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Government R&D subsidies and the manipulative innovation strategy of Chinese renewable energy firms

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ABSTRACT
Renewable energy technology innovation is the key to alleviating environmental issues. The Chinese government promotes corporate innovation in the renewable energy industry by providing R&D subsidies. This paper investigates the impact of R&D subsidies on innovation strategies in Chinese renewable energy listed firms from 2008 to 2017. The results show that R&D subsidies induce firms to adopt a manipulative innovation strategy that increases innovation quantity but reduces innovation quality, especially in regions with low marketization or unfair competition. We further find that the choice of manipulative innovation strategy is caused by the flawed subsidy distribution system and examination procedures of subsidy use. This paper deepens the understanding of the relationship between government subsidies and corporate innovation strategy and provides new enlightenments for emerging economies to enhance the effectiveness of subsidy policies.

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1. Introduction

The impact of environmental issues on economic activities is becoming increasingly prominent (Li et al., 2021). Developing technological innovation of the renewable energy industry has become an important way to alleviate environmental issues and achieve stable economic growth (Bartram et al., 2022). Due to the externality of innovation (Kong et al., 2020), government R&D subsidies are considered an effective policy tool to encourage firms to engage in innovation activities (Liu et al., 2019; Meus et al., 2021). Existing literature on the effect of R&D subsidies mainly finds that subsidies can promote the growth of innovation quantity (Corsatea, 2014; Dang & Motohashi, 2015; Jamasb & Pollitt, 2015; Liu et al., 2019).

As the largest energy producer and consumer in the world, the Chinese government has granted a large number of R&D subsidies to improve innovation

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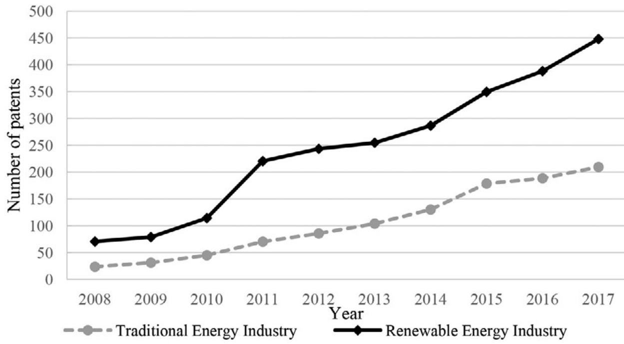

Figure 1. Patent application amounts.
Note: Figure 1 compares the number of patent applications in renewable energy industry and traditional energy industry from 2008 to 2017. The patent data comes from CSMAR Database.
Source: made by the author.

capabilities in the renewable energy industry (Lin & Xu, 2018). According to the China Stock Market & Accounting Research Database (CSMAR) statistics, from 2008 to 2017, the R&D subsidies allocated by the Chinese government to the listed firms in the renewable energy industry were 34.12% higher than that in the traditional energy industry. R&D subsidies directly stimulate firms to spend more on R&D activities and lead to the growth of the innovation quantity in the renewable energy industry. In 2017, the average number of patent applications of listed firms in the renewable energy industry was approximately 448, significantly higher than that in the traditional energy industry (Figure 1).

Although the number of patent applications has grown dramatically, scholars are increasingly concerned about the quality of the patents supported by local government patent subsidy programs (Dang & Motohashi, 2015; Li, 2012). Innovation quality is a critical component of innovation capabilities that significantly affect firms' competitive status and market value in the renewable energy industry (Gatignon et al., 2002; Hall et al., 2005). How the government R&D subsidies affect innovation quality is closely related to the firms' choice of innovation strategies. One strategy for firms to choose is spending subsidies on high-quality R&D activities that genuinely enhance their innovation capabilities. Another innovation strategy, called the manipulative innovation strategy in this paper, is to pursue short-term and low-quality innovations to increase the number of patents so that they can continue to receive subsidies in the future. The objective of the study is to investigate whether the government's R&D subsidies truly promote the innovation capability of the renewable energy industry or induce firms to engage in manipulative innovation, which remains an empirical question.

Using the sample of Chinese listed firms in the renewable energy industry from 2008 to 2017, we empirically test how government R&D subsidies affect the firms' tradeoff between innovation quantity and quality. We find that R&D subsidies induce firms to adopt a manipulative innovation strategy that increases innovation quantity at the sacrifice of innovation quality. This manipulative innovation strategy is more severe in low marketization or unfair competition regions. Our study also explores why firms adopt the manipulative innovation strategy from two aspects. First, under the quantity-based examination procedures of government subsidy use, firms tend to pursue the growth of the innovation quantity at the sacrifice of innovation quality to meet the government's requirements. In addition, a bureaucratic distribution system is likely to divert firms' resources from innovation to political rent-seeking, which further inhibits the improvement of innovation quality.

This paper contributes to theory and practice in three ways.

First, this paper adds to the large literature debating on the effects of government subsidies on economic efficiency. On the positive side, the government subsidies could potentially correct market failures in presence of externalities by compensating the private cost of firms (Kesidou & Demirel, 2012; Rubashkina et al., 2015). On the negative side, government subsidies may distort resource allocation because of the information asymmetry between firms and the government and the agency problem in the bureaucratic distribution of government subsidies (Perez-Sebastian,2015). By using a sample of Chinese renewable energy industry, our paper contributes to the debate by studying the causal effect of government subsidies on innovation and clarifies specific mechanisms that lead to the negative effects of subsidies.

