metrics to measure innovation quantity. The first measure, ln(*Patents* + 1), is the natural logarithm of one plus the sum of firm i's granted invention and utility model patent counts.[5] Considering that invention patents have higher technical contents and are more important to firms, so our second measure, ln(*Inventions* + 1), is the natural logarithm of one plus firm i's granted invention patents.

According to Trajtenberg (1990), however, patents vary widely in their technological and economic significance, so patent counts cannot entirely capture firms' innovation success. Hall, Jaffe, and Trajtenberg (2001, 2005) argue that the number of forward citations of a patent is a suitable indicator to measure its quality. Nonetheless, the raw citation data may suffer from a truncation bias due to finite sample period. That is, patents in the latest years have less time to accumulate citations than those in the earlier years. Hence, we employ the weighting index proposed by Hall et al. (2001, 2005), which is created by constructing a quasi-structural model and multiply it with each patent's raw citation counts. Therefore, our third measure of innovation, ln(*Citations* + 1), is the total number of the adjusted citations ultimately received by the patents applied for during the given year.

3.3.2. Test variable

We use two variables to measure standards-setting involvements. The first one is *StandardsNum*, which is the number of standards-setting processes in which a firm has participated during a year. The other one is *StandardsDum*, a dummy variable which equals to 1 if a firm has involved in at least one standards-setting process in a given year, 0 otherwise.[6]

3.3.3. Control variables

To isolate the effect of standards-setting involvements on innovation outputs, we control for a vector of firm characteristics that have been shown to affect innovation activities by previous studies.

Atanassov (2013) argues that along with physical and human capital, the efforts and creativity of managers and employees, R&D expenditures are a crucial input to innovation outputs, so our first control variable is the natural log of research and development expenditures (*ln*(*R&D*)). Then, we use the natural log of total assets (*ln*(*Assets*)) to account for firm size because large and capital-intensive firms usually generate more patents (Hall & Ziedonis, 2001). The leverage ratio (*Leverage*) is added to control for the effects of a firm's capital structure on innovation. The log of the net property, plant and equipment (PPE) scaled by the number of employees (*ln*(*PPE/#employees*)) is included to proxy for capital intensity as higher capital intensity may result in higher innovation productivity. Then, the log of the net sales scaled by the number of employees (*ln*(*Sales/#employees*)) is employed to capture labor productivity and quality. We use return on assets (*ROA*) to control for a firm's operating productivity. Also added are *Sales growth* and the market-to-book ratio (*M/B*) as proxies for growth opportunities. To control for the impact of cash holdings on innovation outputs, we include the cash-to-assets ratio (*Cash/Assets*) as a control variable. Additionally, the buy-and-hold stock return calculated over the fiscal year (*Stock return*) and the standard deviation of daily stock returns over the fiscal year (*Stock volatility*) are used as indicators for stock performance and uncertainty (Chan, Lakonishok, & Sougiannis, 2001). Due to the inverted U-shape relation between product market competition and innovation outcomes (Aghion, Bloom, Blundell, Griffith, & Howitt, 2005), we include the Herfindahl index (*Herfindahl*) and its squared term (*Herfindahl square*) to control for the extent of market competition as the way Chemmanur and Tian (2018) do.

4. Main results

4.1. Descriptive statistics

Table 1 shows the descriptive statistics for the variables employed in our regressions. For our corporate innovation measures, an

[5] The patent data used in this paper are drawn from the China National Intellectual Property Administration (CNIPA). According to the International Patent Classification (IPC), design patents belong to the design category, so there are other classification methods for them.

[6] We did not distinguish compulsory standards and voluntary standards in the empirical analysis because the number of mandatory standards is so small that we can ignore it in the sample data.

Table 1
Descriptive statistics.

Variables	N	Mean	Std	Median	Min	Max
Panel A: Variables of innovation						
Patents	11,183	19.4629	125.4345	2.0000	0.0000	5516.0000
Inventions	11,183	7.7074	81.6035	0.0000	0.0000	3667.0000
Citations	11,183	27.6718	235.4744	1.6639	0.0000	9363.7231
Panel B: Variables of standards						
StandardsNum	11,183	0.5852	1.6609	0.0000	0.0000	10.0000
StandardsDum	11,183	0.1971	0.3978	0.0000	0.0000	1.0000
Panel C: Control variables						
R&D (in ¥1000)	11,183	78,292.2073	201,707.0044	23,100.0000	0.0000	1,550,000.0000
Assets (in ¥millions)	11,183	6350.3755	17,633.9212	2226.7292	17.9612	511,630.6908
Leverage	11,183	0.4205	0.2113	0.4150	0.0479	0.9925
PPE/#employees (in ¥1000)	11,183	390.2248	1088.1927	239.9877	2.2014	46,569.8170
Sales/#employees (in ¥1000)	11,183	1120.3332	5312.2827	666.0520	4.1471	360,254.5893
ROA	11,183	0.0493	0.0534	0.0480	−0.2005	0.1953
M/B	11,183	0.7774	0.6792	0.5639	0.0981	3.7962
Sales growth	11,183	0.2320	0.2429	0.1647	0.0032	1.5369
Cash/Assets	11,183	0.2434	0.1548	0.2038	0.0159	0.7064
Stock volatility	11,183	0.5006	0.1505	0.4655	0.2307	0.9315
Stock return	11,183	0.3955	0.8047	0.1656	−0.7171	3.3571
Herfindahl	11,183	0.0812	0.0658	0.0669	0.0175	0.4017

average firm in our sample is granted roughly 8 invention patents and 11 utility model patents and receives 28 adjusted citations each year. The mean and standard deviation of granted patent counts (received citation counts) in a given year is 19.4629 and 125.4345 (27.6718 and 235.4744) respectively, indicating that there is a big difference in the innovation outputs among sample firms. Furthermore, the distributions of patents and citations are highly positively skewed, and the median statistics show that more than half of the firms have no granted invention patent in a given year.

Regarding explanatory variables, only 19.71% of firm-year observations have at least one standards-setting involvement on average, although the number of standards-setting involvements can be as high as ten in some firms. In terms of control variables, the firms in our sample have an average *R&D* of 78.2922 million yuan, *Assets* of 6350.3755 million yuan, *Leverage* of 0.4205, *PPE* of 390, 225 yuan per employee, *Sales* of 1, 120, 333 yuan per employee, *ROA* of 0.0493, *M/B* of 0.7774, *Sales growth* of 0.2320, *Cash/Assets* of 0.2434, *Stock volatility* of 0.5006, *Stock return* of 0.3955, *Herfindahl* of 0.0812.

To see the internal structure of the data more clearly, we present distributions of the sample by year and industry in Panel A and Panel B of Table 2, respectively. Panel A shows that not only does the number of firms participating in at least one standards-setting process increase with time, but their proportion also increases, from 9.19% in 2006 to 29.01% in 2015.[7] From Panel B, we can see that the number of firms with standards is highest of 342 in the industry of manufacture of electrical machinery and equipment, following by 304 in the industry of manufacture of computers, communication and other electronic equipment. Nevertheless, the industry which has the highest percentage of firms with standards is the manufacture of rubber and plastics.

