

The Impact of the Social Relationship between CEO and Independent Director on the R&D in Chinese Listed Companies

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Abstract

Relationship culture is one of the important characteristics of China's social culture, and has an impact on financial decision-making for Chinese listed companies. Independent directors as the company's external supervisors play an important supervisory role. However, it is common for independent directors to become ornamental directors. CEO's social relationship is an important factor affecting the source of independent directors. Now there is little literature to discuss the impact of this social relationship on R&D. This paper empirically tests the impact on R&D of the relationship between CEO and independent director in Chinese A-share listed companies. The results show that the social relationship between CEO and independent directors can promote the R&D and the social relationship between CEO and independent directors has a more significant impact on R&D for non-SOE, low level of corporate governance, tight financing constraints in Chinese listed companies. Therefore, the conclusion of this paper provides a unique view for the discussion of the governance role of independent directors in theory and the impact of social networks on decision-making in Chinese Listed Companies and provides a reference for improving the independent director institutions in practice.

Keywords

Independent Directors, Social Relations, R&D Expenditure, R&D Efficiency

1. Introduction

R&D activities are always hot topic for many scholars for R&D is the key to enhancing the core competitiveness of enterprises. With the continuous increase of innovation, R&D also has a positive impact on the company's performance. In

fact, listed companies that give priority to R&D activities have created higher added value and achieved better economic benefits. However, as a transitional economy, China has some special institutional backgrounds which are different from those of mature market countries, and nowadays there are still many influence factors that need in-depth exploration in Chinese listed companies.

Independent director is completely an exotic product, and its role as a resource provider and supervisor of enterprise strategy orientation is very important. In Chinese companies and markets, its connotation to be accurately reflected and thus a high degree of consensus to be made needs to be continuously improved, and the improvement of the system and the actual implementation of the ability of independent directors are particularly important. From the perspective of agency theory, the independent director system can reduce agency cost and improve the level of corporate governance. In recent years, China's independent director system has been gradually improved, and the company law and the securities law have been issued at the legal level. For example, the *Guidance on the Establishment of Independent Director System in Listed Companies* has made clear provisions on the "three person phenomenon" and professionalism of independent directors. At the level of self-discipline management, the China Association for Public Companies issued the *Guidelines on the Performance of Independent Directors of Listed Companies*.

Independent directors as the company's external supervisors play an important supervisory role. However, it is not uncommon for independent directors to become "dummy directors" because they are "social stakeholders". The company is managed and controlled by insiders. The general managers of the company often stay away from independent directors, making it difficult for independent directors to understand the real situation of the company. The chief executive officer (CEO) is the first in command of listed companies and plays the role of organizing, coordinating and representing the company. Therefore, some scholars have found that when there is a certain social relationship between CEO and independent directors, they will play a linkage effect and share information, and independent directors can take this relationship as the starting point to have a deeper understanding of the overall situation of the company, which is conducive to corporate governance and decision-making. Meanwhile, information sharing will strengthen the supervision of independent directors, which will, in turn, inhibit the CEO's motivation to share information. Moreover, if the CEO and the independent directors are too familiar, the independent directors may not dare to say or do not want to say, resulting in the phenomenon of knowing but not reporting out of human sophistication, and then becomes the "protective umbrella" of the CEO. At this time, the independent directors will no longer be "independent", but become "dummy directors" and "vase directors".

Among the many relationships of China's human network, the social relationship between CEO and independent director is one that can't be ignored. Some independent directors are seemingly independent, but in fact they have

direct or indirect social relationships with the CEO. If the CEO and the independent director have one of the following four relationships, it is considered that there is a certain social relationship between them: 1) worked in the same company at the same time, that is, colleague relationship; 2) Graduated from the same educational institution, i.e. alumni relationship; 3) The native place is the same, that is, fellow-townsmen relationship; 4) Join the same club or the same association, that is, member relationship.

This paper does empirical regressions analysis on the personal resumes of CEO and independent directors of China's A-share listed companies from 2006 to 2019 obtained from the financial database, as well as the R&D related data of listed companies, and then explores whether the independent directors who have social relationship with CEO can really perform their duties, and thus have an impact on the R&D investment of listed companies. We employ pool OLS model to empirically test the hypothesis, and also deal with the endogenous problems by PSM method.

From a theoretical point of view, the innovation of this paper is to discuss the relationship between the social relationship which as the breakthrough point between CEO and independent directors, and R&D of listed companies. The previous research results on the impact of independent directors on corporate governance have positive and negative aspects. Based on agency theory and resource dependence theory, independent directors possess human capital and social capital, which will have a positive impact on corporate governance and enhance the value of the company; However, there is also evidence that independent directors are only "vase directors" in some cases, and the increase of the proportion of independent directors has no effect on corporate governance. As for the influencing factors of corporate R&D, previous studies mostly focused on internal factors such as corporate size, internal resources and personal characteristics of executives, as well as external factors such as industry type, market competition and government subsidies, without considering the impact of the key factor of independent directors on corporate governance and R&D strategy, Linking independent directors with R&D activities has certain innovative significance. Therefore, this paper selects the social relationship between CEO and independent directors, as an important branch of social relations, to study the relationship between this social relationship and R&D. This unique perspective provides a relatively novel idea for relevant theoretical research.

From the perspective of policy makers, this study also contributes to the further improvement of China's independent director system. The impact of the social relationship between CEO and independent directors on R&D expenditure can judge whether the independent director system as an exotic product needs to be adjusted according to the local actual situation in China's relationship culture, so as to provide reference for the improvement of the independent director system. From the perspective of company managers, whether such social relations have a positive or negative impact on the company's performance and value will also help the company's managers appoint

independent directors in a more scientific and appropriate way, so that independent directors can better play their role as resource providers and enterprise strategy guidance.

The rest of the paper is organized as follows. Section 2 reviews the related literature. Section 3 proposes hypothesis. Section 4 gives research design and the basic regression results. Section 5 presents the sensitivity test results. Section 6 concludes the paper.

2. Literature Review

2.1. The Impact of Independent Directors on Corporate Governance

Different scholars have different research results on the impact of independent directors on corporate governance. Some scholars hold that independent directors play a positive role in promoting corporate governance. [Malikov et al. \(2021\)](#) believe that independent directors have more allegiance to the CEO relative to other directors, which has a positive impact on corporate governance. [Choi et al. \(2021\)](#) prove that better corporate governance is positively correlated with fewer agency problems, and the independent director system in listed companies, as one of corporate governance mechanisms, can reduce agency problems. Based on agency theory and resource dependence theory, [Herrmen and Datta \(2005\)](#) propose that the human capital and social capital of independent directors are positively correlated with corporate performance. Independent directors are a bridge between the company and other companies, and can better obtain more and higher quality information and valuable resources by virtue of their reputation, so that they can become supervisors and resource providers of enterprises, thus promoting corporate governance ([Tian et al., 2011](#)). [Liu and Sun \(2021\)](#) also point out that when independent directors have professional legal knowledge, they can help enterprises comply with laws and regulations, reduce compliance risks, restrict risk bearing and improve enterprise value.