Second, to the best of our knowledge, this paper is among the first to study the firms' tradeoff between innovation quantity and innovation quality with the presence of external incentive policies. Most of the literature separately discussed the impact of external incentive policies on innovation quantity and quality (e.g. Mateut, 2018). We provide evidence that in the presence of government subsidies, the firms face a tradeoff between improving the quality of innovation and increasing the quantity of innovation, and they tend to choose a manipulative innovation strategy that increase the innovation quantity at the sacrifice of innovation quality.

Third, this paper provides new insights for policymakers on developing subsidy efficiency and renewable energy industry innovation capabilities. Because of information asymmetry, subsidies induce firms to emphasize innovation quantity over quality, which is contrary to the government's intention. Our research offers novel evidence that the information asymmetry in subsidy use and distribution can be reduced by formulating post-subsidy policies and inhibiting rent-seeking.

2. Theoretical background and hypotheses development

Government subsidies are essentially an act of government intervention in the redistribution of resources to mitigate the risk of market failures (Hong et al., 2016). The R&D activities of firms are characterized by externalities, high risk and long return periods, which make firms lack the motivation to invest in innovation (Kong et al., 2020). To address this market inefficiency, government policies are currently used to reallocate valuable and scarce resources in the market economy (Wang et al., 2020). R&D subsidies are regarded as one of the most important tools for the government to support specific technology innovations and have been widely used in many countries such as China (Du & Li, 2019; Xie et al., 2019), Norway (Clausen, 2009), Ireland, and Germany (Aerts & Schmidt, 2008). Although scholars provide empirical evidence that R&D subsidies can promote the growth of the innovation quantity by reducing the costs of R&D and improving managers' risk tolerance (Corsatea, 2014;

Jamasb & Pollitt, 2015; Mateut, 2018), information asymmetry in the subsidy policy implementation may undermine the positive role of subsidies in fostering innovation.

As the principal, the government intends to improve the innovation quality of firms through R&D subsidies. However, the information asymmetry in the process of R&D subsidies use and distribution may induce firms to adopt a manipulative innovation strategy which is to pursue innovation quantity at the sacrifice of innovation quality. The reason lies in the following two aspects.

First, the uncertainty and information opacity of R&D activities make government agencies face information disadvantages when monitoring firms' use of government subsidies (Dimos & Pugh, 2016). This information disadvantage is likely to make government agencies focus more on innovation quantitative indicators instead of quality assessment in the examination procedure of the subsidy program, since quantitative indicators are easy to observe while quality assessment is hard to implement. In practice, the Chinese government often takes firms' R&D expenditures and patent applications as the basis for evaluating the effect of subsidy policy implementation[1]. This evaluation criteria in the information asymmetry context may lead to opportunism and moral hazard for firms in the implementation of government subsidies (Chen et al., 2020). Consequently, the firms could increase the quantity of innovation at the sacrifice of innovation quality to pass the examination successfully.

Second, rent-seeking in the subsidy policy implementation distorts the efficiency of R&D subsidies. As a scarce public resource, R&D subsidies bring subsidy recipient firms cash inflow and reduce R&D costs (Dimos & Pugh, 2016). Moreover, R&D subsidies have a signalling effect, helping the subsidy recipient firm to access debt financing such as bank credit more easily (Wu, 2017), and to attract technical collaboration (Bianchi et al., 2019). These benefits encourage firms to engage in rent-seeking (Cull & Xu, 2005; Shleifer & Vishny, 1994) and actively establish connections with the government to obtain subsidies (Boubakri et al., 2008; Faccio, 2006). The flawed national governance system with widespread corruption allows bureaucratic intervention and rent-seeking during the funding process. Government officials, motivated by maximizing private interests, tend to use public power to distribute subsidies to their stakeholders (Wang et al., 2020). Existing studies have shown that firms with political connections can obtain more financial subsidies from the governments (Du & Mickiewicz, 2016). However, the firms' rent-seeking behaviors to build up political connections may have a negative impact on innovation quality (Faccio et al., 2006). First, the non-productive expenditures incurred in the rent-seeking process could crowd out firms' internal R&D investment (Dimos & Pugh, 2016; Yu et al., 2016), leading to a decline in the quality of innovation (Aghion et al., 2012; Ren et al., 2019). Second, the temptation to obtain short-term excess returns through political rent-seeking will hurt the firms' motivation to invest in innovation continuously (Murphy et al., 1993) and thus reduce the quality of innovation (Ellis et al., 2020; Yi et al., 2021). Third, rent-seeking may allow subsidies to be allocated to the wrong recipient firms, which may result in the subsidy being wasted, undermining the positive effect of subsidies on improving the quality of innovation (Zuo & Lin, 2022).

Accordingly, we propose the following hypothesis:

Hypothesis 1: Government R&D subsidies will induce renewable energy firms to adopt a manipulative innovation strategy, i.e. firms increase the quantity of innovation at the sacrifice of quality.

3. Sample, variable construction and methodology

3.1. Data and sample

We obtain the data on patent applications, government subsidies, R&D investment, financial and accounting information, and corporate governance from the China Stock Market & Accounting Research Database (CSMAR).