4.2. The baseline model

Table 3 reports the results of OLS regression. These models are derived from two dimensions of innovation, innovation quantity and innovation quality. We find that the coefficients on *StandardsNum* in Columns (1), (3) and (5) are 0.0295, 0.0290 and 0.0362, significant at the 1% level, indicating that every additional participation in standards setting results in an increase in total patents, invention patents, and citations by approximately 2.95%, 2.90% and 3.62%, respectively. Also, the coefficients on *StandardsDum* in Columns (2), (4) and (6) are 0.0963, 0.0879 and 0.1068, significant at the 1% level, suggesting that the total patents, invention patents, and patent citations of firms with standards-setting involvements will be higher by averagely 9.63%, 8.79% and 10.68% than those without any standards-setting involvement. Collectively, these results indicate that standards-setting involvements help promote firms' innovation quantity and quality, both statistically and economically.[8] In addition, we can find that the positive effects of standards-setting involvements on innovation quality are more obvious than the promotion of innovation quantity, whether we use *StandardsNum* or *StandardsDum*. The reason may be that participating in the process of standards setting can help the firm attract higher-quality innovation partners. The coefficients on the control variables are generally consistent with previous literature. For example, ln(*R&D*), *ln*(*Assets*), *ROA*, and *M/B* are positively and significantly related to all the three innovation outputs measures.

Then, we perform several additional tests to ensure that our main results are robust to alternative model specifications and variable definitions. For the sake of brevity, we report the results in Appendix B. In particular, none of the following has a significant

[7] The denominator of the fraction is the number of all the sample firms in a year, not the number of firms in a specific industry. For each process of standards setting, generally only less than 1% of firms participate.

[8] Although there is a significant decrease in the magnitude of the critical coefficients compared with the OLS regression results without firm fixed effects, the estimates remain highly robust, which is consistent with our general argument.

Table 2
Distribution of the sample by year and industry.

Panel A: sample distribution by year.

Year	No. of firms	No. of firms with at least one standards-setting involvement	Firms with at least one standards-setting involvement (%)
2006	664	61	9.19
2007	719	66	9.18
2008	789	108	13.69
2009	848	107	12.62
2010	1102	140	12.70
2011	1291	274	21.22
2012	1403	300	21.38
2013	1391	324	23.29
2014	1435	377	26.27
2015	1541	447	29.01

Panel B: sample distribution by industry groups.

Industry	No. of firms	No. of firms with at least one standards-setting involvement	Firms with at least one standards-setting involvement (%)
Special purpose equipment	992	220	22.18
Manufacture of measuring instruments	132	37	28.03
Other manufacturing	106	7	6.60
Processing of food from agricultural products	299	25	8.36
Raw chemical materials and chemical products	1442	190	13.18
Chemical fiber	244	52	21.31
Medical and pharmaceutical products	1470	31	2.11
Printing and recorded media	65	3	4.62
Manufacture of furniture	43	7	16.28
Comprehensive use of waste resources	23	0	0.00
Manufacture of articles for culture, education, art, sports, and entertainment	52	13	25.00
Smelting and pressing of nonferrous metals	574	153	26.66
Processing of timber, manufacture of wood, bamboo, rattan, palm, and straw products	96	13	13.54
Manufacture of rubber and plastics	334	97	29.04
Manufacture of automobiles	777	148	19.05
Manufacture of electrical machinery and equipment	1308	342	26.15
Leather, furs, down and related products	43	6	13.95
Processing of petroleum, coking, processing of nuclear fuel	173	21	12.14
Manufacture of textiles	371	46	12.40
Manufacture of textiles, clothing; apparel industry	179	20	11.17
Manufacture of computers, communication and other electronic equipment	1917	304	15.86
Manufacture of general-purpose machinery	733	173	23.60
Papermaking and paper products	266	48	18.05
Manufacture of alcohol, beverages, and refined tea	440	50	11.36
Manufacture of metal products	334	75	22.46
Manufacture of railway, ships, aerospace and other transportation equipment	373	12	3.22
Nonmetal mineral products	565	97	17.17
Manufacture of foods	283	21	7.42
Smelting and processing of ferrous metals	361	61	16.90

effect on our results: (a) running Poisson regressions without log-transforming dependent variables; (b) running Negative binomial regressions instead of log-transforming procession; (c) and (d) using *StandardsNum* and *StandardsDum* for two-year lag and three-year lag; (e) excluding firms engaging in mergers and acquisitions in the previous two years to address the concern that firms may acquire patents through takeovers rather than in-house innovation activities incentivized by standards setting; (f) excluding firms that are located in the four first-tier cities in China.

4.3. The mediating effect of top management team quality

According to Chemmanur and Simonyan (2017), firms with higher quality top management teams will provide more substantial R &D expenses, generate greater innovation productivity, and have higher innovation efficiency. Thus, we try to learn the role of top management quality in the effect of standards-setting involvements on innovation outputs.

Referring to Chemmanur, Paeglis, and Simonyan (2011), we combine the following nine variables to measure the quality of a

Table 3
Standards and corporate innovation.

Variables	Ln (1 + Patents)		Ln (1 + Inventions)		Ln (1 + Citations)	
	(1)	(2)	(3)	(4)	(5)	(6)
StandardsNum	0.0295***		0.0290***		0.0362***	
	(0.0075)		(0.0075)		(0.0089)	
StandardsDum		0.0963***		0.0879***		0.1068***
		(0.0304)		(0.0273)		(0.0367)
Ln (R&D)	0.0083**	0.0082**	0.0049*	0.0048*	0.0095**	0.0094**
	(0.0035)	(0.0035)	(0.0029)	(0.0029)	(0.0039)	(0.0039)
Ln (Assets)	0.1960***	0.1982***	0.1415***	0.1439***	0.1816***	0.1847***
	(0.0316)	(0.0318)	(0.0262)	(0.0264)	(0.0350)	(0.0352)
Leverage	0.0338	0.0242	−0.0516	−0.0607	0.0258	0.0146
	(0.1052)	(0.1056)	(0.0845)	(0.0848)	(0.1196)	(0.1202)
Ln (PPE/#employees)	0.0065	0.0077	−0.0179	−0.0167	−0.0002	0.0013
	(0.0249)	(0.0249)	(0.0203)	(0.0203)	(0.0284)	(0.0284)
Ln (Sales/#employees)	−0.0701**	−0.0709**	−0.0546**	−0.0555**	−0.0775**	−0.0786**
	(0.0283)	(0.0283)	(0.0228)	(0.0228)	(0.0322)	(0.0322)
ROA	1.0949***	1.0942***	0.8750***	0.8737***	1.1439***	1.1420***
	(0.2211)	(0.2214)	(0.1790)	(0.1787)	(0.2546)	(0.2551)
M/B	0.0478*	0.0492*	0.0561**	0.0576**	0.0641**	0.0659**
	(0.0274)	(0.0274)	(0.0228)	(0.0228)	(0.0302)	(0.0302)
Sales growth	−0.0021	−0.0022	−0.0058	−0.0060	0.0441	0.0437
	(0.0392)	(0.0393)	(0.0325)	(0.0326)	(0.0458)	(0.0459)
Cash/Assets	−0.0699	−0.0687	−0.1039	−0.1026	−0.0339	−0.0323
	(0.1000)	(0.1002)	(0.0825)	(0.0828)	(0.1172)	(0.1174)
Stock volatility	0.0574	0.0549	−0.0921	−0.0946	0.0772	0.0740
	(0.1284)	(0.1287)	(0.1013)	(0.1015)	(0.1471)	(0.1475)
Stock return	−0.0030	−0.0032	−0.0060	−0.0062	−0.0013	−0.0015
	(0.0176)	(0.0176)	(0.0152)	(0.0152)	(0.0201)	(0.0201)
Herfindahl	1.9501*	1.9271*	0.8260	0.7983	1.2266	1.1898
	(1.1487)	(1.1500)	(0.8985)	(0.9000)	(1.2411)	(1.2432)
Herfindahl^2	−2.9885	−2.8932	−0.3994	−0.2928	−0.8138	−0.6751
	(2.7605)	(2.7560)	(2.0882)	(2.0841)	(2.8933)	(2.8921)
Year fixed effect	YES	YES	YES	YES	YES	YES
Firm fixed effect	YES	YES	YES	YES	YES	YES
Observations	9370	9370	9370	9370	9370	9370
Adjusted R^2	0.7668	0.7667	0.7159	0.7155	0.7290	0.7287

