

Article

Social Trust and Green Technology Innovation: Evidence from Listed Firms in China

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Abstract: Green Technology innovation intends to enable the advancement of technologies toward the goals of human health, natural resource sustainability and social equity. Green technology innovation has become an important driving force for the sustainable growth of the global economy. In this study, building upon the theories on informal institutions, we empirically investigate the effects of social trust on green technology innovation. Using a sample of companies listed in A-share markets in China from 2012 to 2017, we find that social trust has a significant positive impact on the performance of green technology innovation. We employ an instrumental variable approach through two-stage-least square estimator, and report consistent results. Further heterogeneity analysis finds that with higher levels of policy uncertainty and lower levels of intellectual property rights protection, the effect of social trust on firms' green technology innovation is more significant. Further, the effect of social trust on firms' green technology of non-SOEs innovation is larger than SOEs. In addition, the positive effect of social trust on green technology innovation in firms is an effective supplement for formal systems to promote green technology innovation in said firms, which provides a new theoretical reference for promoting firms' green technology innovation and achieving high-quality development.

Keywords: social trust; green technology innovation; economic policy uncertainty; intellectual property rights protection; property rights



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1. Introduction

Since the reform and opening up of China 40 years ago, China's factor-driven development model has not only promoted rapid economic growth, but also brought about a huge environmental cost. For example, in the event of a growth model that produces haze, groundwater pollution, and other adverse events, the cost to the environment is bound to be unsustainable over a long period of time and cannot meet the new requirements of high-quality development. Under the new economic normal, it has become an inevitable choice, in order to achieve high-quality economic development in China, to change the mode of development, taking into account the dual goals of environmental protection and economic development, and guide economic growth toward a green, efficient, and sustainable innovation-driven mode. The Fifth Plenary Session of the 19th CPC Central Committee further stressed that we should unswervingly implement the new development concepts of innovation, coordination, greenness, openness, and sharing, which once again highlights the importance of green technology innovation.

As a necessary means to coordinate environmental protection and economic development [1], green technology innovation has become an important field in the new round of industrial revolution and competition. The pursuit of green and innovation-driven development is also included in the key words of China's future economic growth. According to the China Green Patent Statistics Report (2014–2017) issued by the State Intellectual

Property Office, China's green technology innovation activities are active, and the number of green patents in 2017 reached 1.8 times that of 2014. However, 80% of the green patent applicants come from universities. In contrast, the green technology innovation power of firms is obviously insufficient. This is mainly due to the externality problem of green technology innovation [2]; that is, firms do not directly experience the environmental benefits brought by the implementation of green technology innovation, which is bound to lessen the source power needed to actively carry out green technology innovation activities [3]. Green technology innovation in firms has become the focus of theoretical research. The existing literature mainly studies it from the perspective of environmental regulation, government support, and other formal systems, but discussing the relationship between formal systems and green technology innovation in firms is not enough. The focus of the formal system is to solve the problem of an insufficient supply of green technology innovation. In addition, China is in a stage of rapid transformation, and the formal system is not perfect, so it is difficult to really solve the problem of a lack of internal power in the main body of green technology innovation. Therefore, it is necessary to clarify the influence mechanism of informal systems on green technology innovation, so as to make up for the lack of a formal system in green technology innovation. Further research shows that social trust is an important informal institutional factor [4], which is considered to be the most important type of social capital, besides material and human capital [5]. Therefore, from the perspective of informal systems, this paper investigates the influence mechanism and boundary conditions of social trust on green technology innovation in firms in order to provide a theoretical reference for promoting the practice of green technology innovation in firms in China.

2. Literature Review

Institutional factors form an important basis of innovation activities. Due to the externality of green technology innovation, green technology innovation from the perspective of systems is the focus of theoretical attention. The existing research mainly focuses on the formal system level, such as environmental regulation and government support, but the relationship between informal systems and green technology innovation of firms is rarely involved.

There is no consensus on the relationship between environmental regulation and green technology innovation in firms: one view is that environmental regulation has a negative impact on green technology innovation in firms [6]. The pollution control cost and environmental cost caused by environmental regulations increase the "compliance cost" of firms [7], crowd out the innovation activities of firms, and hinder the enthusiasm associated with green technology innovation [8]. Another view is that environmental regulation promotes green technology innovation [9]. As environmental regulation forces firms to engage in technological innovation activities [10], it stimulates firms' green technological innovation behavior and produces an "innovation compensation" effect [11]. In addition, some scholars found that the relationship between environmental regulation and green technology innovation is not a simple linear relationship, but rather a "U" type relationship with a threshold effect [12,13]. Some scholars also pointed out that the relationship between environmental regulation and green technology innovation is an inverted "U" type relationship [14].

There are also different views on the theoretical research on the influence of government support for green technology innovation in firms. Some scholars believe that government subsidies have a positive incentive effect on Firm R&D, which is conducive to improving the green technology innovation ability of firms [15]. For example, Lu et al. took China's listed companies that cause heavy pollution as the research object and found that financial subsidies enhance the investment intensity of firms' environmental protection and have a positive effect on green technology innovation [16]. However, some scholars hold different views, namely, that government subsidies will have an extrusion effect on green technology innovation in firms. For example, David et al. [17] believes that a large number

of government subsidies will weaken the value creation motivation and risk-taking spirit of decision-makers, and R&D subsidies may distort the green technological innovation of low-tech firms [18]. Some scholars in China have found that there is a negative correlation between government subsidies and green technology innovation, and direct R&D funding has not played a good role in stimulating green technology innovation [19].

Scholars also discuss the problems of Green Governance from the perspective of external boards of directors and technology innovation. For example, Li et al. [20] pointed out that media reports arouse public attention, and the legitimacy pressure of stakeholders has a positive effect on green technology innovation in firms. Some scholars also found that media attention has a significant positive impact on green technology innovation input, but the impact on green technology innovation output is moderated by the level of marketization [21]. Taking the listed companies that cause heavy pollution in China's industries as samples, Wang et al. [22] found that board governance has a significant positive impact on green technology innovation. Zhang et al. [23] analyzed the direct impact of subjective norms on green technology innovation behavior and found that environmental ethics in firms has a positive effect on green technology innovation.