Our sample contains listed firms in the renewable energy industry in Shanghai and Shenzhen stock exchanges from 2008 to 2017[2], including firms whose primary businesses include solar energy, hydrogen energy, geothermal energy, wind energy, marine energy, biomass energy, nuclear fusion energy and renewable energy vehicle. We drop all firms with special treatment and particular transfer (Cui et al., 2021). Then, we drop observations with missing data. We further eliminate observations whose net assets are less than or equal to zero. The final sample consists of 355 firm-year observations.

3.2. Variable construction

3.2.1. Corporate innovation quantity

This study uses a renewable energy firm's total number of patent applications filed in a given year that are eventually granted to proxy innovation quantity. This indicator can capture the amount of innovation output. Referring to Zhong (2018), *Patent* is defined as the number of patent applications that are eventually granted divided by revenue (per 10 million RMB). We further divide patents into invention patents and other patents (utility patents and design patents) because invention patents are considered to be more valuable innovation outputs.

3.2.2. Corporate innovation quality

In this paper, innovation quality is measured by the market value of patents, i.e. the correlation between the number of patent applications and Tobin's Q (Zhou & Zhang,2016). The existing literature finds that firms' innovation quality is finally reflected in firm value (Hirshleifer et al., 2013) because high-quality innovation helps these firms enhance competitive advantages and ultimately increase the firm value.

In the robustness test, we also use the number of patent citations as an alternative indicator for measuring innovation quality (He & Tian, 2013).

3.2.3 R&D subsidies

We first obtain the data on the total government subsidies that firms received from CSMAR. Then, we manually collect financial subsidies for 'innovation', 'technology', 'research and development', and 'intellectual property' purposes from the total subsidies and calculate the R&D subsidies that firms obtained. According to Hu et al. (2021), we define the *Subsidy* variable as the ratio of government R&D subsidies to revenue (per 100 RMB).

Table 1. Descriptive statistics.

Variables	Obs.	Mean	SD	Min	Median	Max
TobinQ	355	2.380	1.244	0.968	2.003	6.418
Patent	355	0.174	0.183	0.000	0.121	0.960
Invent	355	0.046	0.056	0.000	0.026	0.257
Other	355	0.128	0.155	0.000	0.082	0.818
Subsidy	355	1.001	1.201	0.000	0.613	7.016
Size	355	22.408	1.336	20.232	22.165	26.487
Lev	355	0.490	0.173	0.091	0.500	0.823
Cash	355	0.048	0.081	−0.174	0.039	0.313
Growth	355	0.258	0.485	−0.618	0.144	2.709
ISHR	355	0.385	0.224	0.000	0.392	0.901
FSHR	355	0.325	0.158	0.084	0.318	0.743
R&D	355	2.346	2.761	0.000	1.405	12.247
Board	355	0.367	0.047	0.308	0.333	0.500
SOE	355	0.563	0.497	0.000	1.000	1.000
Rent	355	0.085	0.044	0.019	0.077	0.236

Note: To alleviate the concerns for outliers, all continuous variables in this table are winsorized at the 1st and 99th percentiles of their distribution.
Source: made by the author.

3.2.4. Control variables

Following Jiang and Chen (2018), we control a series of variables capturing other firm characteristics that could potentially affect both government subsidies and firms' innovation strategies. These firm-specific variables include firm size (*Size*), financial leverage (*Lev*), free cash flow (*Cash*), growth of revenues (*Growth*), institutional ownership (*ISHR*), the percentage of shares held by the largest shareholder (*FSHR*), research and development expenditures (*R&D*), Board size of independent directors (*Board*), and the nature of property rights (*SOE*). All continuous variables are winsorized at the 1% level.

The definition of all variables is given in the Appendix (Table A). The descriptive statistics of these variables are shown in Table 1.

3.3. Empirical models

To investigate the impact of R&D subsidies on innovation quality, we perform an OLS regression on the panel data with the following model:

$$TobinQ_{it+1} = \alpha + \beta_1 Subsidy_{it} + \beta_2 Patent_{it+1} + \beta_3 Subsidy_{it} * Patent_{it+1} + \beta_4 Control_{it} + \sum Year_t + \sum Industry_i + \varepsilon_{it} \quad (1)$$

$$Patent_{it+1} = \alpha + \beta_1 Subsidy_{it} + \beta_2 Control_{it} + \sum Year_t + \sum Industry_i + \varepsilon_{it} \quad (2)$$

Model (1) is used to test the impact of R&D subsidies on innovation quality in the renewable energy industry, where $TobinQ_{it+1}$ is the Tobin's Q of firm i in year t + 1, and $Subsidy_{it}$ represents the government R&D subsidies obtained by firm i in year t, scaled by the total sales revenue. $Patent_{it+1}$ is the number of patent applications of enterprise i in year t + 1, scaled by the total sales revenue. The total patents can be further divided into invention patents and other patents. β_3 represents the change in the sensitivity of Tobin's Q to patents under the influence of R&D subsidies. If β_3 is positive, it means that R&D subsidies improve the firms' innovation quality.

Model (2) tests the impact of R&D subsidies on innovation quantity. We focus on β_1. If β_1 is positive, it means that R&D subsidies improve innovation quantity in the renewable energy industry. Combining Model (1) and Model (2), if β_3 in Model (1) is negative and β_1 in Model (2) is positive, it indicates that the firm increases the quantity of innovation at the sacrifice of quality, i.e. it chooses the manipulative innovation strategy.