firm's management: (1) the top management team size, (2) the number of MBAs in the top management team, (3) the number of top management team members with financial background, (4) the number of top management team members with academic background, (5) the number of top management team members with a doctoral degree, (6) the number of top management team members with overseas experience, (7) the number of top management team members who are also inventors, (8) the number of top management team members with political background, (9) the number of management team members who served as executives in other public firms prior to joining the firm. We adjust the variables for firm size, firm age and industries and then conduct principal component analysis to get a one-dimensional index of top management team quality (*TMT Quality*).

Then, we re-run the model adding *TMT Quality* and the interaction term with *StandardsNum* and report the results in Table 4. We find that *StandardsNum* and *TMT Quality* are both significantly positively associated with innovation measures, indicating that standards-setting involvements and top management quality can both stimulate innovation quantity and quality. This is in line with the results of Chemmanur and Simonyan (2017). What is more, the coefficients on the interaction term are also significantly positive at the 10% level, which means that if a firm has a higher quality top management team, involving in the standards-setting process will have a more positive effect on corporate innovation. Specifically, for each increase in the *TMT Quality* indicator, the positive effects of standards-setting involvements on corporate innovation will increase by 10% to 20%.

4.4. Heterogeneity analysis of SOEs vs. non-SOEs

Though firms are playing an increasingly significant role in China's standardization system, administrative intervene has still been recognized as a crucial institutional characteristic of the standards-setting process in China (see Gao, Yu, & Lyytinen, 2014; Kshetri, Palvia, & Dai, 2011). Considering the unique features of state-owned enterprises (SOEs) that they are controlled by the government, we want to know how the effect of standards-setting involvements on corporate innovation varies between SOEs and non-SOEs in this section.

Since the interests of SOEs are closely related to the direct interests of the government, and the leaders of SOEs in many industries have administrative treatments given by the government, (i.e., they are "quasi" officials), the government will inevitably make decisions that favor SOEs in the process of standards setting. For example, there are more possibilities for SOEs to be chosen as

Table 4
The mediating effect of top management team quality (TMT quality).

Variables	Ln (1 + Patents)		Ln (1 + Inventions)		Ln (1 + Citations)	
	(1)	(2)	(3)	(4)	(5)	(6)
StandardsNum	0.0292***	0.0282***	0.0288***	0.0275***	0.0359***	0.0349***
	(0.0075)	(0.0075)	(0.0075)	(0.0075)	(0.0089)	(0.0090)
TMT Quality	0.0205***	0.0204***	0.0142***	0.0141***	0.0205***	0.0204***
	(0.0065)	(0.0065)	(0.0054)	(0.0054)	(0.0076)	(0.0076)
StandardsNum × TMT Quality		0.0045*		0.0054**		0.0043*
		(0.0024)		(0.0022)		(0.0026)
Ln (R&D)	0.0082**	0.0080**	0.0048*	0.0046	0.0094**	0.0093**
	(0.0035)	(0.0035)	(0.0029)	(0.0029)	(0.0039)	(0.0039)
Ln (Assets)	0.2054***	0.2051***	0.1480***	0.1477***	0.1910***	0.1907***
	(0.0318)	(0.0318)	(0.0263)	(0.0263)	(0.0353)	(0.0353)
Leverage	0.0376	0.0403	−0.0489	−0.0456	0.0296	0.0323
	(0.1051)	(0.1049)	(0.0845)	(0.0842)	(0.1196)	(0.1194)
Ln (PPE/#employees)	0.0078	0.0093	−0.0170	−0.0152	0.0011	0.0025
	(0.0248)	(0.0248)	(0.0202)	(0.0202)	(0.0283)	(0.0283)
Ln (Sales/#employees)	−0.0695**	−0.0690**	−0.0542**	−0.0536**	−0.0769**	−0.0764**
	(0.0282)	(0.0282)	(0.0227)	(0.0227)	(0.0321)	(0.0321)
ROA	1.0944***	1.0927***	0.8746***	0.8726***	1.1434***	1.1418***
	(0.2214)	(0.2208)	(0.1789)	(0.1783)	(0.2548)	(0.2544)
M/B	0.0484*	0.0467*	0.0565**	0.0545**	0.0647**	0.0630**
	(0.0274)	(0.0274)	(0.0228)	(0.0228)	(0.0302)	(0.0302)
Sales growth	−0.0031	−0.0029	−0.0065	−0.0063	0.0431	0.0433
	(0.0391)	(0.0391)	(0.0325)	(0.0324)	(0.0457)	(0.0457)
Cash/Assets	−0.0679	−0.0678	−0.1025	−0.1024	−0.0318	−0.0317
	(0.0999)	(0.0999)	(0.0824)	(0.0824)	(0.1171)	(0.1171)
Stock volatility	0.0528	0.0480	−0.0953	−0.1010	0.0726	0.0681
	(0.1284)	(0.1284)	(0.1012)	(0.1011)	(0.1471)	(0.1471)
Stock return	−0.0011	−0.0007	−0.0047	−0.0042	0.0006	0.0010
	(0.0176)	(0.0176)	(0.0151)	(0.0151)	(0.0201)	(0.0201)
Herfindahl	1.9705*	1.9081*	0.8401	0.7656	1.2470	1.1877
	(1.1455)	(1.1423)	(0.8969)	(0.8909)	(1.2380)	(1.2359)
Herfindahl^2	−3.0770	−2.9936	−0.4608	−0.3611	−0.9021	−0.8228
	(2.7575)	(2.7569)	(2.0874)	(2.0841)	(2.8902)	(2.8896)
Year fixed effect	YES	YES	YES	YES	YES	YES
Firm fixed effect	YES	YES	YES	YES	YES	YES
Observations	9370	9370	9370	9370	9370	9370
Adjusted R^2	0.7671	0.7673	0.7161	0.7164	0.7293	0.7293