[Ongsakul and Jiraporn \(2019\)](#) believe that independent directors are eager to maintain their reputation as monitoring and management experts to help them maintain their current directorships and even obtain additional directorships, so as to have the motivation to challenge the company's decision-making of managers, and be motivated to be vigilant about the protection of shareholders' interests, and then question the decision-making of management, prevent the value reduction strategy, and make the company committed to the strategy of maximizing shareholders' wealth, so as to improve the company's performance and value. [Ahmed and Iwasaki \(2021\)](#) propose that the proportion of independent directors will affect the transparency of the company, which will generally increase with the increase of the proportion of independent directors, promote the formation of an effective market, attract more investment, reduce agency problems and corporate misconduct, and improve the level of corporate gover-

nance. [Andres et al. \(2017\)](#) find that companies with more independent directors tend to grant equity linked compensation more than companies with more non-independent directors, which provides more protection for shareholder value.

However, some scholars have found that independent directors have a negative impact on corporate governance. From the perspective of the proportion of independent directors, [Armstrong et al. \(2014\)](#) believe that although the increase in the proportion of independent directors will enhance the transparency of the company, if the proportion is too large, the positive effect brought by the increase is not enough to offset the negative impact in the coordination process, its supervision function is difficult to play effectively, and the value of the company decreases instead. [Rajkovic \(2020\)](#) proposes that when independent directors exceed a certain proportion, too strict supervision will lead to the “power diffusion” of the management, which will weaken the CEO’s ability to effectively manage the company, and make it difficult for the management team to make correct decisions. Therefore, there is a reverse correlation between the scale of independent directors and corporate value, which shows that the largest part of the value loss will appear in the process of change of the scale of independent directors from small to large.

2.2. The Impact of Social Relations on Corporate Decision-Making

In addition to formal issues such as laws and regulations, social relations have a unique influence in the decision-making of listed companies in China. Some scholars believe that social relations have a positive impact on corporate decision-making. For example, [Fan et al. \(2021\)](#) point out that social networks can promote mutual care, trust and positive impressions between each other. CEOs with social relations have a lower chance of salary reduction and dismissal, making them have a safer career and thus encourage them to take risks. Meanwhile, this social relationship can reduce the transaction costs of listed companies through effective communication and negotiation and produce unique competitiveness in market expansion, and thereby improve the performance and value of the company. [Ishii and Xuan \(2014\)](#) believes that the board of directors and senior managers of the company have rich and complex social networks, including contacts established through alumni networks, employment activities, charitable organizations or other forms such as clubs. These extensive social relations will provide an effective means of information exchange, promote the enhancement of information flow, reduce the cost of information collection and reduce information asymmetry, and thus produce good economic results.

However, some scholars believe that social relations have a negative impact on corporate decision-making. [McPherson et al. \(2001\)](#) point out that when the two with social relations get along well, the simple interaction mode based on exchange will change to an interaction mode more based on trust norms, increasing the sense of trust between the two, and therefore resulting in weak critical

analysis, reducing due diligence standards, or overestimating the resulting synergy benefits. This behavior can be called “familiarity bias”, that is, it shows the tendency of inefficient trading and has a negative impact on the company’s decision-making.

2.3. Influence Factors of R&D

Scholars at home and abroad have studied the influencing factors of R&D to varying degrees. [Sosa et al. \(2002\)](#) find that large companies are more active in research investment than small companies, but small companies have more advantages in flexibility and smooth communication than large companies, and large companies are prone to problems such as low research efficiency and slack, while small companies may find opportunities faster and more flexibly adjust research plans or R&D implementation progress, and it is easier for small companies to adjust the employee incentive mechanism, so that key employees can focus more on R&D related tasks rather than management related tasks. [Rogers \(2004\)](#) points out that the relationship between enterprise scale and R&D investment depends on specific technology and market conditions to a certain extent. Enterprises in mature industries have strong anti-risk ability, sufficient resources such as facilities and financial funds, high credit level and mature technology, and therefore their R&D investment is more likely to succeed, so they are more likely to invest in R&D. Due to the understanding of the high sunk costs of R&D activities, the external capital market also tends to choose large enterprises to disperse the fixed R&D costs on a larger sales scale to reduce the risk of R&D activities ([Bachmann et al., 2021](#)). [Medase \(2020\)](#) reveals the unique advantages of large companies in clustering and high integration, while smaller enterprises must overcome greater obstacles in R&D activities. [Racela and Thourungroje \(2019\)](#) examine the degree of R&D investment between large- and small-sized enterprises. The results show that although the innovation of small enterprises benefits from the practice of promoting employees’ participation in decision-making, large companies have scale related advantages, which enables them to use the resources corresponding to the size to obtain considerable benefits in R&D activities.

Dividend policy decision plays an important role in the overall strategy and value creation of the company. [Baker and Kilincarslan \(2019\)](#) point out that more mature and profitable companies usually pay cash dividends, while smaller and highly leveraged companies are reluctant to distribute profits as cash dividends. If a company is in the growth period, it will choose to retain more funds within the company rather than distribute cash dividends in case of insufficient funds. Firm age also has an important impact on enterprise decision-making. Mature companies may have experienced labor force and lasting organizational memory in some fields. They have a better understanding of their abilities and how to better organize affairs, and the life expectancy and survival status of the company will increase with age, which will improve their accuracy in the direction search and selection process of R&D and reduce the possibility of wrong

R&D investment, while young companies are obviously inexperienced in this field (Peyruzzelli et al., 2018). From the beginning, young company has no customary system or mode of organizational operation, and has little effective information. It needs to quickly establish daily operation procedures and higher-level R&D innovation ability. Therefore, it may lack internal ability to benefit from R&D investment, thus inhibiting R&D willingness (Coad et al., 2016). Based on the resource-based view, Canto and Gonzalez (1999) believe that the internal financial resources, physical resources and intangible resources will have an impact on the possibility of enterprises carrying out R&D activities. Intangible factors are the main determinants of enterprises' R&D investment, which are often considered to be the most important from the perspective of strategy.