We include industry and year fixed effects in regressions. Standard errors are clustered at the firm level to account for possible correlations between firms.

4. Empirical results and discussions

4.1. Main regression results

To test the hypothesis, we conduct regression analysis to examine the impact of R&D subsidies on corporate innovation strategies. We present the baseline results in Table 2. In Panel A of Table 2, the coefficient of *Subsidy***Patent* in column (1) is significantly negative at the 1% level, indicating that a higher level of R&D subsidies is associated with a lower level of innovation quality. The results in columns (2) - (3) show that the above effect still exists after dividing all patents into invention patents and other patents.

In Panel B, the coefficient of *Subsidy* in column (1) is significantly positive at the 5% level, indicating that R&D subsidies can promote the number of patent applications. It should be noted that this effect is not only statistically significant but also has economic significance. The coefficient of *Subsidy* is 0.028, which indicates that a one standard deviation increase in the number of R&D subsidies is associated with an increase of 6.04% of a standard deviation in the patent application, ceteris paribus. The results in columns (2) - (3) show that the promotion effect of R&D subsidies on the number of patent applications is mainly for invention patents.

The results in Table 2 show that R&D subsidies have induced the renewable energy firms to choose the manipulative innovation strategy, which increases the innovation quantity at the sacrifice of innovation quality, confirming Hypothesis 1.

We further investigate the heterogeneous effects of the R&D subsidies on firms in the provinces with different degrees of external governance. We use the index of regional marketization (Wang et al., 2016) and the degree of unfair competition[3] as two proxy variables for external governance. We expect that in regions with low marketization and unfair competition, firms have less incentive to invest in high-quality innovations to win the market competition because of the high degree of information asymmetry between the firm and shareholders and weak property rights protection, which result in low returns on innovation (Fang et al., 2017; Liu et al., 2021).

The regression results for subsamples in the regions with different degrees of marketization are presented in columns (1)—(6) of Table 3. We can find that the adverse effect of R&D subsidies on firms' choice of innovation strategies is more significant in the regions with lower marketization levels.

Table 2. Effect of government R&D subsidies on corporate innovation quality and quantity.

Panel A

Dep. Var.=	$TobinQ_{t+1}$ (1)	$TobinQ_{t+1}$ (2)	$TobinQ_{t+1}$ (3)
$Subsidy_t$	0.250***	0.192**	0.205**
	(2.70)	(2.24)	(2.21)
$Patent_{t+1}$	0.422		
	(0.95)		
$Subsidy_t$* $Patent_{t+1}$	−0.512***		
	(-2.62)		
$Invent_{t+1}$		1.481	
		(1.17)	
$Subsidy_t$* $Invent_{t+1}$		−1.441**	
		(-2.49)	
$Other_{t+1}$			0.465
			(0.89)
$Subsidy_t$* $Other_{t+1}$			−0.522**
			(-2.37)
$Size_t$	−0.394***	−0.383***	−0.387***
	(-8.26)	(-8.03)	(-7.79)
Lev_t	−0.859**	−1.005**	−0.880**
	(-1.98)	(-2.30)	(-2.01)
$Cash_t$	2.048***	2.031***	2.037***
	(2.76)	(2.70)	(2.73)
$Growth_t$	−0.045	−0.029	−0.046
	(-0.39)	(-0.25)	(-0.40)
$ISHR_t$	0.065	0.021	0.030
	(0.21)	(0.07)	(0.09)
$FSHR_t$	1.008***	1.122***	0.953**
	(2.60)	(2.76)	(2.50)
$R\&D_t$	0.055**	0.055**	0.054**
	(2.26)	(2.29)	(2.18)
$Board_t$	1.155	1.164	0.878
	(1.05)	(1.05)	(0.75)
SOE_t	−0.147	−0.177	−0.133
	(-1.17)	(-1.42)	(-1.05)
Ind FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Obs	355	355	355
Adj. R^2	0.535	0.527	0.530

Panel B

Dep. Var.=	$Patent_{t+1}$ (1)	$Invent_{t+1}$ (2)	$Other_{t+1}$ (3)
$Subsidy_t$	0.028**	0.008***	0.018
	(2.13)	(2.80)	(1.48)
CONTROL	Yes	Yes	Yes
Ind FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Obs	355	355	355
Adj. R^2	0.316	0.247	0.287

Note: Table 2 presents the results of baseline regressions that examine the impact of government R&D subsidies on corporate innovation quality and quantity. In Panel A, the dependent variable, innovation quality, is defined as the sensitivity between $Patent_{t+1}$ ($Invent_{t+1}$, $Other_{t+1}$) and TobinQt + 1. In Panel B, the dependent variable, innovation quantity, is defined as the number of patent applications ($Patent_{t+1}$, $Invent_{t+1}$, $Other_{t+1}$). The t-statistics in parentheses below the coefficient estimates are based on standard errors clustered at the firm and year level. ***, **, and * indicate 1%, 5%, and 10% significance, respectively.
Source: made by the author.

Table 4 shows the regression results in groups with different degrees of competition fairness. It suggests that R&D subsidies are more likely to increase firms'

Table 3. Effect of R&D subsidies on the quality and quantity of innovation in regions with different degrees of marketization.