participants of the standards-setting process than non-SOEs. In our sample data, about 21.58% of SOEs can participate in at least one standards-setting process, while the number is 18.47% for non-SOEs. Also, government agencies are more likely to appoint SOEs as the chief editorial unit, leading the participating editorial unit to draw up standards. This endows SOEs a greater voice in the standards-setting process. Besides, as the agent of standards setting, the government may tend to choose the draft terms proposed by SOEs to maximize its own interests. As mentioned above, the advantageous position of SOEs will help incorporate more technologies or technical terms to their interests into standards, which can help them better play the role of technology accumulations. Therefore, with the same chance of involving in the standards setting, SOEs are more likely to show better innovation performance than non-SOEs.

According to actual controllers, we divide the sample enterprises into SOEs and non-SOEs. We employ the dummy variable *SOEs* and the interactive item of *SOEs* and *StandardsNum* in the benchmark model. Table 5 reports the results. The estimated coefficients on the interaction in Column (2), (4) and (6) are significantly positive, indicating that the increase in the number of standards-setting involvements has a more significant effect on the innovation quantity and quality of SOEs than that of non-SOEs, which is consistent with our expectations. Specifically, the promotion effects of standards-setting involvements on corporate innovation of SOEs are more than twice than that of non-SOEs.

5. Endogeneity issues and channel tests

In this section, we first focus on alleviating the concern about endogeneity. Then, we try to explore the possible influence mechanisms of standards-setting involvements on corporate innovation.

5.1. The instrumental variable approach

Although we document a strong positive association between standards-setting involvements and corporate innovation, the results may be driven by two types of endogeneity. The first type is omitted variable bias. While we have controlled for a standard set of

Table 5
SOEs vs. non-SOEs.

Variables	Ln (1 + Patents)		Ln (1 + Inventions)		Ln (1 + Citations)	
	(1)	(2)	(3)	(4)	(5)	(6)
StandardsNum	0.0296***	0.0257***	0.0291***	0.0257***	0.0363***	0.0319***
	(0.0075)	(0.0075)	(0.0075)	(0.0076)	(0.0090)	(0.0090)
SOEs	0.1519**	0.1404**	0.1031*	0.0933	0.1330*	0.1200
	(0.0708)	(0.0707)	(0.0615)	(0.0612)	(0.0767)	(0.0765)
StandardsNum × SOEs		0.0383***		0.0326***		0.0433***
		(0.0099)		(0.0093)		(0.0111)
Ln (R&D)	0.0082**	0.0080**	0.0049*	0.0047	0.0095**	0.0092**
	(0.0035)	(0.0035)	(0.0029)	(0.0029)	(0.0039)	(0.0039)
Ln (Assets)	0.1942***	0.1905***	0.1403***	0.1372***	0.1801***	0.1759***
	(0.0317)	(0.0316)	(0.0263)	(0.0262)	(0.0351)	(0.0350)
Leverage	0.0321	0.0465	−0.0527	−0.0405	0.0244	0.0406
	(0.1049)	(0.1044)	(0.0844)	(0.0842)	(0.1194)	(0.1188)
Ln (PPE/#employees)	0.0055	0.0095	−0.0185	−0.0152	−0.0011	0.0034
	(0.0248)	(0.0247)	(0.0202)	(0.0202)	(0.0284)	(0.0283)
Ln (Sales/#employees)	−0.0697**	−0.0693**	−0.0544**	−0.0541**	−0.0771**	−0.0767**
	(0.0283)	(0.0282)	(0.0228)	(0.0227)	(0.0321)	(0.0321)
ROA	1.1352***	1.1457***	0.9023***	0.9112***	1.1792***	1.1911***
	(0.2228)	(0.2207)	(0.1807)	(0.1797)	(0.2568)	(0.2546)
M/B	0.0450	0.0423	0.0542**	0.0519**	0.0616**	0.0585*
	(0.0274)	(0.0273)	(0.0228)	(0.0228)	(0.0302)	(0.0300)
Sales growth	−0.0037	−0.0047	−0.0069	−0.0077	0.0427	0.0416
	(0.0393)	(0.0391)	(0.0325)	(0.0324)	(0.0458)	(0.0457)
Cash/Assets	−0.0653	−0.0698	−0.1008	−0.1046	−0.0299	−0.0349
	(0.0999)	(0.0997)	(0.0824)	(0.0822)	(0.1171)	(0.1170)
Stock volatility	0.0538	0.0498	−0.0945	−0.0979	0.0741	0.0696
	(0.1281)	(0.1277)	(0.1010)	(0.1008)	(0.1469)	(0.1464)
Stock return	−0.0039	−0.0036	−0.0066	−0.0064	−0.0021	−0.0018
	(0.0176)	(0.0176)	(0.0152)	(0.0151)	(0.0201)	(0.0200)
Herfindahl	1.9054*	1.9468*	0.7957	0.8309	1.1875	1.2342
	(1.1457)	(1.1426)	(0.8976)	(0.8942)	(1.2398)	(1.2376)
Herfindahl^2	−2.9492	−3.1107	−0.3727	−0.5101	−0.7794	−0.9618
	(2.7537)	(2.7519)	(2.0850)	(2.0874)	(2.8882)	(2.8911)
Year fixed effect	YES	YES	YES	YES	YES	YES
Firm fixed effect	YES	YES	YES	YES	YES	YES
Observations	9370	9370	9370	9370	9370	9370
Adjusted R^2	0.7670	0.7675	0.7160	0.7166	0.7291	0.7296

variables that have been shown by prior literature to affect innovation, there may be some omitted variables affecting both the number of standards-setting involvements and corporate innovation. The second one is a reverse causality concern that firms with high innovation are much easier to involve in setting standards. The coefficients estimated from OLS regressions will be biased and inconsistent in both cases.

In addition to using the one-period lag values of independent variables as well as applying firm fixed effects, we further address the potential endogeneity issues in several alternative ways, including the instrumental variable approach, tests for omitted variables, and the propensity score matching (PSM) model. Due to space limitations, we only analyze the instrumental variable estimates here in detail, the results of omitted variables tests and the PSM model, which are consistent with the general argument of the paper, are attached in Appendix C and Appendix D, respectively.

We choose the number of academic conferences held in a province each year (*LocConferencesNum*) as our instrumental variable for *StandardsNum*. The academic conference data collected from the China Conference Proceedings Database include national and international conferences with paper discussions as the main agenda held by various societies, associations, colleges and universities, party and government agencies, scientific research institutions, publishing institutions, enterprises, science and technology association systems, hospitals, key research bases, key laboratories and so on.