Through the abovementioned literature review, we can see that most studies focus on the impact of formal institutional factors on green technology innovation in firms, and the research on green technology innovation in firms from the informal institutional level is not sufficient. In informal institutions, social trust is the most important type of social capital for promoting innovation and development [5], and it is also the proxy variable commonly used in most studies on the economic consequences of informal institutions [24,25]. In other words, social trust is the most important informal institutional factor, but it has not been fully studied in the literature, so it is necessary to deeply explore the role of social trust as an informal institutional factor in green technology innovation in firms. There are obvious differences in the protection of intellectual property rights in different regions due to the different levels of economic and social trust [26]. Based on this, this paper further investigates the situational mechanism that affects the relationship between social trust and green technology innovation. The discussion of the abovementioned issues is not only helpful for expanding the theoretical research on the economic consequences of informal institutions, but also of great value for exploring the practice of promoting green technological innovation in firms from the perspective of informal institutions.

3. Research Hypothesis

3.1. Social Trust and Green Technology Innovation in Firms

Green technology innovation is an innovative way to realize a combination of environmental protection and economic benefits. Compared with the general significance of technological innovation, green technology innovation emphasizes resource conservation and environmental protection. The peculiarity of environmental concerns is that they increase innovation investment and risk and have multiple externalities [27], including technology spillover, innovation output, environmental pollution, and other external factors, which are important factors affecting choices of green technology innovation. In particular, these multiple externalities are the main reason for the lack of a force in firms that drives them toward implementing green technology innovation. Therefore, countries actively adopt formal systems of regulation to drive the green technology innovation of firms, and the existing theoretical literature also focuses on this research. However, the relationship between regulation and green technology innovation is complex, and there is no consistent conclusion in the literature. Even in some studies, it is pointed out that regulation may inhibit innovation enthusiasm [8]. In fact, social trust, as an important informal institutional factor [5], can be an important supplement for the formal system. The influence of social trust on green technology innovation in firms is mainly reflected in the following two aspects: (1) Social trust can alleviate the external problems of green technology innovation in firms. As the social income from investment in green technology innovation is greater than that of the firm, it lacks the power to bear the cost of green

technology innovation [28]. In other words, firms bear the cost of a large amount of green technology innovation and bear higher uncertainty risks, but they have difficulty obtaining all or most of the benefits, which causes obvious constraints on the firms that prevent them from carrying out green technology innovation activities. Generally speaking, in the areas with a higher social trust level, firms or individuals are more likely to abide by moral constraints, pay more attention to maintaining their own credibility [29], weaken the “speculation” behavior of firms in the process of innovation, and reduce the occurrence of “hitchhiking” or infringement. To some extent, social trust can help to alleviate the external problems of green technology innovation and stimulate the enthusiasm of firms to engage in green technology innovation. (2) Social trust can help to alleviate the problem of information asymmetry in firms. As we all know, there is a serious information asymmetry in innovation activities, and the high risk and uncertainty of innovation require continuous capital input, especially the support of external funds. Obviously, information asymmetry makes external investors unable to trust or invest in a firm [30], which leads to severe financing constraints on green technology innovation in the firm. However, in areas with a higher social trust, the information disclosure of firms will be more transparent, and the information quality will be higher [31], which is conducive to a better understanding of firms by external investors, thus alleviating the financing constraints on green technology innovation [32]. Based on the analysis above, we can propose the following hypothesis:

Hypothesis 1 (H1). *Social trust is positively correlated with green technology innovation.*

3.2. Social Trust, Policy Uncertainty, and Green Technology Innovation in Firms

Policy uncertainty is an important source of firms’ uncertainty about the external environment [33]. Especially in the important transition stage of China’s high-quality development, new changes in policy may bring about higher uncertainty, which makes it difficult for firms to formulate an objective and accurate prediction of future trends, which inevitably has a potential impact on their decision-making behavior. Specifically, the effect of policy uncertainty on the relationship between social trust and green technology innovation is mainly reflected in the following two aspects: (1) On the one hand, with the increase in policy uncertainty, the external business environment of firms will continue to fluctuate, and the business risk will increase accordingly [34]. As a high-risk activity, green technology innovation is bound to further lead to risk superposition and greater uncertainty in the case of policy uncertainty, which may hinder the major innovation decisions of firms. (2) On the other hand, policy uncertainty leads to an increase in uncertainty in the external business environment, thus further aggravating information asymmetry and resulting in a reduction in external investors’ trust in firms, which reduces the investment behavior of firms to avoid risks. Firms’ green technology innovation activities will face more severe financing constraints [35]. Based on the above analysis, in the case of a high degree of policy uncertainty, a good social trust environment can promote better information disclosure and information sharing [31], which helps to reduce the adverse impact of policy uncertainty on innovation. In the case of a low degree of policy uncertainty, the external environment of firms is less uncertain, which weakens the incentive effect of social trust on green technology innovation. Based on the analysis above, we can propose the following hypothesis:

Hypothesis 2 (H2). *The relationship between social trust and green technology innovation is moderated by policy uncertainty. Specifically, the relationship between social trust and green technology innovation is more prominent when the policy uncertainty is higher.*

3.3. Social Trust, Intellectual Property Rights Protection, and Green Technology Innovation in Firms

Intellectual property is an important resource of firms, but it also has obvious spillover characteristics. If competitors imitate and copy, the actual profit will be far lower than the expected profit. This will not only reduce the enthusiasm for R&D investment, but

also reduce the willingness of external investors to invest in firm innovation. Therefore, firms are often reluctant to disclose R&D-related information to external investors, which further aggravates the information asymmetry between the firms and external investors, making it difficult for external investors to make a reasonable judgment regarding firm innovation and increasing the financing constraints on green technology innovation in firms. In addition, under the condition of limited intellectual property rights protection, it is difficult for firms to completely avoid imitation of other firms [36], even some patent infringement. As an important informal system, social trust is a kind of moral constraint on the behavior of individuals or firms, and dishonest individuals or firms may face moral condemnation. In other words, the better the level of social trust, the more help there will be to reduce the occurrence of intellectual property infringement. Therefore, in the case of weak intellectual property rights protection, the higher the level of social trust in the region where the firm is located, the lower the possibility of seizing private interests by dishonest information disclosure [37], so the spillover of green technology innovation achievements will be reduced. In addition, if the protection of intellectual property rights is weakened, the investment interests of external investors may suffer losses due to intellectual property rights infringements. Therefore, a higher level of trust is more conducive to reducing the risk taken by external investors and eases the financial constraints on green technology innovation in firms. Therefore, the weaker the protection of intellectual property rights, the more obvious the effect of social trust on firms' green technology innovation. Based on the analysis above, we can propose the following hypothesis:

Hypothesis 3 (H3). *The relationship between social trust and green technology innovation is moderated by protection of intellectual property rights. Specifically, the relationship between social trust and green technology innovation is more prominent when the protection of intellectual property rights is weaker.*

3.4. Social Trust, Property Rights, and Green Technology Innovation in Firms

Under the special institutional background of China, there is a strong correlation between the nature of property rights and firm management behavior [38]. Thus, to a certain extent, the nature of property rights will affect the relationship between social trust and green technology innovation in firms; that is, the relationship between social trust and green technology innovation in firms may be heterogeneous under different property rights. Specifically, compared with non-state-owned firms, on the one hand, state-owned firms are more likely to use the relationship with the government to obtain policy resources, such as R&D subsidies and tax incentives, and they are often not subject to credit "discrimination" by banks and other financial institutions. They are also less likely to be subject to financing constraints. Therefore, for the state-owned firm group, the incentive effect on green technology innovation will become less obvious due to the easing of financing constraints caused by social trust. Due to the lack of this connection, the social trust has a higher impact on green technology innovation. On the other hand, there is a natural internal relationship between the state-owned firms and the government, such that they can understand the direction of policy evolution more accurately and in a timely fashion [39] and better deal with environmental uncertainty, which helps to reduce the innovation risk brought by environmental uncertainty. In this sense, the role of social trust in promoting green technology innovation in state-owned firms will not be obvious. In addition, state-owned firms need to pay more attention to environmental benefits and social benefits and undertake more non-economic responsibilities. Due to the externality of green technology innovation, the enthusiasm of non-state-owned firms in this respect is relatively low. Therefore, the green technology innovation behavior of non-state-owned firms requires more moral constraints and social norms, and social trust will play a greater role in the green technology innovation of firms. Based on the analysis above, we can propose the following hypothesis:

Hypothesis 4 (H4). *The relationship between social trust and green technology innovation is moderated by property rights. Specifically, in non-state-owned firms, the relationship between social trust and green technology innovation is more prominent.*

4. Data and Method

4.1. Sample Construction

This paper uses the companies listed in A-share markets in China from 2012 to 2017 as the research sample. In particular, we construct our sample according to the following steps: (1) exclude companies in the financial industry; (2) delete all special treatment (ST) and particular transfer (PT) companies; (3) exclude samples with missing variables. Finally, 4583 sample observations were obtained. This research was acquired from the Guotai'an Economic and Financial Database (CSMAR). To keep away extreme values' impact on the estimation results, we trimmed one percent of the sample on both tails. Industry and Year represent the industry effect and year effect of the firm separately, which are controlled in the regression analysis.

In order to verify the relationship between social trust and green technology innovation in firms, this paper constructs the following econometric model:

$$GP_{it} = \beta_0 + \beta_1 Trust_{it} + \sum Control_{it} + \sum Industry_{it} + \sum Year_{it} + \varepsilon \quad (1)$$

Among them, the explained variable includes three kinds of patent output indicators to measure the green technology innovation of firms; the main explanatory variable (Trust) is the level of social trust in the region where the firms are located; Control contains a series of firm level control variables; Industry is the industry fixed effect; Year is the time fixed effect; and ε is a random disturbance term. If the estimated coefficient of social trust is significantly positive, this shows that social trust can promote green technology innovation. The specific definitions of each variable are shown in Table 1.

Table 1. Definition of Variables.

Type	Name	Symbol	Explanation
Dependent Variable	Green technology innovation	Patent_Application	Patent_Application = $\ln(1 + \text{green patents}/\text{applied patents})$
		Patent_Grant	Patent_Grant = $\ln(1 + \text{green patents}/\text{granted patents})$
		Patent_Total	Patent_Total = $\ln\{1 + \text{green patents}/(\text{applied patents} + \text{granted patents})\}$
Independent Variable	Social trust	Trust	China City Commercial Credit Environment Index
Control Variable	Size of firm	Size	$\ln(\text{total assets at the end of the period})$
	Return on assets	ROA	Net profit/average total capital
	Debt to asset ratio	Leverage	Net debt/total assets
	Ownership concentration	Largest	Proportion of the largest shareholder
	Book-to-market ratio	MB	Shareholders' equity/market value
Moderating variables	Economic policy uncertainty	EPU	Annual data based on weighted average of news indices prepared by Baker et al. [40]
	Intellectual property rights protection	IPR	Number of patent disputes filed/Number of patent disputes authorized
	State ownership	SOE	State-owned as 1; non-state-owned as 0

4.2. Variable Operationalization

4.2.1. Dependent Variable—Green Technology Innovation

In previous studies, green innovation is usually measured by output or input, such as green R&D input, green patent output, or total factor productivity [41]. Compared with other indicators, the patent is the most valuable output form of regional technological innovation and invention effort [42]. Green patents are used to measure output of green science and technology R&D [43]. Given the availability of data, this study used green patents as a measure of green technology innovation [44]. In this paper, we measure the level of green technology innovation using three indicators: the proportion of green patents in patent applications, patent authorizations, and the total number of patents in the current year. This is because, compared with the direct use of patent applications or authorizations, the use of proportion data can more effectively eliminate the influence of other unobservable factors [45]. Referring to Li's literature [46], firstly, the patent application, patent grant and international patent classification (IPC) number of Listed Companies in heavy pollution industry are manually searched from the search page of State Intellectual Property Office (SIPO). Then, the IPC number of green patents in the "IPC Green Inventory" launched by World Intellectual Property Organization (WIPO) in 2010 is used. By matching the enterprise level patent types retrieved from State Intellectual Property Office (SIPO), we can obtain the number of green patents applied and authorized by enterprises every year. It is generally believed that green patents are mainly divided into invention patents, utility model patents, and design patents. Therefore, in order to further investigate the impact on different patent types, in the robustness test, the proportion of green patents to all authorized invention patents, authorized utility model patents, and authorized design patents in the year is used as an alternative variable. The reason why the number of authorized patents is adopted is that it can better reflect the actual green technology innovation ability of firms [47]. Referring to the practice in the existing research, all of the above indicators of patent output are the proportion plus 1, considering the logarithm [48].