Panel A

	High Marketization			Low Marketization		
Dep. Var.=	$TobinQ_{t+1}$ (1)	$TobinQ_{t+1}$ (2)	$TobinQ_{t+1}$ (3)	$TobinQ_{t+1}$ (4)	$TobinQ_{t+1}$ (5)	$TobinQ_{t+1}$ (6)
$Subsidy_t$	−0.183	−0.195	−0.107	0.227**	0.181*	0.175
	(−1.34)	(−1.34)	(−0.93)	(2.10)	(1.85)	(1.65)
$Patent_{t+1}$	−0.973			0.295		
	(−0.91)			(0.54)		
$Subsidy_t$* $Patent_{t+1}$	2.218			−0.489**		
	(1.48)			(−2.07)		
$Invent_{t+1}$		−3.552			2.840*	
		(−1.55)			(1.81)	
$Subsidy_t$* $Invent_{t+1}$		5.269*			−1.724***	
		(1.81)			(−2.74)	
$Other_{t+1}$			−0.636			0.205
			(−0.48)			(0.31)
$Subsidy_t$* $Other_{t+1}$			2.488			−0.470*
			(1.13)			(−1.72)
CONTROL	Yes	Yes	Yes	Yes	Yes	Yes
Ind FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs	144	144	144	211	211	211
Adj. R^2	0.664	0.667	0.661	0.520	0.514	0.514

Panel B

	High Marketization			Low Marketization		
Dep. Var.=	$Patent_{t+1}$ (1)	$Invent_{t+1}$ (2)	$Other_{t+1}$ (3)	$Patent_{t+1}$ (4)	$Invent_{t+1}$ (5)	$Other_{t+1}$ (6)
$Subsidy_t$	−0.028	−0.007	−0.020	0.031*	0.011***	0.017
	(−1.59)	(−0.98)	(−1.59)	(1.96)	(3.18)	(1.22)
CONTROL	Yes	Yes	Yes	Yes	Yes	Yes
Ind FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs	144	144	144	211	211	211
Adj. R^2	0.488	0.332	0.553	0.349	0.287	0.303

Note: Column (1)-(3) in Table 3 shows the regression results for renewable energy firms located in regions with high marketization. Column (4)-(6) shows the results for the subsample in regions with low marketization. Table A details the construction of these variables. The t-statistics in parentheses below the coefficient estimates are based on standard errors clustered at the firm and year level. ***, **, and * indicate 1%, 5%, and 10% significance, respectively.
Source: made by the author.

innovation quantity but lead to a decline in the innovation quality in circumstances of unfair competition.

Overall, we find that weak external governance will reduce the efficiency of R&D subsidies and induce firms to choose the manipulative innovation strategy.

4.2. Possible mechanisms

Our evidence so far is consistent with the hypothesis that government R&D subsidies induce firms to increase innovation quantity at the sacrifice of quality. In this section, we are going to discuss two possible underlying mechanisms driving this result. The

Table 4. Effect of R&D subsidies on the quality and quantity of innovation in regions with different degrees of competition fairness.

Panel A

	Unfair competition			Fair competition		
Dep. Var.=	$TobinQ_{t+1}$ (1)	$TobinQ_{t+1}$ (2)	$TobinQ_{t+1}$ (3)	$TobinQ_{t+1}$ (4)	$TobinQ_{t+1}$ (5)	$TobinQ_{t+1}$ (6)
$Subsidy_t$	0.276***	0.231**	0.214**	−0.053	−0.030	−0.071
	(2.62)	(2.39)	(1.97)	(-0.58)	(-0.34)	(-0.84)
$Patent_{t+1}$	0.185			0.873		
	(0.30)			(1.43)		
$Subsidy_t$* $Patent_{t+1}$	−0.492**			−0.090		
	(-2.06)			(-0.27)		
$Invent_{t+1}$		1.953			2.283*	
		(1.33)			(1.72)	
$Subsidy_t$* $Invent_{t+1}$		−1.669**			−0.175	
		(-2.54)			(-0.22)	
$Other_{t+1}$			0.001			1.184*
			(0.00)			(1.77)
$Subsidy_t$* $Other_{t+1}$			−0.437			0.023
			(-1.61)			(0.06)
CONTROL	Yes	Yes	Yes	Yes	Yes	Yes
Ind FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs	236	236	236	119	119	119
Adj. R^2	0.538	0.530	0.531	0.648	0.647	0.656

Panel B

	Unfair competition			Fair competition		
Dep. Var.=	$Patent_{t+1}$ (1)	$Invent_{t+1}$ (2)	$Other_{t+1}$ (3)	$Patent_{t+1}$ (4)	$Invent_{t+1}$ (5)	$Other_{t+1}$ (6)
$Subsidy_t$	0.030**	0.008**	0.020	0.016	0.008	0.008
	(2.05)	(2.35)	(1.49)	(0.64)	(0.80)	(0.38)
CONTROL	Yes	Yes	Yes	Yes	Yes	Yes
Ind FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs	236	236	236	119	119	119
Adj. R^2	0.316	0.248	0.305	0.516	0.365	0.473

Note: Column (1)-(3) in Table 4 shows the regression results for the subsample located in regions with unfair competition. Column (4)-(6) shows the results for the subsample in regions with fair competition. Table A details the construction of these variables. The t-statistics in parentheses below the coefficient estimates are based on standard errors clustered at the firm and year level. ***, **, and * indicate 1%, 5%, and 10% significance, respectively.
Source: made by the author.

first mechanism is the defective examination procedures of R&D subsidy use, while the second is the distorted distribution of R&D subsides with the presence of firms' rent-seeking expenditures.