On the one hand, a firm is more likely to be the industry leader if it has more standards-setting involvements because the government usually chooses the influential or authoritative firms in the industry (we call this kind of firms industry leaders) to participate in the standards-setting process. When selecting a venue for a standards-setting meeting, the government usually considers the locations of the participants first. Since there is more than one participant, the government will also consider other factors like infrastructures and cultural tourism. Therefore, a region with more standards-setting meetings is more likely to be the place where industry leaders located and have well-integrated infrastructures such as convenient transportation or developed cultural tourism.

Because there is no database collecting the venues of standards-setting processes, we employ the number of academic conferences held in a province each year instead. The bridge connecting standards-setting meetings and academic meetings is that the infrastructure environment and cultural tourism are critical considerations when the organizer chooses the meeting place at the very beginning in both scenarios. The decision to choose the meeting location is usually made before the meeting whether for the government organizing standards-setting meetings for a certain standard or various institutions organizing the academic meeting for a certain academic subject. Although the standards-setting process may take more than one year, it is unlikely for the venue of the meetings to be changed frequently at the provincial level. As a result, once the standards-setting meetings on a certain standard are decided to be held in a certain province (no matter how many meetings are held), we can say that the infrastructure environment or cultural tourism of this province has been recognized by the organizer once. The same is true for academic conferences. Hence, our instrument satisfies the relevance criteria.

On the other hand, the number of academic conferences organized by academic communities does not directly bring an increase in the ability of firms to innovate. Firstly, the academic conferences included in the data are organized by various host units, so the venues of academic conferences may not be gathered in provinces with more universities. Cultural centers or scenic summer resorts may also be considerations. Besides, firms in the province with many universities may not be strong in innovation due to China's incomplete industry-university-research transformation mechanism so far.

Secondly, regions with more industry leaders may have a higher level of economic development. However, the relevance between regional development and corporate innovation is not obvious. We should distinguish between the two concepts of regional development and innovation environment. A good innovation environment can promote innovation outputs of firms in that region. However, regions with a high level of economic development may not necessarily have a good innovation environment. This mainly depends on local political strategies. For example, since the reform and opening-up, China's economic growth has been driven by cheap labor force and technology transfer for a long time, which could not promote innovation. The policy of establishing a good innovation environment was proposed around 2014. We can also understand this point from the Solow model. Fast regional development may be caused by the cheap labor force, enough capital, technology transfer, original technological innovation, or efficient resource allocation of local firms, which indicates that firms in a region with good regional development may not have strong innovative abilities.

Finally, industry leaders do not always have strong innovation capabilities. The "industry leaders" we call in this paper are leaders in the eyes of the government, that is, firms that are qualified to participate in the standards-setting process. When choosing participants, the government usually considers several factors such as product quality, market share and so on. There is no evidence showing that firms with high product quality or large market shares certainly have strong innovation abilities. For example, some fake products (or called "shanzhai products") in China can rival the real ones, that is, their quality can be comparable to the real ones, but the firms producing these fake products are poor in innovation. In fact, improving product quality or developing corporate innovation are production decisions in two directions. Firms with high product quality focus more on strict requirements of key parameters such as performance and durability, while firms with large innovation outputs are more inclined to explore the frontier of related fields. Some firms focus on developing product quality and innovative output at the same time, while some firms only focus on one aspect. The correlation relationship between market share and corporate innovation is also vague. There exist firms occupying large market shares due to innovation, such as Huawei, and there also exist firms that dominate large market shares due to imitation strategies, such as MIUI. In fact, innovation output is not an indicator of profitability. For developing countries such as China, factors like inadequate patent protection mechanisms and high innovation risks make following and imitation (not innovation) the best choice of firms. In a word, innovation ability is not the only consideration of the government when choosing standards-setting participants. Other factors such as product quality, market share, or even political connection may also affect the decision of the government. These factors may be positively related, negatively related, or even irrelevant to corporate innovation, depending on the development strategies and production decisions of different firms. Therefore, our instrument is likely to satisfy the exclusion criteria as well. Taken together, we anticipate *LocConferencesNum* to affect a firm's innovation only through the firm's standards-setting involvement counts.

We apply the Hausman-Wu test to see whether the independent variable is endogenous before formal instrumental variable regression. The results show that the model has endogenous problems which cannot be ignored. Table 6 presents the results obtained by using a two-stage least squares (2SLS) regression. Besides, we also employ alternative methods of generalized method of moments (GMM) and limited information maximum likelihood (LIML) and get consistent results with the two-stage least squares estimations.

Column (1) shows the first-stage regression results. We can see that the coefficients of *LocConferencesNum* are significantly positive, indicating that the number of local academic conferences is positively associated with the number of a firm's standards-setting involvements, which is in line with our expectations. The instrumental variable also passes the relevance test because the F-statistic from the joint test of excluded instruments is 18.01, significant at the 1% level. The second-stage regressions for each of the three dependent variables are reported in Columns (2)–(4). We find that the number of standards-setting involvements is still positively related to $\ln(Patents + 1)$, $ln(Inventions + 1)$, and $ln(Citations + 1)$, all significant at the 5% level. In summary, the instrumental variable estimation results further validate that the standards-setting involvements can promote corporate innovation outputs.

5.2. Channel tests

To verify our hypotheses proposed in Section 2, we will try to explore the empirical evidence of potential mechanisms in which standards-setting involvements motivate corporate innovation in this part.

5.2.1. Standards-setting involvements and R&D efficiency

First, we study if there exists any positive relation between standards-setting involvements and R&D efficiency. Because participants can gain time and information advantages against outsiders of the standards setting, their innovation activities may be more

Table 6
Instrumental variable approach.