The research on the combination of corporate governance and enterprise's R&D investment has also achieved rich results. Ostadhashemi and Nejad (2019) elaborate its impact on firm R&D expenditure from the perspective of ownership structure, and conclude that there is a positive correlation between equity concentration and R&D expenditure, which is mainly due to the influence of institutional investors rather than individual investors. Zhao Jie and Zhang Ling (2020) believe that equity concentration can be used as a regulating variable for the research on the impact of R&D investment on enterprise performance, but once it exceeds a certain limit, it will have a negative impact on R&D investment. Wen Fang (2008) finds that equity concentration and R&D investment are not "inverted U-shaped", but "N-shaped", and private property holding has the strongest incentive effect on the enterprise's R&D investment, and the holding of state-owned asset management institutions has the weakest incentive effect. As for the research on the nature of equity, most of the research conclusions of scholars at home and abroad tend to be consistent, believing that more equity controlled by the government will have a negative impact on the enterprise's R&D investment. Chen Shouming et al. (2012) take the nature of state-owned enterprises as regulatory variables and believe that they play a negative regulatory role in the relationship between R&D investment and enterprise value. State-owned enterprises should give more power to senior managers of enterprises, and non-state-owned enterprises are more motivated in innovation. Therefore, more policies should be introduced to subsidize them.

In terms of institutional investor shareholding, scholars' research conclusions are not consistent. Wahal and McConnell (2000) prove that there is a negative correlation between R&D expenditure and the shareholding ratio of institutional investors, because institutional investors with short-term vision will have "management myopia", only care about immediate interests and ignore the long-term development of enterprises, so they lack investment in long-term return projects such as R&D. However, Unsal and Rayfield (2019) find that there is a positive causal relationship between a higher proportion of institutional ownership and firm R&D investment, and institutional investors should play a role in improving enterprise innovation performance measured by innovation quantity and innovation quality. Aghion et al. (2013) make a study on the relationship be-

tween institutional investors and firm R&D and put forward two hypotheses: lazy management hypothesis and management occupational risk hypothesis. The former assumes that managers who like a quiet life or want to maintain the status quo will not invest in innovation, but institutional investors will put pressure on them to force them to carry out R&D activities; The latter believes that managers are worried that the failure of R&D activities will have an adverse impact on themselves, but avoiding R&D is not good for institutional investors. Therefore, institutional investors will provide a “fault tolerant” environment for the management who are unwilling to undertake high-risk R&D projects due to the concerns of investors to increase the R&D expenditure of enterprises. [Sakaki and Jory \(2019\)](#) finds that at the enterprise level, the higher the proportion of shares held by institutional investors, the higher the number of patent applications and citations.

2.4. The Impact of Independent Directors on R&D

[Aboody and Lev \(2000\)](#) believe that independent directors can effectively restrain opportunistic R&D expenditure under the condition of income related incentive mechanism. Independent directors have human capital, i.e. sufficient professional knowledge and experience, and exert pressure on the management to reduce opportunistic short-term profits and corresponding R&D expenditure. Taking the incidence of opportunistic R&D expenditure reduction as the measurement index and then analyzing the supervision role of independent directors on a group of real earnings management decisions, [Osma \(2008\)](#) concludes that independent directors can reduce the probability of enterprises reducing R&D expenditure due to unsatisfactory performance in the early stage, or reduce the probability of enterprises pushing income to the current target. Therefore, the inclusion of independent directors in R&D intensive enterprises may improve their long-term performance.

[Boone et al. \(2007\)](#) believe that diversified companies will deploy more independent directors to facilitate wider monitoring of their business scope. Independent directors use their external resources to make the company’s information more diversified, and can provide more suitable opinions for the long-term development of the enterprise from the perspective of a third party. Without the supervision of independent directors, companies often choose not to carry out high-risk R&D activities because of avoiding risks. Therefore, independent directors have an incentive effect on R&D activities. However, due to its “independence”, the independent directors cannot fully understand the internal information of the enterprise, so its decisions and opinions may not really help the enterprise, and even have a negative impact on the enterprise’s R&D activities.

In short, at present, there are many studies on the influencing factors of enterprise R&D activities and the impact of independent directors on corporate governance, as well as the impact of social relations on corporate decision-making. However, there is no domestic study on the influence of the social relationship between CEO and independent directors on enterprise R&D activi-

ties. According to the above literature, this influence is meaningful in theory and practice, so this paper will make a further analysis.

3. Hypothesis

The independence of independent directors will be affected not only by the open contact between independent directors and CEO, but also by the existence of intangible social relations. When there is a social relationship between CEO and independent directors, it will lead to an increase in mutual respect and acceptance between them, which will affect the supervision and management of CEO by independent directors and is not conducive to the establishment and consolidation of good management. The “friendly” relationship and even collusion between the two will also reduce the possibility of CEO dismissal when the company produces low value and low performance. Even when the CEO obtains less strict monitoring or discipline, it will enhance his/her power in the board of directors, and the CEO with greater power can obtain more economic resources, higher respect and more positive social attention, In addition, he/she is less interfered by others or controlled by potential returns when making decisions, which will improve the CEO’s ability to bear risks, and therefore his/her perception of risks tends to be optimistic. The lower risk of salary reduction and dismissal will also encourage him to pay more attention to the potential returns of risk projects such as R&D. For this reason, companies with social relations between CEOs and independent directors tend to pursue more exploratory innovation and invest more funds in R&D activities. Furthermore, this social relationship can also strengthen the advisory function of independent directors, promote “mutual care” and frequent and positive interaction and communication between them and the CEO, and thus produce linkage effect and realize information sharing, reduce the cost of information collection, and urge the CEO to reduce short-term behavior and improve the company’s investment in R&D activities. Therefore, hypothesis H is proposed in this paper.

H: when there is a social relationship between the CEO and the independent director, the R&D expenditure of the enterprise increases.

4. Research Design and the Basic Regression Results

4.1. Data

This paper discusses whether this social network can promote enterprise R&D when there is a social relationship between CEO and independent directors under the conditions of different property rights, different institutional shareholding ratio, different proportion of independent directors, separation or combination of CEO and chairman positions, and different financing constraints. The native place, educational background, employment history and social activities of CEO and independent directors and related financial data are all from CSMAR database. CSMAR database is the most widely used database to study the problems of Chinese listed companies. It contains stock market transaction

data, financial reports and notes of listed companies, and is widely used by the Journal of Finance, the Journal of Financial Economics, the Review of Financial Studies etc. The screening methods of the social relationship between CEO and independent directors are as follows: first, download the resume of CEO and independent directors from CSMAR database, and then compare whether they have the following relationship: 1) whether their birthplace belongs to the same prefecture level city; 2) whether they ever attended the same school; 3) whether they participate in a social activity at the same time, such as theme clubs or other social organizations; 4) whether they worked in the same company in the past, that is, whether there is a professional connection between individuals. If one of the above relationships exists, it is recognized that there is a certain social relationship between the independent directors and the CEO.