4.2.1. The defective examination procedures of R&D subsidy use

In the early stage of government subsidy policy, the government usually assessed the prospects and economic benefits of the innovation projects based on materials submitted by firms to decide whether to provide R&D subsidies to a renewable energy firm. After receiving the government subsidies and completing the innovation project, the firm needs to submit the corresponding R&D expenditure records, patent applications, patent authorizations, and other technical materials as the basis for the examination of subsidy use. Since the innovation quantity is countable while the innovation quality is hard to measure directly, the government tends to set explicit requirements on quantity indicators instead of quality indicators. Consequently, firms have the motivation to adopt the manipulative innovation strategy to pass the examination procedure of subsidy use. To improve the utilization efficiency of R&D subsidies, the Ministry of Finance and the Ministry of Science and Technology of China issued the 'Regulations on Post-subsidy Management of National Science and Technology Plan' in November 2013, namely, the 'post-subsidy' policy. The policy stipulates that firms should independently conduct scientific research and innovation projects first, and then the government would decide the number of subsidies to firms based on the technological advancement and economic benefits of firms' innovation achievements after the innovation project is completed. The 'post-subsidy' mode links the subsidy distribution to the value of scientific research and forms a pattern that focuses on corporate innovation quality. If the earlier defective examination requirements of R&D subsidy use is an important reason for the firms to choose manipulative innovation strategy, then we should expect to find a significant reduction in the degree of firms' manipulative innovation after the introduction of the 'post-subsidy' policy.

We collect the promulgation time of the 'post-subsidy' policy in 35 cities where the sample firms are located and divide the original sample into two groups according to the policy implementation time at the municipal level. The subsample regression results are shown in Table 5. We find that R&D subsidies had a significant and negative impact on patent quality in renewable energy firms before introducing the 'post-subsidy' policy, but this adverse effect has been mitigated after the 'post-subsidy' policy. It indicates that excessive attention to quantity in the examination of R&D subsidy use is a possible mechanism through which R&D subsidies induce firms to choose the manipulative innovation strategy.

4.2.2. The distorted subsidy distribution with rent-seeking

In the distribution of subsidies, the government bureaucrat has the power to evaluate firms' innovation capabilities and determine the amounts of subsidies. This bureaucratic distribution system creates a rent for the firms to compete. Subsidies can bring direct and indirect benefits, such as increasing cash inflows and reducing financing costs, so firms are motivated to engage in political rent-seeking to obtain more subsidies from the government. We take the introduction of renewable energy vehicle industry subsidy policy as a quasi-natural experiment to test whether the rent-seeking of firms in this industry will increase after the government introduces an R&D subsidy policy. Following Cai et al. (2011), we use the ratio of administrative expenses to sales revenue to measure political rent-seeking.

In 2010, the Chinese government issued the 'Notice on Carrying Out the Pilot Subsidy for Private Purchase of New-energy Vehicles'. This policy provides generous subsidies for the R&D activities of renewable-energy vehicles. The R&D subsidies provided by Chinese governments to renewable-energy vehicle firms exceeded 100 billion yuan in the five years after 2010, much more than the subsidies granted to the traditional energy industry.

Table 5. Effect of R&D subsidies on the quality and quantity of innovation before or after the 'post-subsidy' policy.

Panel A

	Before the 'post-subsidy' policy			After the 'post-subsidy' policy		
Dep. Var.=	$TobinQ_{t+1}$ (1)	$TobinQ_{t+1}$ (2)	$TobinQ_{t+1}$ (3)	$TobinQ_{t+1}$ (4)	$TobinQ_{t+1}$ (5)	$TobinQ_{t+1}$ (6)
$Subsidy_t$	0.334***	0.198*	0.348***	−0.154	−0.060	−0.165*
	(2.89)	(1.96)	(3.13)	(-1.37)	(-0.54)	(-1.77)
$Patent_{t+1}$	0.378			1.516*		
	(0.71)			(1.77)		
$Subsidy_t$* $Patent_{t+1}$	−0.838**			−0.183		
	(-2.35)			(-0.81)		
$Invent_{t+1}$		0.738			2.399	
		(0.47)			(0.82)	
$Subsidy_t$* $Invent_{t+1}$		−0.908			−0.968	
		(-0.95)			(-1.31)	
$Other_{t+1}$			0.662			1.994*
			(1.04)			(1.89)
$Subsidy_t$* $Other_{t+1}$			−1.222***			−0.224
			(-2.79)			(-0.88)
CONTROL	Yes	Yes	Yes	Yes	Yes	Yes
Ind FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs	286	286	286	69	69	69
Adj. R^2	0.499	0.481	0.504	0.838	0.829	0.841

Panel B

	Before the 'post-subsidy' policy			After the 'post-subsidy' policy		
Dep. Var.=	$Patent_{t+1}$ (1)	$Invent_{t+1}$ (2)	$Other_{t+1}$ (3)	$Patent_{t+1}$ (4)	$Invent_{t+1}$ (5)	$Other_{t+1}$ (6)
$Subsidy_t$	0.014	0.006**	0.007	0.068**	0.012**	0.049
	(1.44)	(2.05)	(0.89)	(2.54)	(2.50)	(1.63)
CONTROL	Yes	Yes	Yes	Yes	Yes	Yes
Ind FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs	286	286	286	69	69	69
Adj. R^2	0.345	0.242	0.326	0.594	0.547	0.544

Note: Table 5 presents the results for panel regressions that examine whether examination procedures of subsidy use distort the effect of R&D subsidies on corporate innovation quality and quantity using the 'Regulations on Post-subsidy Management of National Science and Technology Plan' issued by the Chinese government in November 2013. Column (1)-(3) shows the regression results for the subsample before the 'post-subsidy' policy. Column (4)-(6) shows the results for the subsample after the 'post-subsidy' policy. Table A details the construction of these variables. The t-statistics in parentheses below the coefficient estimates are based on standard errors clustered at the firm and year level. ***, **, and * indicate 1%, 5%, and 10% significance, respectively.
Source: made by the author.