Variables	1st Stage	2nd Stage		
	StandardsNum	Ln(1 + Patents)	Ln(1 + Inventions)	Ln(1 + Citations)
	(1)	(2)	(3)	(4)
StandardsNum	N/A	0.7330**	0.5160**	0.6355**
		(0.3227)	(0.2458)	(0.3188)
LocConferencesNum	0.0034***	N/A	N/A	N/A
	(0.0012)			
Ln (R&D)	0.0183***	0.0128	0.0070	0.0159*
	(0.0058)	(0.0085)	(0.0065)	(0.0084)
Ln (Assets)	0.3996***	−0.0224	−0.0137	−0.0111
	(0.0493)	(0.1403)	(0.1068)	(0.1386)
Leverage	−0.5964***	0.4591*	0.2442	0.4622*
	(0.2056)	(0.2592)	(0.1974)	(0.2561)
Ln (PPE/#employees)	−0.0579	0.0729	0.0263	0.0547
	(0.0527)	(0.0504)	(0.0384)	(0.0498)
Ln (Sales/#employees)	0.0102	−0.0731	−0.0672*	−0.0828*
	(0.0557)	(0.0492)	(0.0375)	(0.0486)
ROA	−0.5786	1.0890***	0.9248***	1.1073***
	(0.4323)	(0.4220)	(0.3214)	(0.4169)
M/B	−0.0337	0.0139	0.0552*	0.0208
	(0.0431)	(0.0412)	(0.0314)	(0.0407)
Sales growth	−0.0712	−0.0196	0.0170	0.0237
	(0.0800)	(0.0751)	(0.0572)	(0.0742)
Cash/Assets	−0.0319	0.1667	0.1277	0.3408
	(0.2554)	(0.2252)	(0.1715)	(0.2224)
Stock volatility	−0.4525***	0.0533	−0.0514	0.0847
	(0.1668)	(0.1905)	(0.1451)	(0.1882)
Stock return	0.0004	−0.0601***	−0.0422***	−0.0680***
	(0.0234)	(0.0206)	(0.0157)	(0.0203)
Herfindahl	−2.3046	3.7790*	1.6888	3.3431*
	(2.0426)	(1.9741)	(1.5037)	(1.9500)
Herfindahl^2	9.7352**	−11.0852**	−4.3260	−8.6768
	(4.9158)	(5.3992)	(4.1126)	(5.3334)
Year fixed effect	YES	YES	YES	YES
Firm fixed effect	YES	YES	YES	YES
Joint test of excluded instruments	F (1, 6212) = 18.01	N/A	N/A	N/A
	Prob > F = 0.0000			
Observations/ Adjusted R^2	7624/0.0924	7624	7624	7624

efficient. According to Hirshleifer, Hsu, and Li (2013), we construct three measurements of R&D efficiency as follows:

$$Innovation\ Efficiency\_1 = \frac{Patents_{i,t+1}}{R\&D_{i,t} + 0.8 \times R\&D_{i,t-1}} \tag{2}$$

$$Innovation\ Efficiency\_2 = \frac{Patents_{i,t+1}}{R\&D_{i,t} + 0.8 \times R\&D_{i,t-1} + 0.6 \times R\&D_{i,t-2}} \tag{3}$$

$$Innovation\ Efficiency\_3 = \frac{Patents_{i,t+1}}{R\&D_{i,t} + 0.8 \times R\&D_{i,t-1} + 0.6 \times R\&D_{i,t-2} + 0.4 \times R\&D_{i,t-3}} \tag{4}$$

We report the regression results of *R&D efficiency* on *StandardsNum* and *StandardsDum* in Panel A of Table 7. We find that the coefficients of *StandardsNum* and *StandardsDum* are all significantly positive at the 1% level, indicating that the increase of the standards-setting involvements will promote the firm's innovation efficiency, therefore accelerating its innovation outputs. In summary, **H1** is supported by empirical results.

5.2.2. Standards-setting involvements and financial constraints

Then, we examine the signal effect of attracting potential investors and thus reducing financial constraints. To represent the level of firms' financial constraints, we use Hadlock and Pierce's (2010) index (*SA index*), annual dividend payout ratio (*Dividend ratio*), and annual subsidy from the government (*ln*(*govsubsidy*)) and regress them on *StandardsNum* and *StandardsDum* respectively. The larger these indicators are, the fewer the financial constraints are. The results reported in Panel B of Table 7 show that a firm's standards-setting involvements can significantly reduce its financial constraints, which is consistent with **H2**.

Table 7
Possible mechanism analysis.

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Standards and innovation efficiency.						
Variables	Innovation Efficiency_1		Innovation Efficiency_2		Innovation Efficiency_3	
StandardsNum	0.0190***		0.0162***		0.0160***	
	(0.0055)		(0.0051)		(0.0057)	
StandardsDum		0.1312***		0.1182***		0.1083***
		(0.0234)		(0.0221)		(0.0236)
Firm control variables	YES	YES	YES	YES	YES	YES
Year fixed effect	YES	YES	YES	YES	YES	YES
Industry fixed effect	YES	YES	YES	YES	YES	YES
Observations	6662	6662	5643	5643	4578	4578
Adjusted R^2	0.0909	0.0940	0.1058	0.1094	0.1185	0.1214
Panel B: Standards and financial constraints.						
Variables	SA index		Dividend ratio		Ln (govsubsidy)	
StandardsNum	0.0056***		0.0054**		0.0434***	
	(0.0013)		(0.0024)		(0.0120)	
StandardsDum		0.0090*		0.0246**		0.2034***
		(0.0049)		(0.0098)		(0.0398)
Firm control variables	YES	YES	YES	YES	YES	YES
Year fixed effect	YES	YES	YES	YES	YES	YES
Industry fixed effect	YES	YES	YES	YES	YES	YES
Observations	9370	9370	8446	8446	9370	9370
Adjusted R^2	0.2520	0.2505	0.0812	0.0813	0.3880	0.3883
Panel C: Standards and collaborative innovation.						
Variables	PatentPartnerNum		Ln (1 + PatentInventor)		Ln (1 + CitationInventor)	
StandardsNum	0.2968***		0.0144***		0.0259***	
	(7.1398)		(7.4062)		(9.6226)	
StandardsDum		0.6643***		0.0957***		0.1434***
		(7.9487)		(9.8531)		(11.4998)
Firm control variables	YES	YES	YES	YES	YES	YES
Year fixed effect	YES	YES	YES	YES	YES	YES
Industry fixed effect	YES	YES	YES	YES	YES	YES
Observations	9370	9370	9370	9370	9370	9370
Adjusted R^2	0.1611	0.1302	0.1331	0.1381	0.1335	0.1390

5.2.3. Standards-setting involvements and collaborative innovation

Finally, we would like to see if **H3** holds. We employ the number of institutions that share the same patents with the firm (*PatentPartnerNum*) to stand for the firm's ability to cooperate with other institutions. And we use the average number of patents held by each investor (*PatentInventor*) and the average number of citations held by each investor (*CitationInventor*) to measure the quality of the firm's human capital. We present the results in Panel C of Table 7 and find that the coefficients on *StandardsNum* and *StandardsDum* are significantly positive at the 1% level for all the three dependent variables, indicating that standards-setting involvements can not only increase the number of potential partners but also help improve the quality of firms' human capitals.

6. Conclusion

Innovation has become a core strategy to enhance firms' competitiveness with time, so there is abundant literature studying the spur or impediment of various factors on innovation. However, none has examined the role of involvements in standards setting in the innovation process. Our paper fills this gap.

In this paper, we use a panel data set covering more than 11,000 firm years to explore how, and to what extent, standards-setting involvements impact corporate innovation. Using several econometric techniques specifically designed to address the inherent endogeneity, we find that the number of standards-setting involvements is positively and significantly related to innovation outputs, especially in firms with high-quality top management teams and in state-owned enterprises. We further analyze three plausible mechanisms for the positive impact, including improving firms' R&D efficiency, reducing financial constraints, and inducing collaborative innovation.