This paper selects China's A-share listed companies as a sample, the sample period is 2007-2019, and makes the following preliminary processing of the data: 1) due to the significant differences between the financial industry and other industries in business operation or measurement, the data of the financial industry are excluded; 2) because the financial situation of ST and *ST sample companies is abnormal from other situations, and they are usually a shares with negative net profit for two consecutive years after listing, it is meaningless to study the R&D of listed companies, so this part of the data is excluded; 3) eliminate the samples with serious data loss; 4) after the preliminary data processing, the regression analysis will be carried out by STATA. In final, we get 29,759 observations in our sample.

4.2. Research Design

4.2.1. Definition of Independent Variable

The independent variable of this paper is the social relationship between CEO and independent directors, which is named *Relationship*, and the virtual variable method is adopted. When they have one of the following social relationship: colleagues, alumni, fellow townsmen (born in the same prefecture level city) or joining the same social group, the sample observation value *Relationship* in that year is 1; On the contrary, if there is no one of the above four relationships, the sample observation value *Relationship* in that year is 0.

4.2.2. Definition of Dependent Variable

The dependent variable of this paper is the R&D activities of listed companies, which can be further sub-divided into R&D expenditure and R&D efficiency. R&D expenditure is named *RD*. Following the France-Germany-Japan system, China's R&D efficiency can be sub-divided into Invention patents, Utility model patents and Design patents, and the Patents are equal to the sum of the above three variables: $Patents = Invention + Utilitymodel + Design$. Therefore, R&D efficiency is named *Patents*, *Invention*, *Utility model* and *Design* respectively.

4.2.3. Regression Model

In order to verify hypothesis H, establish the model (4-1):

$$RD_{i,t} = \alpha_0 + \beta_1 Relationship_{i,t} + \beta_2 Size_{i,t} + \beta_3 Lev_{i,t} + \beta_4 Roa_{i,t} + \beta_5 Mb_{i,t} + \beta_6 Cash_{i,t} + \sum Year + \sum Industry + \varepsilon_{i,t} \quad (4-1)$$

The control variables of models (4-1) conclude that *Size* is the size of the company, which is measured by the total assets of the company in this paper; *Lev* is the debt operation ratio, which is the ratio of total liabilities to total assets; *Roa* is the net interest rate of assets, which is the ratio of total profit after tax to total assets at the beginning of the year; *Mb* is the market-to-book ratio, which is the ratio of market value to book value; *Cash* is the operating cash flow, which is the ratio of operating cash flow to total assets; *Year* and *Industry* are dummy variables for year and industry.

4.2.4. Definition of Intermediary Variable

In order to test the sensitivity of the impacts of the nature of enterprise property rights, the level of corporate governance and financing constraints, this paper introduces intermediary variables: state-owned enterprises and non-state-owned enterprises (*Soe*); proportion of institutional shareholders (*Dummyinsti*); separation or combination of chairman and CEO positions (*Dual*); proportion of independent directors in the board of directors (*Dummydir*); company size (*Dummysize*); dividend policy (*Dummydiv*); company age (*Dummyage*); KZ index (*DummyKZ*). The specific definitions of the above variables are shown in **Table 1**.

4.3. Descriptive Statistics

Table 2 is the descriptive statistical results of all variables. Among them, the mean value of the independent variable *Relationship* is 6.8%, that is, an average of 6.8% of the company CEOs have a social relationship with independent directors in the same industry. Therefore, it is necessary and important to study the impact of the social relationship between CEOs and independent directors on R&D. The mean value of the intermediary variable *Dummydir*, i.e. proportion of independent directors, for sensitivity test is 97.7%, which means that the proportion of independent directors in the board of directors is relatively high, reflecting the importance of studying the social relationship between CEO and independent directors.

4.4. Main Empirical Results

Table 3 shows the regression results of how the social relationship between CEO and independent directors affects the R&D expenditure and patents of listed enterprises. The regression coefficient between the independent variable *Relationship* and R&D expenditure is +0.410 and the corresponding t value is 4.56, which passes the 1% significance level test. This shows that the social relationship between CEO and independent directors has a significantly positive impact on the R&D expenditure of listed enterprises, that is, the R&D expenditure of listed enterprises with this relationship is 41% higher than that of enterprises

without this relationship. The empirical results support hypothesis H1. When there is a social relationship between CEO and independent directors, they can produce linkage effect, strengthen information communication and improve the R&D expenditure of enterprises.

Table 1. Definition of each variable.

Variable type	Variable symbol	Variable name	Variable definition
Dependent variable	<i>RD</i>	R&D expenditure	Various expenses in the process of research and development.
	<i>Patents</i>	patents	Protected exclusive interests owned by an R&D originator.
	<i>Invention</i>	invention	New solutions in products, designs and methods.
	<i>Utilitymodel</i>	utility model	Different schemes for shape or internal structure.
	<i>Design</i>	appearance design	Put forward new schemes for appearance, shape, color, pattern, etc.
Independent variable	<i>Relationship</i>	social relationship between CEO and independent director	When they have one of the following social relationship: colleagues, alumni, fellow townsmen (born in the same prefecture level city) or joining the same social group, the value is "1", otherwise it is "0".
control variable	<i>Size</i>	company size	Natural logarithm of total assets of the company.
	<i>Roa</i>	return on assets	Net profit/total assets.
	<i>Mb</i>	market-to-book ratio	Market value/book value.
	<i>Lev</i>	debt operation ratio	Total liabilities/total assets.
	<i>Cash</i>	operating cash flow	Operating cash flow/total assets.
	<i>Year</i>	year dummy	Year dummy variable from 2007 to 2019.
	<i>Industry</i>	industry dummy	Defined according to the industry classification of CSRC.
Intermediary variable	<i>Soe</i>	property rights	"state-owned" value is "1", otherwise the value is "0".
	<i>Dummyinsti</i>	proportion of institutional shareholders	When it is higher than the median value of the sample, take "1", otherwise take "0".
	<i>Dual</i>	separation or combination of chairman and CEO positions	"1" is taken for separation, otherwise "0" is taken.
	<i>Dummydir</i>	proportion of independent directors in the board of directors	If it is higher than the median (1/3) of the sample, the value is "1", otherwise it is "0".
	<i>Dummysize</i>	company size	When the total assets of the company are greater than the median of all sample data, the value is "1", otherwise it is "0".
	<i>Dummyage</i>	company age	When it is greater than the median of all sample data, the value is "1", otherwise it is "0".
	<i>Dummydiv</i>	dividend policy	The value of "cash dividend" is "1", otherwise it is "0".
	<i>DummyKZ</i>	KZ index	When the KZ index is greater than the mean value of all sample data, the value is "1", otherwise it is "0".