We use firms related to renewable-energy vehicles as the treatment group (treat = 1) and the firms in the traditional energy industry as the control group (treat = 0) through the Propensity Score Matching (PSM) method. Taking the renewable energy vehicle subsidy policy in 2010 as a quasi-natural experiment, we examine whether renewable energy vehicle firms have engaged in more rent-seeking behaviors under government subsidy policies. To further identify the causal relationship, we conduct a cross-sectional analysis based on the level of provincial science and technology grants. Government scientific and technological grants give rise to rents, and induce firms to

Table 6. Rent-seeking in the renewable energy vehicle industry.

Dep. Var.=	Full sample $Renting_{t+1}$ (1)	Provinces with more scientific and technological investment $Renting_{t+1}$ (2)	Provinces with less scientific and technological investment $Renting_{t+1}$ (3)
$Treat_t$	−0.003	−0.002	−0.008
	(-0.50)	(-0.28)	(-0.66)
$Treat_t*Post_t$	0.019**	0.030***	0.012
	(2.19)	(2.97)	(0.88)
CONTROL	Yes	Yes	Yes
Ind FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Obs	302	153	149
Adj. R^2	0.400	0.662	0.206

Note: Table 6 presents the results of DiD regressions that examine whether renewable energy vehicle firms have engaged in more rent-seeking behaviors under government subsidy policies using the renewable energy vehicle pilot subsidy policy. The t-statistics in parentheses below the coefficient estimates are based on standard errors clustered at the firm and year level. ***, **, and * indicate 1%, 5%, and 10% significance, respectively.
Source: made by the author.

compete for the rents. We expect that the rent-seeking behavior of firms should be more severe in provinces with more scientific and technological grants. The regression results are shown in Table 6. The coefficient of *Treat*Post* in columns (1) is 0.019, which is significantly positive at the 5% level, indicating that renewable energy vehicle firms spend more on rent-seeking after introducing the renewable energy vehicle subsidy policy. The results in columns (2) and (3) show that renewable energy vehicle firms have stronger rent-seeking motives in provinces with more scientific and technological grants.

Next, we examine whether rent-seeking will enhance the negative effect of R&D subsidies on firms' innovation quality. We divide the sample into two groups, the firms with the high level of rent-seeking and the firms with the low level of rent-seeking, according to the sample median. The results shown in Panel A of Table 7 suggest that R&D subsidies have a significantly negative effect on innovation quality in renewable energy firms with a high level of rent-seeking. For the group of firms with a low level of rent-seeking, the R&D subsidies have no significant effect on corporate innovation quality when they increase corporate innovation quantity significantly. The above results show that rent-seeking in R&D subsidy distribution could be another economic mechanism that helps explain how R&D subsidies could induce firms' manipulative innovation strategies.

4.3. Robustness checks

In this section, we conduct a series of robustness tests. First, we use the number of citations each patent receives as an alternative indicator to measure the quality of innovation in baseline regression (He & Tian, 2013). We extract patent and citation information from the Chinese Research Data Services Platform (CNRDS) and adjust the measure to address the truncation problem involving citation counts. Patents tend to receive citations over a long period of time, but for patents in the later years during the sample period, there is not a long enough period to count the number of citations they could receive. We follow Hall et al. (2005) to correct the truncation problem in

Table 7. Effect of R&D subsidies on the quality and quantity of innovation under different rent-seeking levels.

Panel A

	High degree of rent-seeking			Low degree of rent-seeking		
Dep. Var.=	$TobinQ_{t+1}$ (1)	$TobinQ_{t+1}$ (2)	$TobinQ_{t+1}$ (3)	$TobinQ_{t+1}$ (4)	$TobinQ_{t+1}$ (5)	$TobinQ_{t+1}$ (6)
$Subsidy_t$	0.378***	0.236**	0.297**	0.013	−0.018	0.012
	(3.06)	(2.25)	(2.29)	(0.13)	(-0.20)	(0.12)
$Patent_{t+1}$	0.464			−0.288		
	(0.67)			(-0.53)		
$Subsidy_t$* $Patent_{t+1}$	−1.117***			−0.040		
	(-2.99)			(-0.26)		
$Invent_{t+1}$		1.391			0.204	
		(0.81)			(0.10)	
$Subsidy_t$* $Invent_{t+1}$		−1.561**			−0.167	
		(-2.33)			(-0.20)	
$Other_{t+1}$			0.747			−0.399
			(0.83)			(-0.61)
$Subsidy_t$* $Other_{t+1}$			−1.256**			−0.045
			(-2.18)			(-0.25)
CONTROL	Yes	Yes	Yes	Yes	Yes	Yes
Ind FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs	176	176	176	179	179	179
Adj. R^2	0.608	0.584	0.593	0.537	0.535	0.538