4.2.2. Independent Variable—Social Trust

Referring to the research of Liu et al. [49], this paper uses the China city commercial credit environment index (CEI), compiled by the China academy of management sciences, to measure the social trust index. Some missing years of data are supplemented by the commonly used processing methods in the literature, even if the data of adjacent years are used as an alternative. In recent sociological and economic studies, the index is widely used to measure social trust [50,51]. Among them, the CEI index mainly includes seven different aspects, such as dishonesty and the violation of regulations, integrity education, etc., It comprehensively evaluates a city's credit environment. The index ranges from 0 to 100. It can reflect the overall social trust level of a region more comprehensively and accurately, to a certain extent. The larger the value is, the better the city's business trust environment is.

4.2.3. Control Variable

The basis for including these controls was established on prior research and the following logic. Referring to the research of Cai et al. [52], Wang et al. [53], and Li et al. [54], the paper selects the size of the firm (Size), return on assets (ROA), debt to asset ratio (Leverage), ownership concentration (Largest), and return on assets (MB) as the control variables. To a certain extent, the size of the firm reflects the different stages of the growth of the firm and has a certain impact on the green innovation of the enterprise; return on assets (ROA) is an important index to measure the profitability of firms, and the profitability of firms directly affects the investment in innovation; the debt to asset ratio (Leverage) is a comprehensive index to evaluate the company's debt level, as a firm with low debt to asset ratio has stronger profitability, and such a firm may be more inclined towards green technology innovation; the board ratio of the largest shareholder (Largest) has two effects

of “hollow out” and “supervision”. It may have different impacts on the company’s green technology innovation; the higher the book-to-market ratio (MB) is, the better the company’s performance is, and the more inclined it is to carry out green technology innovation. The industry is classified according to the guidelines for Industry Classification of listed companies revised by China Securities Regulatory Commission (CSRC) in 2012.

4.2.4. Moderating Variables

In the grouping test, three variables are used. Economic policy uncertainty, intellectual property rights protection, and property nature are included. (1) Economic policy uncertainty. The economic policy uncertainty index constructed by Baker et al. is used to measure the degree of economic policy uncertainty [40]. Since the index is monthly data, the simple arithmetic average method is used to calculate the annual value. (2) Intellectual property rights protection. Referring to the research on the patent infringement rate of Wu et al. [35], this paper measures the degree of intellectual property rights protection using the proportion of the number of patent disputes filed each year in the number of authorized patents. If the patent infringement rate in a region is high, this means that the protection of intellectual property rights is poor. (3) The nature of property rights. If the firm is a state-owned firm, the value is 1; otherwise, it is 0.

5. Empirical Results

5.1. Descriptive Analysis

The descriptive statistical results of each variable are reported in Table 2. It can be seen that the minimum value of social trust is 66.45, the maximum value is 90.63, and the standard deviation is 6.494, which indicates that there are relatively large differences in the level of social trust among different regions in China. The mean value of the proportion of green patents in applied patents, granted patents, and total patents is 0.095, 0.159, and 0.057, respectively, which reflects the relatively low level of green technology innovation output of Chinese firms, to a certain extent.

Table 2. Descriptive Analysis.

	Count	Mean	SD	Min	p50	Max
Patent_Application	4583	0.0955	0.1028	0.0028	0.0606	0.588
Patent_Grant	4583	0.1590	0.1945	0.0043	0.0905	1.099
Patent_Total	4583	0.0568	0.0606	0.0016	0.0364	0.336
Trust	4583	73.6933	6.4944	66.4540	70.8050	90.630
Size	4583	22.6172	1.3545	20.2951	22.3859	26.660
ROA	4583	0.0449	0.0424	−0.0945	0.0403	0.182
Largest	4583	34.8442	15.1845	8.1100	32.9200	75.250
LEV	4583	0.4420	0.1904	0.0748	0.4426	0.852
MB	4583	2.1179	1.8368	0.0909	1.6366	24.941

5.2. Correlation Analysis

Table 3 is the Pearson correlation coefficient. The results show that there is a significant positive correlation between social trust and green technological innovation in firms, which provides preliminary evidence for Hypothesis 1. At the same time, the correlation coefficient between the main variables is not large, indicating that there is no serious multicollinearity problem between the main variables.

5.3. Baseline Regression

In order to ensure the robustness of the research conclusions, three indicators (Patent_Application, Patent_Grant, and Patent_Total) reflecting green technology innovation are used as dependent variables for regression, and other control variables and industry and annual dummy variables are added. A robust standard error is used. The regression results are shown in Table 4. Columns (1) and (3) of Table 4 report the regression results

of the impact of social trust on green technology innovation in firms. It can be seen that the coefficients of the three indicators of green technology innovation in firms are significantly positive at the level of 1%, indicating that under the same other factors, the level of regional social trust significantly improves the green technology innovation ability of Chinese firms and thus plays a positive role in the development of the real economy, which supports Hypothesis H1. Further, from the three patent levels, patent_Grant's estimation coefficient is the largest, which indicates that social trust has a stronger role in promoting green innovation authorized patents. From the perspective of the control variables, firm size and return on assets are significantly negatively correlated with green technology innovation, which is consistent with the conclusions of Wang et al. [22] and Pang et al. [55]. The regression results of other control variables are similar to the existing research conclusions [56].

Table 3. Pearson correlation coefficient matrix.