Table 2. Descriptive statistics.

Stats	mean	p25	p50	p75	sd	N
<i>RD</i>	2.737	0.000	1.160	3.860	4.736	29759
<i>Patents</i>	2.777	1.792	2.639	3.555	1.299	7354
<i>Invention</i>	1.193	0.000	1.099	1.946	1.216	7354
<i>Utilitymodel</i>	1.059	0.000	0.000	2.079	1.381	7354
<i>Design</i>	0.327	0.000	0.000	0.000	0.843	7354
<i>Relationship</i>	0.0680	0.000	0.000	0.000	0.251	29759
<i>Cash</i>	0.171	0.0720	0.128	0.223	0.145	29759
<i>Mb</i>	0.612	0.428	0.616	0.797	0.245	29759
<i>Roa</i>	4.307	1.438	3.967	7.366	21.98	29759
<i>Size</i>	21.940	20.990	21.770	22.690	1.360	29759
<i>Lev</i>	0.521	0.273	0.441	0.610	6.064	29759
<i>Soe</i>	0.418	0.000	0.000	1.000	0.493	29759
<i>Dummyinsti</i>	0.500	0.000	0.500	1.000	0.500	29759
<i>Dual</i>	0.268	0.000	0.000	1.000	0.443	29759
<i>Dummydir</i>	0.500	0.000	0.500	1.000	0.500	29759
<i>Dummysize</i>	0.500	0.000	0.500	1.000	0.500	29759
<i>Dummydiv</i>	0.391	0.000	0.000	1.000	0.488	29759
<i>Dummyage</i>	0.500	0.000	0.000	1.000	0.500	29759
<i>DummyKZ</i>	0.500	0.000	0.500	1.000	0.500	29759

Table 3. Results of the social relationship between CEO and independent directors on R&D.

	<i>RD</i>	<i>Patents</i>	<i>Invention</i>	<i>Utilitymodel</i>	<i>Design</i>
<i>Cons</i>	1.954*** (4.32)	-11.616*** (-32.11)	-6.326*** (-15.47)	3.378*** (7.31)	0.531* (1.86)
<i>Relationship</i>	0.410*** (4.56)	-0.052 (-1.00)	0.186*** (3.18)	-0.047 (-0.72)	0.043 (1.04)
<i>Size</i>	-0.108*** (-4.72)	0.629*** (37.16)	0.320*** (16.71)	-0.179*** (-8.27)	-0.016 (-1.21)
<i>Lev</i>	-0.006 (-1.59)	-0.070 (-0.71)	-0.027 (-0.24)	0.116 (0.92)	-0.093 (-1.19)
<i>Roa</i>	-0.003 (-1.38)	0.004*** (3.13)	-0.001 (-0.55)	0.001 (0.62)	0.001 (1.14)
<i>Mb</i>	-1.558*** (-9.53)	-0.702*** (-7.82)	-0.374*** (-3.69)	0.271** (2.36)	0.038 (0.53)
<i>Cash</i>	2.989*** (12.09)	0.044 (0.38)	0.138 (1.07)	-0.303** (-2.07)	0.101 (1.12)
Industry Fixed Effect	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes
F	217.13	55.28	13.79	11.87	6.41
P > F	0.0000	0.0000	0.0000	0.0000	0.0000
R2	0.323	0.3763	0.131	0.115	0.065
Obs	28,861	5558	5558	5558	5558

Note: *, **, *** correspond to 10%, 5% and 1% significance levels respectively.

The coefficient of the independent variable *Relationship* and *Invention* is positive, which is 0.186, and passes the 1% significance test. However, *Patents*, *Utilitymodel* and *Design* fail the significance test. The empirical evidence shows that when there is a social relationship between CEO and independent directors, the supervision and consulting functions of independent directors will be strengthened, and thus increase the number of invention patents and improve the R&D efficiency of enterprises. The reason is that the number of invention patents is the most important index to measure the efficiency of R&D.

4.5. Endogenous Test

Considering that the impact of the social relationship between CEO and independent directors on the R&D of listed enterprises may be endogenous, while the social relationship between CEO and independent directors affects enterprise R&D, enterprise R&D may also affect the social relationship between CEO and independent directors. Therefore, this paper uses the tendency matching method to test its endogeneity. **Table 4** shows the results of endogeneity test by PSM-DID method. This paper takes the listed companies with social relations between CEO and independent directors as the treatment group and the listed companies without social relations between them as the control group, establishes Probit model and calculates the fitting value, that is, the annual propensity score of each company. Then, the propensity score is used to match whether there is a social relationship between CEO and independent directors in the range of $p = 0.05$. The results showed that the ATT difference was positive after sample matching, and passed the 1% significance test. This further confirms the empirical results. After the sample matching, listed companies with social relationship between CEO and independent directors tend to increase R&D expenditure than those without social relationship between CEO and independent directors. The research hypothesis H1 is further supported.

5. Sensitivity Test

5.1. Impact of the Nature of Property Rights

According to the previous research assumptions, **Table 5** is the empirical results of analyzing the impact of the social relationship between CEO and independent directors on the R&D of listed companies under different property rights backgrounds. According to whether the actual controller of the listed company is the SASAC at all levels, it is divided into two sub samples: state-owned listed companies and non-state-owned listed companies, and the data of state-owned listed companies and non-state-owned listed companies are substituted into the regression Equations (4-1). It can be seen from the table that in the sample of non-state-owned listed companies, the regression coefficient of the independent variable *Relationship* is +0.381, and the corresponding t value is 3.13, which passes the 1% significance level test; In the sample of state-owned listed companies, the regression coefficient of the independent variable *Relationship* is

+0.041, and the corresponding t value is 0.46, which does not pass the significance level test. Therefore, compared with state-owned listed companies, the social relationship between CEO and independent directors in non-state-owned listed companies has a more significant impact on enterprise R&D expenditure. From the perspective of invention patents, in the sample of non-state-owned listed companies, the regression coefficient of the independent variable *Relationship* is +0.073, which passes the significance test of 5%; In the sample of state-owned listed companies, the regression coefficient of the independent variable *Relationship* is -0.003, which does not pass the significance test. As a result, compared with state-owned listed companies, the social relationship between CEO and independent directors in non-state-owned listed companies has a significant impact on enterprise R&D efficiency.