Our findings not only provide theoretical value but also offer advice to the government aiming at promoting innovation. Although firms have occupied a place in China's standards-setting process with the transition of a planned economy to a market economy, there is still a big gap compared to the market-leading standardization process in some industries of developed countries. Considering the benefits brought by standards-setting involvements of firms, the government might consider allowing more firms to participate in the process of standards setting. Besides, the government can even pilot projects in some areas and gradually decentralize to non-profit organizations such as industry associations to dominate the standardization process, in which way can we give full play to the vitality of the market players, and thus enhance firms' performance.

Acknowledgements

The authors would like to thank Xiaobo Zhang (Editor), Cheryl Long (Co-Editor), and three anonymous reviewers for insightful comments and suggestions. The authors acknowledge the financial support from the program of China Scholarship Council (Grant No. 201806010164) and the Key Laboratory of Mathematical Economics and Quantitative Finance (Peking University), Ministry of Education of China.

Appendix A. Variable definitions

Variables	Definitions
Panel A: dependent variables	
Patents	Firm *i*'s total number of invention and utility model patents filed (and eventually granted) in year *t*.
Inventions	Firm *i*'s total number of invention patents filed (and eventually granted) in year *t*.
Citations	Firm *i*'s total number of citations received by patents applied for in year *t*. Raw citation count is scaled by the weights proposed by Hall et al. (2001, 2005) to account for possible truncation bias issues.
Panel B: tested variables	
StandardsNum	The number of standards-setting processes involved by the firm.
StandardsDum	Dummy variable equals to 1 if the firm participates in at least one standards-setting process, otherwise equals to 0.
Panel C: control variables	
R&D (in ¥1000)	Research and development expenditure of firm *i* during year *t* (in ¥1000). (CSMAR database)
Assets (in ¥millions)	The total assets of firm *i* during year *t* (in ¥millions). (CSMAR database)
Leverage	Firm *i*'s book value of total debts divided by the book value of total assets during year *t*. (CSMAR database)
PPE/#employees (in ¥1000)	Firm *i*'s net property, plant, and equipment (PPE) scaled by the number of employees during year *t* (in ¥1000). (CSMAR database)
Sales/#employees (in ¥1000)	Firm *i*'s net sales scaled by the number of employees during year *t* (in ¥1000). (CSMAR database)
ROA	Firm *i*'s return on assets, which equals to net income divided by total assets during year *t*. (CSMAR database)
M/B	Firm *i*'s market value divided by book value during year *t*.
Sales growth	Firm *i*'s increased percentage of sales during year *t*.
Cash/Assets	Firm *i*'s cash-to-assets ratio during year *t*. (CSMAR database)
Stock volatility	The standard deviation of daily stock returns over the fiscal year.
Stock return	The buy-and-hold stock return calculated over the fiscal year.
Herfindahl	The Herfindahl index of the industry during year *t*.
Herfindahl^2	The squared term of Herfindahl index during year *t*.
Panel D: other related variables	
TMT Quality	The top management team quality index is measured by a principal component analysis using nine individual proxies of top management ability refer to Chemmanur et al. (2011).
SOEs	Dummy variable equals to 1 if a firm is a state-owned enterprise, otherwise equals to 0.
LocConferencesNum	The number of academic conferences held in a province during year *t*.
SA index	SA index (i.e. Hadlock and Pierce's (2010) index) is defined as $-0.737 \times \text{Ln(Assets)} + 0.043 \times \text{Ln(Assets)}^2 – 0.04 \times \text{Firm age}$. By construction, higher scores of the SA index indicate that firms are less financially constrained.
Dividend ratio	Firm i's dividend payout ratio during year t.
govsubsidy	The government subsidy the firm i received during year t.
PatentPartnerNum	The number of institutions that share the same patents with the firm during year *t*.
PatentInventor	The average number of patents held by each inventor.
CitationInventor	The average number of citations held by each inventor.
G Index	The G Index is measured by a principal component analysis using eight individual proxies of corporate governance refer to Gompers, Ishii, and Metrick (2003).
CEO Age	CEO's age.
CEO Male	Dummy variable equals to 1 if the CEO's gender is male, otherwise equals to 0.
CEO Tenure	CEO tenure, defined as the number of months a CEO is in office.
Ln(Locgdppp)	Natural logarithm of local GDP per person during year *t*.
LocUniversityNum	The number of local universities during year *t*.
Loclotterypp	The local average lottery sales per person during year *t*.
Past3yearPatents	The average number of total patents filed during the last three years.

Appendix B. Robustness checks

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Poisson regressions without log-transforming dependent variables ($N = 9370$).						
	Patents		Inventions		Citations	
StandardsNum	0.1248***		0.1657***		0.1476***	
	(0.0182)		(0.0167)		(0.0192)	
StandardsDum		0.8093***		1.0048***		0.9464***
		(0.0761)		(0.0770)		(0.0774)

Panel B: Negative regressions without log-transforming dependent variables (N = 9370).						
	Patents		Inventions		Citations	
StandardsNum	0.1759***		0.2233***		0.2170***	
	(0.0111)		(0.0133)		(0.0129)	
StandardsDum		0.7907***		0.9957***		0.9582***
		(0.0443)		(0.0529)		(0.0503)
Panel C: Standards variables measured at t-2 (*N* = 8387).						
	Ln(1 + Patents)		Ln(1 + Inventions)		Ln(1 + Citations)	
StandardsNum	0.0147*		0.0250***		0.0209**	
	(0.0082)		(0.0081)		(0.0100)	
StandardsDum		0.0804**		0.0932***		0.0862**
		(0.0323)		(0.0300)		(0.0394)
Panel D: Standards variables measured at t-3 (*N* = 7624).						
	Ln(1 + Patents)		Ln(1 + Inventions)		Ln(1 + Citations)	
StandardsNum	0.0042		0.0209**		0.0031	
	(0.0088)		(0.0089)		(0.0106)	
StandardsDum		0.0711**		0.1028***		0.0390
		(0.0351)		(0.0327)		(0.0437)
Panel E: Excluding firms engaging in mergers and acquisitions in the previous two years (*N* = 7329).						
	Ln(1 + Patents)		Ln(1 + Inventions)		Ln(1 + Citations)	
StandardsNum	0.0322***		0.0245***		0.0346***	
	(0.0083)		(0.0084)		(0.0102)	
StandardsDum		0.0944***		0.0635**		0.1017**
		(0.0358)		(0.0319)		(0.0426)
Panel F: Excluding firms located in Beijing, Shanghai, Guangzhou, and Shenzhen (*N* = 7507).						
	Ln(1 + Patents)		Ln(1 + Inventions)		Ln(1 + Citations)	
StandardsNum	0.0315***		0.0271***		0.0392***	
	(0.0081)		(0.0081)		(0.0097)	
StandardsDum		0.0810**		0.0726**		0.1019**
		(0.0334)		(0.0296)		(0.0403)