	Patent_Application	Patent_Grant	Patent_Total	Trust	Size	ROA	Largest	LEV	MB
Patent_Application	1.0000								
Patent_Grant	0.6534 ***	1.0000							
Patent_Total	0.9387 ***	0.8190 ***	1.0000						
Trust	0.0414 **	0.0375 *	0.0445 **	1.0000					
Size	−0.2213 ***	−0.2009 ***	−0.2217 ***	0.1351 ***	1.0000				
ROA	−0.0469 **	0.0071	−0.0296 *	0.0213	−0.1274 ***	1.0000			
Largest	−0.1307 ***	−0.1038 ***	−0.1267 ***	0.0469 **	0.2694 ***	0.4044 ***	1.0000		
LEV	−0.0984 ***	−0.1000 ***	−0.1034 ***	0.0116	0.5905 ***	−0.3997 ***	0.0164	1.0000	
MB	0.1123 ***	0.1334 ***	0.1219 ***	−0.0227	−0.5298 ***	0.3758 ***	0.0460 **	−0.5120 ***	1.0000

Note: Robust standard errors are presented in parentheses. *, **, and *** indicate significance at 10%, 5% and, 1% levels, respectively.

Table 4. Impact of social trust on green technology innovation in firms.

	(1)	(2)	(3)
	Patent_Application	Patent_Grant	Patent_Total
Trust	0.0013 *** (0.000)	0.0020 *** (0.000)	0.0008 *** (0.000)
Size	−0.0168 *** (0.002)	−0.0250 *** (0.003)	−0.0097 *** (0.001)
ROA	−0.1164 ** (0.050)	−0.0121 (0.084)	−0.0484 * (0.028)
Largest	−0.0007 *** (0.000)	−0.0015 *** (0.000)	−0.0004 *** (0.000)
LEV	0.0154 (0.011)	0.0457 ** (0.023)	0.0115 * (0.007)
MB	0.0023 * (0.001)	0.0090 *** (0.003)	0.0018 ** (0.001)
Constant	0.3809 *** (0.034)	0.5564 *** (0.069)	0.2140 *** (0.021)
Observations	4443	4443	4443
Industry FE	YES	YES	YES
Year FE	YES	YES	YES
Adj_R2	0.0637	0.0523	0.0647

Note: Robust standard errors are presented in parentheses. *, **, and *** indicate significance at 10%, 5% and, 1% levels, respectively.

5.4. Social Trust, Uncertainty of Economic Policy, and Green Technology Innovation in Firms

Table 5 shows the differentiated impact of economic policy uncertainty on the relationship between social trust and green technological innovation in firms. According to the median of the degree of economic policy uncertainty, it is divided into high and low groups. An assignment that is higher than the median is 1; and an assignment that is lower than the median is 0. The other variables are set in accordance with the benchmark model in Table 4, and the results are shown in Table 5. It can be seen that in the group of severe economic policy uncertainty, when the dependent variable is three proportions (Patent_Application, Patent_Grant, and Patent_Total), the coefficient of social trust is significantly positive at

a 1% significance level. Moreover, the Patent_Grant coefficient of the group with serious environmental uncertainty is the largest, indicating that social trust has the greatest impact on green authorized patents. At the same time, the p values of the Chows test, which is used to test whether there are structural differences among grouped samples, are 0.0439, 0.0130, and 0.0110, respectively, which are all below the 0.05 significance level, indicating that there are significant differences in the coefficient of social trust in the grouped samples. This shows that in the environment of serious economic policy uncertainty, the improvement of social trust can alleviate the uncertainty risk of green technology innovation, which is conducive to the communication and transmission of information and stimulates the enthusiasm of firms to carry out green technology innovation.

Table 5. Social trust, uncertainty of economic policy, and green technology innovation in firms.

	EPU = 0			EPU = 1		
	(1)	(2)	(3)	(4)	(5)	(6)
	Patent_Application	Patent_Grant	Patent_Total	Patent_Application	Patent_Grant	Patent_Total
Trust	0.0010 ** (0.000)	0.0016 ** (0.001)	0.0006 ** (0.000)	0.0015 *** (0.000)	0.0023 *** (0.001)	0.0010 *** (0.000)
Size	−0.0186 *** (0.002)	−0.0227 *** (0.004)	−0.0103 *** (0.001)	−0.0138 *** (0.002)	−0.0280 *** (0.005)	−0.0085 *** (0.001)
ROA	−0.1169 * (0.065)	−0.0896 (0.114)	−0.0656 * (0.038)	−0.1350 * (0.077)	0.0670 (0.125)	−0.0367 (0.043)
Largest	−0.0005 * (0.000)	−0.0012 ** (0.001)	−0.0003 ** (0.000)	−0.0009 *** (0.000)	−0.0017 *** (0.000)	−0.0006 *** (0.000)
LEV	0.0156 (0.015)	0.0121 (0.029)	0.0077 (0.009)	0.0169 (0.018)	0.0820 ** (0.035)	0.0162 (0.011)
MB	0.0012 (0.001)	0.0100 ** (0.004)	0.0014 (0.001)	0.0050* (0.003)	0.0068 * (0.004)	0.0027 * (0.001)
Constant	0.4421 *** (0.044)	0.5473 *** (0.087)	0.2463 *** (0.027)	0.2969 *** (0.056)	0.5978 *** (0.102)	0.1747 *** (0.033)
Observations	2443	2443	2443	2000	2000	2000
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Adj_R2	0.0655	0.0525	0.0679	0.0608	0.0507	0.0592

Note: Robust standard errors are presented in parentheses. *, **, and *** indicate significance at 10%, 5% and, 1% levels, respectively.

5.5. Social Trust, Intellectual Property Rights Protection, and Green Technology Innovation in Firms

Table 6 shows the differentiated impact of intellectual property right protection on the relationship between social trust and green technological innovation in firms. According to the median of the degree of intellectual property rights protection, it is divided into two groups with a high and low degree of intellectual property rights protection. Among them, the sample with the high degree of intellectual property rights protection is assigned to 1; and the other is assigned to 0. The other variables are set as in the benchmark model shown in Table 6. The estimated coefficients of social trust are significantly positive at the 1% level and are listed in columns (1) and (3) of Table 6 as the regression results in the case of a low level of intellectual property rights protection; columns (4) and (6) list the regression results under the condition of a high degree of intellectual property rights protection, where the regression coefficient is significantly positive, but the coefficient is significantly lower than that in the case of the low degree of intellectual property rights protection group. Moreover, the Patent_Grant coefficient in the group with weak intellectual property rights is the largest, indicating that social trust has the greatest impact on green authorized patents. Further, the p values of the Chows test were 0.0000, 0.0000, 0.0110, which are below the 0.05 significant level, indicating that there were significant differences in the coefficient of social trust in the grouping samples. This result shows that there is a certain substitution relationship between social trust and the degree of intellectual property rights

protection; that is, when the formal system of a region is not sufficient to protect the green technological innovation of firms, social trust can make up for this defect to a certain extent and create a good external environment for the green technological innovation of firms. Hypothesis H3 is supported.