Table 4. Results of PSM.

Variable	Sample	Treated	Controls	Difference	S.E.	T-stat
<i>RD</i>	Unmatched	4.0128	2.6526	1.3602	0.1095	12.43
	ATT	4.0128	3.1880	0.8248	0.1790	4.61

Table 5. Empirical results of the impact of the nature of property rights.

	<i>RD</i>		<i>Invention</i>	
	SOE	non-SOE	SOE	non-SOE
<i>Cons</i>	-0.453 (-0.97)	0.474 (0.60)	-7.055*** (-10.22)	-4.933*** (-10.43)
<i>Relationship</i>	0.041 (0.46)	0.381*** (3.13)	-0.003 (-0.03)	0.073** (2.12)
<i>Size</i>	0.048* (1.70)	-0.037 (-0.99)	0.355*** (11.54)	0.237*** (10.99)
<i>Lev</i>	-1.051*** (-6.89)	-0.005 (-1.61)	-0.506*** (-2.59)	0.057 (0.49)
<i>Roa</i>	-0.005 (-0.79)	-0.006* (-1.66)	-0.003 (-0.47)	-0.001 (-0.28)
<i>Mb</i>	-1.180*** (-5.27)	-2.095*** (-9.38)	-0.546*** (-3.10)	-0.139 (-1.37)
<i>Cash</i>	0.455 (1.37)	3.790*** (11.64)	-0.271 (-0.91)	-0.095 (-0.78)
Industry Fixed Effect	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
F	89.16	123.41	9.19	9.85
P > F	0.0000	0.0000	0.0000	0.0000
R ²	0.243	0.325	0.190	0.109
Obs	12,147	16,714	2283	4898

Note: *, **, *** correspond to 10%, 5% and 1% significance levels respectively.

5.2. Impact of Corporate Governance

This paper uses the shareholding ratio of institutional investors, separation or combination of chairman and CEO positions and the proportion of independent directors to measure the level of corporate governance. The high shareholding ratio of institutions, the separation of chairman and CEO positions and the high proportion of independent directors indicate the high level of corporate governance of the company.

Table 6 shows the empirical results of analyzing the impact of the social relationship between CEO and independent directors on the R&D heterogeneity of listed enterprises through the above three corporate governance indicators. According to the fact that the shareholding ratio of institutional investors is higher or lower than the median of the sample, this paper divides it into two sub samples: high and low shareholding ratio, and substitutes the sample data into the regression Equations (4-1). As can be seen from the table, in terms of R & D expenditure, in the sample with low shareholding ratio of institutional investors, the regression coefficient of the independent variable *Relationship* is +0.409, and the corresponding t value is 3.00, which passes the 1% significance level test; in the samples with high shareholding ratio, the regression coefficient of the independent variable *Relationship* is +0.282, and the corresponding t value is 2.47, which passes the 5% significance level test. For invention patents, in the sample with low shareholding ratio of institutional investors, the regression coefficient of the independent variable *Relationship* is +0.023, and the corresponding t value is 1.78, which passes the 10% significance level test; in the samples with high shareholding ratio, the regression coefficient of the independent variable *Relationship* is -0.074 and the corresponding t value is -0.96, which does not pass the significance test. Therefore, compared with companies with high institutional shareholding ratio, the social relationship between CEO and independent director in companies with low shareholding ratio has a more significant impact on enterprise R&D expenditure and R&D efficiency.

In terms of separation or combination of chairman and CEO positions, this paper is divided into two sub samples: combination and separation, and substitute the sample data into the regression Equations (4-1). It can be seen from **Table 6** that in the sample with two concurrent positions, the regression coefficient of the independent variable *Relationship* is +0.936, and the corresponding t value is 4.30, which passes the 1% significance level test; in the sample of two separated positions, the regression coefficient of the independent variable *Relationship* is 0.094, and the corresponding t value is 0.92, but it does not pass the significance test. Therefore, compared with the separation of CEO and chairman positions, the social relationship between the CEO, who is also the chairman, and independent directors has a more significant impact on enterprise R&D expenditure. As for the influence of the two samples on the invention patent, the regression coefficients of the independent variable *Relationship* fail to pass the significance test.

Table 6. Empirical results of the impact of corporate governance.

	<i>RD</i>						<i>Invention</i>					
	high-level corporate governance			low-level corporate governance			high-level corporate governance			low-level corporate governance		
	HR	SN	HP	LR	CN	LP	HR	SN	HP	LR	CN	LP
<i>Cons</i>	0.580 (1.00)	1.979*** (2.65)	0.701 (1.11)	0.704 (0.87)	-0.680 (-0.47)	2.310 (0.48)	-6.094*** (-10.55)	-7.382*** (-13.89)	-6.470*** (-9.83)	-5.857*** (-11.66)	-4.643*** (-5.82)	-18.415 (-1.58)
<i>Relationship</i>	0.282** (2.47)	0.094 (0.92)	0.175 (1.36)	0.409*** (3.00)	0.936*** (4.30)	0.161** (2.17)	-0.074 (-0.96)	0.047 (0.66)	-0.009 (-0.12)	0.023* (1.78)	0.001 (0.01)	2.363 (2.11)
<i>Size</i>	-0.031 (-0.95)	-0.075** (-2.16)	-0.051 (-1.52)	-0.027 (-0.69)	-0.051 (-0.79)	0.100 (0.43)	0.317*** (13.16)	0.322*** (14.22)	0.331*** (10.37)	0.254*** (11.32)	0.232*** (6.49)	0.993 (2.11)
<i>Lev</i>	-0.892*** (-2.93)	-0.330* (-1.86)	-0.170** (-2.36)	-0.141*** (-2.69)	-0.143*** (-3.40)	-0.438 (-0.48)	-0.390*** (-2.67)	0.273* (-1.94)	-0.268* (-1.80)	0.152 (1.13)	-0.067 (-0.33)	-7.509 (-0.97)
<i>Roa</i>	-0.021*** (-3.10)	-0.010** (-2.05)	-0.010*** (-2.77)	-0.008*** (-3.20)	-0.019*** (-4.19)	0.039 (1.28)	-0.006 (-1.56)	-0.001 (-0.35)	-0.003 (-0.89)	0.001 (0.43)	-0.005 (-1.08)	-0.165 (-1.47)
<i>Mb</i>	-1.385*** (-6.26)	-1.775*** (-6.79)	-1.972*** (-8.04)	-2.245*** (-8.55)	-2.314*** (-6.28)	-3.683*** (-3.03)	-0.224* (-1.76)	-0.299** (-2.40)	-0.368*** (-2.65)	-0.294** (-2.36)	-0.256 (-1.44)	0.061 (0.02)
<i>Cash</i>	1.016*** (3.17)	3.550*** (10.45)	2.602*** (8.13)	4.429*** (11.67)	3.905*** (9.46)	-1.245 (-0.64)	-0.225 (-1.17)	-0.049 (-0.27)	-0.125 (-0.79)	-0.062 (0.43)	-0.118 (-0.57)	2.304 (0.37)
Industry Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F	129.57	109.54	112.98	125.37	46.74	2.69	9.27	11.85	9.47	8.69	3.31	1.06
P>F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R2	0.304	0.315	0.312	0.352	0.355	0.388	0.136	0.161	0.143	0.129	0.099	0.903
Obs	14283	15010	13140	13289	5329	284	3520	3838	3421	3651	1740	40