Appendix C. Tests for omitted variables and reverse causality

Variables	Ln(1 + Patents)		Ln(1 + Inventions)		Ln(1 + Citations)	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: controlling for financial constraints.						
SA index	1.7834***	1.8330***	1.9831***	2.0321***	2.0047***	2.0705***
	(0.3126)	(0.3130)	(0.2750)	(0.2764)	(0.3393)	(0.3389)
StandardsNum	0.0242***		0.0231***		0.0302***	
	(0.0074)		(0.0073)		(0.0089)	
StandardsDum		0.0878***		0.0785***		0.0972***
		(0.0303)		(0.0271)		(0.0366)
Panel B: controlling for corporate governance.						
G Index	0.0099	0.0104	0.0086	0.0090	0.0164	0.0169
	(0.0192)	(0.0193)	(0.0165)	(0.0166)	(0.0220)	(0.0221)
StandardsNum	0.0295***		0.0290***		0.0362***	
	(0.0075)		(0.0075)		(0.0089)	
StandardsDum		0.0965***		0.0881***		0.1072***
		(0.0304)		(0.0273)		(0.0367)
Panel C: controlling for CEO characteristics.						
CEO Age	−0.0048**	−0.0047**	−0.0022	−0.0022	−0.0050*	−0.0050*
	(0.0022)	(0.0022)	(0.0017)	(0.0017)	(0.0026)	(0.0026)
CEO Male	0.0813	0.0858	0.0229	0.0271	0.0723	0.0774
	(0.0691)	(0.0691)	(0.0607)	(0.0605)	(0.0835)	(0.0834)
CEO Tenure	−0.0000	−0.0000	−0.0003	−0.0002	0.0001	0.0001
	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0005)	(0.0005)
StandardsNum	0.0296***		0.0291***		0.0364***	
	(0.0075)		(0.0075)		(0.0090)	
StandardsDum		0.0972***		0.0886***		0.1083***
		(0.0305)		(0.0273)		(0.0367)
Panel D: controlling for local characteristics.						
Ln (Locgdppp)	0.4218**	0.4303**	0.3460**	0.3547**	0.3404	0.3504
	(0.2003)	(0.2004)	(0.1682)	(0.1683)	(0.2337)	(0.2338)
LocUniversityNum	0.0060*	0.0061*	0.0065**	0.0066**	0.0096***	0.0098***
	(0.0032)	(0.0032)	(0.0027)	(0.0027)	(0.0037)	(0.0037)

Loclotterypp	−0.0004	−0.0004	−0.0002	−0.0002	−0.0004	−0.0003
	(0.0003)	(0.0003)	(0.0002)	(0.0002)	(0.0004)	(0.0004)
StandardsNum	0.0168**		0.0162**		0.0223**	
	(0.0075)		(0.0079)		(0.0095)	
StandardsDum		0.0615**		0.0644**		0.0688*
		(0.0306)		(0.0282)		(0.0384)
Panel E: controlling for past innovation success.						
Past3yearPatents	0.0002	0.0003	0.0006	0.0006	0.0002	0.0002
	(0.0004)	(0.0004)	(0.0005)	(0.0005)	(0.0004)	(0.0004)
StandardsNum	0.0301***		0.0272***		0.0364***	
	(0.0089)		(0.0088)		(0.0104)	
StandardsDum		0.1337***		0.1031***		0.1483***
		(0.0380)		(0.0338)		(0.0454)

Appendix D. Propensity score matching procedure

Panel A: The results of covariate balance checks.

Variable	Unmatched	Mean		% bias	% reduct	t-test		V(Tre)/V(Con)
	Matched	Treated	Control		|bias|	t	p > |t|	
Ln (R&D)	U	9.6431	7.9233	42.4	95.1	16.14	0.000	0.79*
	M	9.6274	9.5437	2.1		0.71	0.478	1.13*
Ln (Assets)	U	8.2905	7.6898	52.5	99.8	21.72	0.000	1.39*
	M	8.2818	8.2832	−0.1		−0.04	0.971	1.03
Leverage	U	0.4335	0.4213	5.9	91.7	2.27	0.023	0.82*
	M	0.4331	0.4321	0.5		0.15	0.878	0.82*
Ln (PPE/	U	5.5240	5.4555	7.9	83.8	3.12	0.002	1.03
#employees)	M	5.5230	5.5119	1.3		0.39	0.695	0.95
Ln (Sales/	U	6.7568	6.5021	33.9	99.3	13.02	0.000	0.83*
#employees)	M	6.7531	6.7549	−0.2		−0.07	0.942	0.82*
ROA	U	0.0550	0.0504	9.3	97.3	3.50	0.000	0.72*
	M	0.0550	0.0548	0.2		0.08	0.933	0.98
M/B	U	0.9520	0.7924	22.3	86.3	9.15	0.000	1.31*
	M	0.9511	0.9729	−3.1		−0.85	0.393	0.83*
Sales growth	U	0.2162	0.2402	−10.5	65.6	−3.93	0.000	0.71*
	M	0.2164	0.2081	3.6		1.24	0.214	1.02
Cash/Assets	U	0.2570	0.2471	6.4	20.7	2.47	0.014	0.88*
	M	0.2567	0.2646	−5.1		−1.56	0.120	0.83*
Stock volatility	U	0.4401	0.4773	−30.2	93.5	−11.59	0.000	0.82*
	M	0.4404	0.4428	−2.0		−0.65	0.515	1.02
Stock return	U	0.2718	0.3619	−11.5	92.6	−4.36	0.000	0.77*
	M	0.2721	0.2654	0.8		0.29	0.773	1.06
Herfindahl	U	0.0836	0.0817	3.1	98.0	1.16	0.245	0.69*
	M	0.0836	0.0836	−0.1		−0.02	0.982	1.03
Herfindahl^2	U	0.0101	0.0112	−5.7	91.2	−2.11	0.034	0.60*
	M	0.0101	0.0101	0.5		0.18	0.854	1.05

Panel B: The regression results using PSM procedure.

Dependent variable: Ln(1 + Patents).

	One to One	Neighbors	Caliper	Radius	Kernel	Local Linear	Spline	Mahalanobis
Unmatched	1.4671***	1.4671***	1.4671***	1.4671***	1.4671***	1.4671***	1.4671***	1.4671***
	(0.0356)	(0.0356)	(0.0356)	(0.0356)	(0.0356)	(0.0356)	(0.0356)	(0.0356)
ATT	1.0560***	1.0436***	1.0384***	1.0473***	1.0632***	1.0539***	1.0515***	1.1452***
	(0.0724)	(0.0454)	(0.0595)	(0.0405)	(0.0394)	(0.0478)	(0.0460)	(0.0408)
ATU	0.9197***	0.8978***	0.8983***	0.9242***	0.9520***	0.9385***	0.9386***	1.1138***
	(0.0567)	(0.0509)	(0.0542)	(0.0523)	(0.0449)	(0.0533)	(0.0491)	(0.0473)
ATE	0.9486***	0.9288***	0.9280***	0.9504***	0.9756***	0.9630***	0.9626***	1.1204***
	(0.0479)	(0.0434)	(0.0474)	(0.0450)	(0.0404)	(0.0477)	(0.0443)	(0.0423)
Observations	9356	9356	9356	9356	9356	9356	9356	9356

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