Table 6. Social trust, intellectual property rights protection, and green technology innovation in firms.

	IPR = 0			IPR = 1		
	(1)	(2)	(3)	(4)	(5)	(6)
	Patent_Application	Patent_Grant	Patent_Total	Patent_Application	Patent_Grant	Patent_Total
Trust	0.0068 *** (0.001)	0.0170 *** (0.002)	0.0051 *** (0.001)	0.0011 *** (0.000)	0.0013 *** (0.000)	0.0006 *** (0.000)
Size	−0.0071 ** (0.004)	−0.0045 (0.007)	−0.0033 (0.002)	−0.0129 *** (0.002)	−0.0131 *** (0.002)	−0.0067 *** (0.001)
ROA	−0.1558 * (0.091)	0.0882 (0.156)	−0.0584 (0.051)	−0.1508 *** (0.045)	−0.2348 *** (0.066)	−0.0834 *** (0.025)
Largest	−0.0010 *** (0.000)	−0.0021 *** (0.001)	−0.0006 *** (0.000)	−0.0004 ** (0.000)	−0.0008 *** (0.000)	−0.0003 *** (0.000)
LEV	0.0214 (0.021)	0.0635 (0.042)	0.0141 (0.012)	0.0133 (0.012)	0.0360 ** (0.017)	0.0110 * (0.007)
MB	0.0025 (0.002)	0.0069 (0.005)	0.0015 (0.001)	0.0019 (0.001)	0.0093 *** (0.002)	0.0018 ** (0.001)
Constant	−0.1610 (0.102)	−0.7843 *** (0.202)	−0.1835 *** (0.061)	0.2886 *** (0.031)	0.3076 *** (0.049)	0.1509 *** (0.018)
Observations	1782	1782	1782	2661	2661	2661
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Adj_R2	0.0791	0.1135	0.1089	0.0720	0.0673	0.0731

Note: Robust standard errors are presented in parentheses. *, **, and *** indicate significance at 10%, 5% and, 1% levels, respectively.

5.6. Social Trust, Property Rights, and Green Technology Innovation in Firms

State-owned firms are naturally associated with the government, and can more easily obtain government subsidies and resource support, thus greatly reducing their degree of resource constraints. This may be more conducive to the implementation of green technological innovation activities. Moreover, state-owned firms attach greater importance to environmental responsibility than non-state-owned firms [57]. Therefore, this paper compares the relationship between social trust and green technological innovation in firms under different property rights scenarios, and the specific results are shown in Table 7. Columns (1) and (3) of Table 7 lists the test results of the sample group of non-state-owned firms, and the estimation coefficients of social trust are significantly positive at the 1% level. Table 7 lists the test results of the sample group of state-owned firms in columns (4) and (6). The results in columns (4) and (5) show that the estimation coefficient of social trust is not significant, and the estimation coefficient of social trust in column (6) is significant at the level of 10%, but the coefficient is relatively small. Moreover, the Patent_Grant coefficient of non-state-owned companies is the largest, indicating that social trust has the greatest impact on green authorized patents. The further Chows test p values are 0.0000, indicating that there are significant differences in the coefficients of social trust in the grouped samples. To some extent, non-state-owned firms have a better green technology innovation policy execution, and the improving social trust level will also promote the green technology innovation output of non-state-owned firms. That is, compared with state-owned firms, the role of social trust in green technology innovation in non-state-owned firms is more obvious, so H4 is supported.

Table 7. Social trust, property rights, and green technology innovation in firms.

	SOE = 0			SOE = 1		
	(1)	(2)	(3)	(4)	(5)	(6)
	Patent_Application	Patent_Grant	Patent_Total	Patent_Application	Patent_Grant	Patent_Total
Trust	0.0015 *** (0.000)	0.0029 *** (0.001)	0.0010 *** (0.000)	0.0006 * (0.000)	0.0006 (0.001)	0.0004 * (0.000)
Size	−0.0242 *** (0.003)	−0.0335 *** (0.006)	−0.0136 *** (0.002)	−0.0130 *** (0.002)	−0.0204 *** (0.004)	−0.0079 *** (0.001)
ROA	−0.1371 ** (0.067)	0.0271 (0.111)	−0.0549 (0.038)	−0.0278 (0.070)	−0.0178 (0.125)	−0.0068 (0.041)
Largest	−0.0002 (0.000)	−0.0010 ** (0.000)	−0.0002 (0.000)	−0.0011 *** (0.000)	−0.0018 *** (0.001)	−0.0006 *** (0.000)
LEV	0.0242 (0.017)	0.0597* (0.032)	0.0144 (0.010)	0.0098 (0.016)	0.0219 (0.032)	0.0100 (0.009)
MB	0.0026 (0.002)	0.0102 *** (0.004)	0.0020 ** (0.001)	−0.0032 (0.002)	−0.0032 (0.005)	−0.0017 (0.001)
Constant	0.5166 *** (0.067)	0.6653 *** (0.133)	0.2810 *** (0.041)	0.3488 *** (0.045)	0.5830 *** (0.093)	0.2059 *** (0.028)
Observations	2763	2763	2763	1680	1680	1680
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Adj_R2	0.0643	0.0535	0.0661	0.0489	0.0372	0.0485

Note: Robust standard errors are presented in parentheses. *, **, and *** indicate significance at 10%, 5% and, 1% levels, respectively.