Note: *, **, *** correspond to 10%, 5% and 1% significance levels respectively.

Under the two sub samples of high and low proportion of independent directors, it can still be seen from **Table 6** that the regression coefficient of the independent variable *Relationship* in the high sample is +0.175, and the corresponding t value is 1.36, which fails to pass the significance level test; The regression coefficient of the independent variable *Relationship* in the low sample was +0.161, and the corresponding t value is 2.17, which passes the 5% significance level test. Therefore, compared with companies with high proportion of independent directors, the social relationship between CEO and independent directors has a more significant impact on enterprise R&D expenditure in companies with low proportion of independent directors. As for the influence of the two samples on the invention patent, the regression coefficients of the independent variable *Relationship* did not pass the significance test.

Therefore, except that the impact of corporate governance level, measured by the proportion of independent directors and separation or combination of chairman and CEO positions, on enterprise R&D efficiency fails to pass the significance test (possibly due to insufficient sample size), other indicators show that, compared with listed companies with higher corporate governance level,

the social relationship between CEO and independent director in the listed companies with low governance level has a more significant impact on enterprise R&D, and the hypothesis H4 is empirically supported.

5.3. Impact of Financing Constraints

Financing constraints will affect the R&D of enterprises, so this paper introduces company size, dividend policy, company age and KZ index to quantify the tightness of financing constraints of listed companies. Among them, small and young companies with no cash dividend policy and a large KZ index have tight financing constraints; On the contrary, corporate financing constraints are relatively loose.

Compared with large companies, due to the lack of assets as loan collateral and other reasons, small companies are subject to tighter financing constraints. According to the fact that the total assets of the company are higher and lower than the median of the total assets of the sample companies, this paper divides them into two sub samples: loose financing constraints-large size and tight financing constraints-small size, and then brings the sample data into the regression models (4-1). **Table 7** is the empirical results of quantifying financing constraints by using company size. It can be seen that the regression coefficient of the independent variable *Relationship* of the sub sample with large sized companies is +0.009, and the corresponding t value is 0.09, which fails to pass the significance test; the regression coefficient of the independent variable *Relationship* of the sub sample with small sized companies is +0.699, and the corresponding t value is 4.90, which passes the 1% significance level test. Therefore, compared with larger companies, the social relationship between CEO and independent directors of smaller companies has a more significant impact on the improvement of enterprise R&D expenditure. For invention patents, the independent variables *Relationship* of two sub samples do not pass the significance test.

In terms of whether to pay dividends, investors prefer companies that pay cash dividends. Therefore, companies that pay cash dividends are subject to loose financing constraints, while companies that do not pay cash dividends are subject to tight financing constraints. According to this, this paper divides them into two sub samples: loose financing constraints-paying dividends and tight financing constraints-not paying dividends. Then the sample data are brought into the regression models (4-1). The empirical results are also listed in **Table 7**. It can be seen from the table that for the impact on R&D expenditure, the regression coefficient of the independent variable *Relationship* of the sub sample with cash dividend payment is +0.34, and the corresponding t value is 2.06, which passes the 5% significance level test; the regression coefficient of the independent variable *Relationship* of the sub sample without cash dividend payment is +0.42, and the corresponding t value is 3.85, which passes the 1% significance level test. For the impact on invention patents, the regression coefficient of the independent variable *Relationship* of the sub sample with cash dividend payment is +0.087, and the corresponding t value is 0.97, which does not pass the

Table 7. Results of the impacts of company size and cash dividends.

	<i>RD</i>				<i>Invention</i>			
	loose financing constraints		tight financing constraints		loose financing constraints		tight financing constraints	
	Large	paying dividends	Small	not paying dividends	Large	paying dividends	Small	not paying dividends
<i>Cons</i>	1.932** (2.38)	0.900 (0.85)	-4.305*** (-3.46)	2.274*** (3.24)	-7.307*** (-10.68)	-6.734*** (-9.63)	-5.126*** (-7.90)	-5.713*** (-9.63)
<i>Relationship</i>	0.009 (0.09)	0.340** (2.06)	0.699*** (4.90)	0.420*** (3.85)	0.053 (0.57)	0.087 (0.97)	0.052 (1.04)	0.076** (2.14)
<i>Size</i>	-0.014 (-0.30)	0.076 (1.46)	0.159*** (2.68)	0.017 (0.53)	0.337*** (11.21)	0.338*** (10.68)	0.248*** (8.18)	0.255*** (11.08)
<i>Lev</i>	-1.166** (-2.03)	-4.076*** (-13.18)	-0.116** (-2.31)	-3.306*** (-14.27)	-0.249 (-1.39)	-0.127 (-0.66)	-0.030 (-0.27)	0.001 (0.01)
<i>Roa</i>	-0.033*** (-3.19)	-0.086*** (-5.95)	-0.007*** (-3.23)	-0.058*** (-8.12)	0.001 (0.18)	0.002 (0.25)	-0.003 (-1.29)	-0.009* (-1.91)
<i>Mb</i>	-2.492*** (-7.47)	-2.492*** (-8.22)	-0.852*** (-3.64)	-2.886*** (-14.63)	-0.327** (-2.07)	-0.361** (-2.06)	-0.148 (-1.46)	-0.399*** (-2.99)
<i>Cash</i>	1.276*** (2.61)	3.455*** (8.25)	3.516*** (11.45)	1.113*** (4.90)	-0.461 (-1.61)	0.325 (1.26)	0.033 (0.29)	-0.145 (-0.96)
Industry Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F	121.87	81.78	128.98	140.62	7.87	6.06	6.76	8.86
P > F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R2	0.282	0.398	0.349	0.437	0.131	0.140	0.090	0.135
Obs	13290	8110	14316	11860	3113	2288	4067	3539

Note: *, **, *** correspond to 10%, 5% and 1% significance levels respectively.

significance level test; the regression coefficient of the independent variable *Relationship* of the sub sample without cash dividends payment is +0.076, and the corresponding t value is 2.14, which passes the 5% significance level test. Therefore, compared with companies that pay cash dividends the social relationship between CEO and independent directors has a more significant impact on enterprise R&D expenditure and R&D efficiency under the background that the company does not pay cash dividends.