6. Endogeneity and Robustness Test

6.1. IV Estimation

Whether social trust can promote green technology innovation in firms may be affected by endogenous problems, making the estimation results biased and inconsistent. In order to solve the deviation of the estimation results caused by the endogeneity of social trust, this paper uses the instrumental variable method to deal with the potential endogeneity problem. Referring to the studies of Li et al. [58], Li et al. [5], and Sun et al. [42], the number of social organizations per million people in each region, the provincial blood donation rate, and the per capita GDP of each region are selected as the instrumental variables of social trust. Among them, social organizations are composed of volunteers for the purpose of meeting social needs [59], and blood donation is voluntary, which may have an impact on social trust, but it does not have an obvious impact on green technology innovation. In addition, per capita GDP reflects the level of regional economic development, and it does not have an obvious impact on corporate innovation decisions [42]. Thus, the above variables meet the exogenous requirements of tool variables.

Table 8 reports the results of IV estimation. Among them, the Kleibergen–Paap rk LM statistic value is 1289, and the *p* value is less than 0.01, thus rejecting the original hypothesis of an insufficient identification of instrumental variables. The Kleibergen–Paap Wald rk F statistic value is 3307, which is much larger than the critical value of 19.93 at the 10% level [60], indicating that the model does not have the problem of weak instrumental variables. The *p* value of the Hansen J statistic is greater than 0.1; that is, the original assumption that the instrumental variables are exogenous is not rejected, indicating that the selected instrumental variables are exogenous. Columns (1) and (3) of Table 8 show the regression results of the second stage. The results show that after controlling for endogeneity, there is still a significant positive correlation between social trust and green technological innovation in firms.

Table 8. Endogeneity test.

	2SLS		
	(1)	(2)	(3)
	Patent_Application	Patent_Grant	Patent_Total
Trust(instrumented)	0.0010 *** (0.0003)	0.0016 *** (0.0005)	0.0006 *** (0.0002)
Size	−0.0163 *** (0.0016)	−0.0242 *** (0.0031)	−0.0094 *** (0.0010)
ROA	−0.1195 ** (0.0496)	−0.0121 (0.0836)	−0.0500 * (0.0283)
Largest	−0.0007 *** (0.0002)	−0.0015 *** (0.0003)	−0.0004 *** (0.0001)
LEV	0.0140 (0.0114)	0.0417 * (0.0226)	0.0108 (0.0068)
MB	0.0025 * (0.0013)	0.0089 *** (0.0030)	0.0019 ** (0.0008)
Constant	0.3932 *** (0.0340)	0.5698 *** (0.0686)	0.2220 *** (0.0207)
Observations	4441	4441	4441
Industry FE	YES	YES	YES
Year FE	YES	YES	YES
Adj_R2	0.0634	0.0521	0.0644
Kleibergen–Paap_rk_LM	1304	1304	1304
Kleibergen–Paap_rk_Wald_F	3284	3284	3284
p–Value of Hansen J	0.616	0.348	0.724

Note: Robust standard errors are presented in parentheses. *, **, and *** indicate significance at 10%, 5% and, 1% levels, respectively.

6.2. Propensity Score Matching(PSM)

In order to further control for the endogeneity problem caused by sample selection bias and improve the reliability of the results, the samples are divided into two groups according to the level of social trust: one group is greater than the median value of 1; in the other, it is 0. The firm size (Size), return on assets (ROA), debt to asset ratio (Leverage), ownership concentration (Largest), and choices of auditors (Big4) are selected as the covariates. The 1:1 nearest neighbor matching method was used for PSM pairing. There is no significant difference in the covariates between the matching post-processing group and the control group (Table 9), and the parallel hypothesis test is passed. The matched sample to re-estimate formula is in column (1). The results in columns (1) and (3) of Table 10 show that the regression coefficients of social trust are significantly positive at the 1% level; that is, after controlling for the sample selection bias, social trust still significantly improves the output of green technological innovation in firms.

Table 9. Balance test.

	Unmatched/Matched	Treated	Control	%bias	t-Value	p-Value
Size	U	22.661	22.597	4.700	1.560	0.118
	M	22.661	22.641	1.400	0.450	0.650
ROA	U	0.0477	0.0431	10.800	3.590	0.000
	M	0.0476	0.0482	−1.400	−0.450	0.655
Largest	U	11.246	10.672	6.100	2.030	0.042
	M	11.237	11.432	−2.100	−0.660	0.507
LEV	U	0.4395	0.4444	−2.600	−0.860	0.392
	M	0.4396	0.4368	1.500	0.470	0.641
MB	U	2.0311	2.1935	−8.800	−2.940	0.003
	M	2.0311	2.0622	−1.700	−0.570	0.566

Table 10. Robustness test results.

	(1)	(2)	(3)	(4)	(5)	(6)
	Patent_Application	Patent_Grant	Patent_Total	Patent_Invention	Patent_Utility	Patent_Design
Trust	0.0012 *** (0.000)	0.0020 *** (0.001)	0.0007 *** (0.000)	0.0017 *** (0.001)	0.0044 *** (0.001)	0.0086 *** (0.002)
Size	−0.0161 *** (0.002)	−0.0227 *** (0.004)	−0.0093 *** (0.001)	−0.0458 *** (0.004)	−0.0272 *** (0.004)	0.0255 (0.018)
ROA	−0.0566 (0.067)	−0.0105 (0.119)	−0.0341 (0.039)	−0.1513 (0.115)	−0.3385 *** (0.114)	−1.8380 *** (0.352)
Largest	−0.0010 *** (0.000)	−0.0020 *** (0.000)	−0.0006 *** (0.000)	−0.0017 *** (0.000)	−0.0002 (0.000)	−0.0039 ** (0.002)
LEV	0.0123 (0.016)	0.0552 * (0.030)	0.0110 (0.009)	0.0738 *** (0.027)	−0.0878 *** (0.029)	0.3706 *** (0.104)
MB	0.0023 (0.002)	0.0139 *** (0.004)	0.0024 ** (0.001)	−0.0048 * (0.003)	0.0135 *** (0.003)	0.0212 ** (0.009)
Constant	0.3783 *** (0.048)	0.5145 *** (0.094)	0.2148 *** (0.030)	1.1446 *** (0.082)	0.5239 *** (0.084)	−0.5980 (0.380)
Observations	2440	2440	2440	4351	4258	2226
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Adj_R2	0.0605	0.0588	0.0661	0.0552	0.0656	0.0520

Note: Robust standard errors are presented in parentheses. *, **, and *** indicate significance at 10%, 5% and, 1% levels, respectively.

6.3. Replacement of Dependent Variables

In order to further test the robustness of the results, this paper analyzes the impact of social trust on different types of green patents and uses the ratio of the number of green patents to the number of invention patents, utility model patents, and appearance design patents in the current year as a substitute variable. The regression results are shown in columns (4) and (6) of Table 10. The regression coefficients of social trust are significantly positive at the 1% level, indicating that social trust has a promoting effect on invention patents, utility model patents, and design patents. That is, after replacing the measurement of explained variables, the positive role of social trust in promoting green technological innovation in firms is again verified.

7. Conclusions and Discussion

7.1. Research Conclusions

The existing research mainly explores the important influence of formal systems on green technology innovation in firms, but discussing the relationship between informal systems and green technology innovation in firms is not enough, especially given the influence of social trust, an important informal institutional factor. Based on the perspective of informal institutions, this paper empirically tests the influence of the micro-mechanism of social trust on green technology innovation in Chinese A-share listed companies from 2012 to 2017 and further discusses the effects of economic policy uncertainty, intellectual property rights protection, and property rights on the results. The results show that: (1) Social trust has an incentive effect on green technology innovation in firms; that is, the better the social trust is, the higher the input and patent output level of green technology innovation in firms is, which shows that a good level of social trust helps to reduce the negative externality of green technology innovation in firms' activities and enhances the willingness of firms to engage in green technology innovation activities. To a certain extent, this indicates that social trust is an important informal institutional factor to promote green technology innovation in firms. (2) Further, the analysis results show that the higher the uncertainty of economic policy, the more obvious the incentive effect of social trust on green technology innovation in firms. When considering the differences in intellectual property rights protection, it is found that the lower the degree of intellectual property rights protection, the higher the social trust, which is helpful for improving the green technology

innovation in firms. Compared with state-owned firms, the impact of social trust on green technology innovation in non-state-owned firms is significant, and innovation has a greater impact. In this paper, we use the instrumental variable method to deal with the endogenous problems that may exist in the model, and through further robustness tests, such as replacing the estimation model and using alternative variables, we find that the above empirical results are still valid.

7.2. Theoretical Contribution

Compared with the existing research, the marginal contribution of this paper in theory is reflected in the following two points: (1) The previous literature review found that while some scholars began to explore the relationship between social trust and firm innovation, they ignored the important role of social trust in green technology innovation. This paper reveals the incentive effect of social trust on green technology innovation in firms from the perspective of informal institutions. On the one hand, it enriches the theoretical literature on the influence of institutional factors on green technology innovation in firms and provides a new perspective for deepening the understanding of the influencing factors of green technology innovation in firms in the context of China; on the other hand, it expands the related research on the influence of social trust on micro-firm behavior, which is helpful for further study. This paper aims to enrich the theoretical literature on the microeconomic consequences of informal institutions. (2) Considering that the green technology innovation in firms will be affected by internal and external factors, this paper inputs the heterogeneity characteristics of economic policy uncertainty, intellectual property rights protection, and the nature of property rights into the model to analyze and test the different effects of the informal system of social trust on green technology innovation in firms under different scenarios. The results show that the effect of social trust on green technology innovation in firms is heterogeneous, which can be used as an effective supplement for the formal system. To a certain extent, this helps to clarify the boundary conditions of social trust influencing green technology innovation in firms and provides a useful reference for further exploring the factors influencing green technology innovation in firms from the perspective of informal systems.

7.3. Practical Enlightenment

The policy significance of the research conclusions of this paper mainly lies in the following. (1) Under the premise of ensuring the positive role of formal systems in green technology innovation in firms, it is necessary to give importance to the supplementary role of informal systems. By strengthening the construction of the social trust mechanism, strengthening the trust relationship within the main body of the firm, and shaping a good social trust atmosphere, it is necessary to build a dual wheel-driven firm with a formal system and an informal system. The green technology innovation mechanism has an important practical value in relation to achieving comprehensive, coordinated, and sustainable development. (2) The formal institutional factors, such as economic policy uncertainty and intellectual property rights protection, have a differential impact on the relationship between social trust and green technology innovation in firms; that is, by reducing policy uncertainty and enhancing intellectual property rights protection, the role of social trust is weakened. Therefore, policy makers or regulators should fully understand the relationship between informal systems, such as social trust, and formal systems in order to develop a mutual relationship for effectively employing social trust in the process of green technology innovation to bring about the firm incentive effect. (3) Compared with state-owned firms, the impact of social trust on the relationship of firms with green technology innovation is more obvious in non-state-owned firms. We should formulate targeted policies to promote firms to establish a sound incentive and restraint mechanism for green technology innovation, so as to reduce the impact of property rights differentiation and improve the quality of firms and the green technology innovation level of the industry itself. In general, the government and its relevant departments need to

further improve the institutional environment to support green technology innovation in firms, optimize the “green” allocation of resources, and guide the rational and orderly flow of resources to “green” firms, so as to promote the vitality of green technology innovation in firms and promote the sustainable development of the real economy.

7.4. Research Limitations and Prospects

There are still some limitations of this study: (1) this paper studies the impact of social trust on green technology innovation in firms from the perspective of informal institutions, and other informal institutional factors may also play a role. However, due to the limitations associated with the data, among other factors, we were not able to carry out an empirical test in this regard. We will consider revealing the role of other informal institutional factors in the future. (2) This paper empirically tests the relationship between social trust and green technology innovation in firms and examines the differential effects on the relationship between social trust and green technology innovation from the aspects of economic policy uncertainty, intellectual property rights protection, property rights, etc. However, due to the limitation of the research perspective, it is unable to explore other possible influencing mechanisms. The follow-up study will further develop this research to improve on the abovementioned limitations.

Supplementary Materials: (1) China Green Patent statistical report, the 14th patent statistical bulletin of the planning and Development Department of the State Intellectual Property Office in 2018, is detailed in the following link: <https://www.cnipa.gov.cn/col/col87/index.html?uid=669&pageNum=2> (accessed on 25 April 2021). (2) IPC GREEN INVENTORY, is detailed in the following link: <https://www.wipo.int/classifications/ipc/green-inventory/home> (accessed on 25 April 2021).

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