Company age has an important impact on enterprise decision-making. With the growth of the company's age, mature companies may have experienced labor force and lasting organizational memory in some fields, while young companies are significantly more risky. Therefore, investors tend to choose mature companies. Mature companies are subject to loose financing constraints, while young companies are subject to tight financing constraints. Based on the fact that the age of listed companies is higher and lower than the median age of companies in the sample, this paper divides them into two sub samples: loose financing con-

straints-mature companies and tight financing constraints-young companies, and then brings the sample data into the regression models (4-1). **Table 8** is the empirical results of quantifying financing constraints by company age. It can be seen that the regression coefficient of the independent variable *Relationship* of the sub sample of mature companies is +0.219, and the corresponding t value is 2.23, which passes the 5% significance level test; the regression coefficient of the independent variable *Relationship* of the sub sample of young companies is +0.322, and the corresponding t value is 3.12, which passes the 1% significance level test. Therefore, compared with mature companies, the social relationship between CEO and independent directors of young companies has a more significant impact on enterprise R&D expenditure. For the impact of invention patents, the regression coefficients of the independent variable *Relationship* of mature companies and young companies do not pass the significance level test.

Table 8. Empirical results of the impacts of company age and KZ index.

	<i>RD</i>				<i>Invention</i>			
	loose financing constraints		tight financing constraints		loose financing constraints		tight financing constraints	
	mature	small KZ index	young	large KZ index	mature	small KZ index	young	large KZ index
<i>Cons</i>	3.433*** (5.00)	2.621*** (4.40)	0.683 (1.12)	0.622 (0.59)	-6.468*** (-13.76)	-5.873*** (-9.56)	-5.630*** (-8.70)	-4.820*** (-7.51)
<i>Relationship</i>	0.219** (2.23)	0.214** (2.22)	0.322*** (3.12)	0.520*** (3.24)	-0.004 (-0.06)	0.073 (1.02)	0.110 (1.49)	0.054*** (3.65)
<i>Size</i>	-0.144*** (-4.36)	-0.029 (-0.97)	-0.068** (-2.14)	0.079 (1.61)	0.303*** (13.95)	0.265*** (10.16)	0.261*** (10.28)	0.241*** (8.47)
<i>Lev</i>	-0.214* (-1.77)	-2.454*** (-11.46)	-0.004* (-1.70)	-4.466*** (-13.15)	0.108 (0.78)	0.004 (0.02)	-0.246* (-1.74)	0.092 (0.44)
<i>Roa</i>	-0.013** (-2.27)	-0.038*** (-4.72)	-0.003 (-1.32)	-0.070*** (-7.77)	-0.001 (-0.30)	-0.009** (-1.98)	-0.002 (-0.55)	0.010 (1.31)
<i>Mb</i>	-2.417*** (-10.27)	-2.020*** (-11.67)	-1.175*** (-5.48)	-2.965*** (-11.87)	-0.361** (-2.06)	-0.374*** (-2.75)	-0.198 (-1.49)	-0.229 (-1.38)
<i>Cash</i>	3.673*** (9.53)	1.033*** (3.73)	1.946*** (6.46)	1.741*** (5.73)	0.059 (0.40)	-0.131 (-0.86)	-0.091 (-0.48)	0.083 (0.30)
Industry Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F	124.91	126.57	134.36	97.28	11.40	8.26	7.20	6.21
P > F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R2	0.359	0.469	0.311	0.397	0.162	0.143	0.111	0.135
Obs	13,558	9370	15,303	9503	3658	2990	3528	2478

Note: *, **, *** correspond to 10%, 5% and 1% significance levels respectively.

In terms of the impact of KZ index, referring to the classification of corporate financing constraints by Kaplan and Zingales (1997). The empirical results of KZ index quantifying financing constraints are also listed in Table 8. It can be seen from the table that for the impact on R&D expenditure, the regression coefficient of the independent variable *Relationship* of the sub sample with small KZ index is +0.214 and the corresponding t value is 2.22, which passes the 5% significance level test, while the regression coefficient of the independent variable *relationship* of the sub sample with large KZ index is +0.520 and the corresponding t value is 3.24, which passes the 1% significance level test. However, for the impact of invention patents, the regression coefficient of the independent variable *relationship* of the sub sample with small KZ index do not pass the significance test, while the regression coefficient of the independent variable *Relationship* of the sub sample with large KZ index is +0.054, corresponding to t value of 3.65, which passes the 1% significance level test. Therefore, compared with companies with small KZ index and loose financing constraints, the social relationship between CEO and independent director in companies with large KZ index and tight financing constraints has a more significant impact on R&D expenditure and R&D efficiency of listed enterprises. The hypothesis H5 is empirically verified.

6. Conclusion

R&D activities are not only one of the important activities to promote the long-term survival of the company, but also an important development direction of the country. The research on the influencing factors of R&D activities has always been an important topic concerned by many scholars. Independent directors play an important role in corporate governance and are responsible for supervising and advising managers, which can effectively reduce agency costs and provide more opinions and expertise beyond the ability of management. This may mean that enterprises can directly explore emerging fields and avoid some information collection costs. However, due to the potential conflict of interest between the independent director and the CEO, or the difference in their familiarity with the industry and technology, the quality of independent directors' suggestions on enterprise R&D may also be different. Therefore, from the unique perspective of the social relationship between CEO and independent directors, it is of great significance to explore whether this relationship network can promote enterprise R&D activities.

This paper chooses the data of Chinese A-share listed companies from 2006 to 2019 and studies the impact of the social relationship between CEO and independent directors on the R&D of listed companies, and does different sensitivity tests. The results show that the social relationship between CEO and independent directors can promote the R&D expenditure of enterprises. And compare with SOE, the social relationship between CEO and independent directors in non-SOE has a more significant impact on their R&D; compared with a high

level of corporate governance, the social relationship between CEO and independent directors with a low level of corporate governance has a more significant impact on R&D; compared with enterprises with loose financing constraints, the social relationship between CEO and independent directors with tight financing constraints has a more significant impact on the R&D expenditure.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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