Panel B

	High degree of rent-seeking			Low degree of rent-seeking		
Dep. Var.=	$Patent_{t+1}$ (1)	$Invent_{t+1}$ (2)	$Other_{t+1}$ (3)	$Patent_{t+1}$ (4)	$Invent_{t+1}$ (5)	$Other_{t+1}$ (6)
$Subsidy_t$	−0.011	−0.000	−0.014	0.078***	0.017***	0.060***
	(-1.12)	(-0.03)	(-1.48)	(3.34)	(4.05)	(2.97)
CONTROL	Yes	Yes	Yes	Yes	Yes	Yes
Ind FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs	176	176	176	179	179	179
Adj. R^2	0.465	0.303	0.448	0.387	0.366	0.354

Note: Table 7 presents the results for panel regressions that examine whether rent-seeking of firms distorts the effect of R&D subsidies on corporate innovation quality and quantity. We group samples according to firms' rent-seeking levels. Column (1)-(3) shows the regression results for the severer rent-seeking group. Column (4)-(6) shows the results for the less rent-seeking group. Table A details the construction of these variables. The t-statistics in parentheses below the coefficient estimates are based on standard errors clustered at the firm and year level. ***, **, and * indicate 1%, 5%, and 10% significance, respectively.
Source: made by the author.

citation counts and construct an alternative indicator for innovation quality based on the total number of citations a patent received in the 10 years after it is granted.

We use the OLS, Tobit, Poisson models and the two-step system GMM estimate method to perform baseline regression, and columns (1) - (4) in Table 8 show the estimation results. The coefficients of $Subsidy_t$ are significantly negative, which indicates that R&D subsidies decrease the quality of innovation in the renewable energy industry. Therefore, our results are robust to the alternative proxy of innovation quality.

In the second robustness test, we add other subsidies besides the R&D subsides into the control variables in the regressions. Table 9 shows the results after controlling the

Table 8. Regression results using an alternative measure of innovation quality.

Dep. Var.=	$Citation_{t+1}$ OLS model (1)	$Citation_{t+1}$ Tobit model (2)	$Citation_{t+1}$ Poisson model (3)	$Citation_{t+1}$ System GMM (4)
$Citation_t$				0.263***
				(14.08)
$Subsidy_t$	−0.051**	−0.051**	−0.067**	−0.033**
	(-2.19)	(-2.27)	(-2.20)	(-2.10)
CONTROL	Yes	Yes	Yes	Yes
Ind FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Obs	355	355	355	345
AR(2)				0.692
Hansen test				0.812
Adj. R^2	0.160	0.077	.	0.550

Note: This alternative innovation quality measure ($Citation_{t+1}$) is defined as the number of citations each patent receives. Columns (1) - (4) perform the regressions using the OLS model, Tobit model, Poisson model and two-step system GMM, respectively. The t-statistics in parentheses below the coefficient estimates are based on standard errors clustered at the firm and year level. ***, **, and * indicate 1%, 5%, and 10% significance, respectively.
Source: made by the author.

effect of other subsidies. We find that R&D subsidies still significantly induce firms to adopt the manipulative innovation strategy after controlling other government subsidies.

5. Conclusion and policy implications

To develop the technological innovation of the renewable energy industry so as to alleviate environmental pollution, the Chinese government has granted a large number of R&D subsidies to renewable energy firms. Using the data of the government R&D subsidies given to Chinese renewable energy listed firms from 2008 to 2017, this paper examines the impact of R&D subsidies on the innovation capabilities in the renewable energy industry.

Our evidence shows that government R&D subsidies to renewable energy firms could induce their manipulative innovation strategy that increases innovation quantity at the sacrifice of innovation quality, especially in regions with low marketization and unfair competition. This paper also demonstrates why firms adopt the manipulative innovation strategy from two aspects. First, the renewable energy firms tend to sacrifice quality for the growth of innovation quantity to meet the examination requirements when the existing examination procedures of R&D subsidy use focus more on quantity indicators instead of quality measures. Second, the bureaucratic distribution of government subsidies induces firms to consume more resources in political rent-seeking instead of real investment in innovation, which further inhibits the improvement of innovation quality.

This study not only enriches the literature about the role of government intervention in the redistribution of market resources by discussing how R&D subsidies affect firms' tradeoff between the innovation quantity and quality, but also pioneers disclosing the specific mechanisms through which government subsidies could distort corporate innovation. Our findings also have important implications for policymakers. While existing studies mainly focus on the positive role of government subsidies in promoting corporate innovation, our findings reveal the negative effect of government subsidies on innovation quality with the presence of a bureaucratic subsidy distribution system and quantity-based examination procedures of government subsidy use. It is urgent for

Table 9. Regression results when controlling the impacts of other subsidies.

Panel A

Dep. Var.=	$TobinQ_{t+1}$ (1)	$TobinQ_{t+1}$ (2)	$TobinQ_{t+1}$ (3)
$Subsidy_t$	0.362***	0.314***	0.330***
	(3.41)	(2.82)	(3.20)
$Patent_{t+1}$	0.422		
	(0.95)		
$Subsidy_t$* $Patent_{t+1}$	−0.588***		
	(-2.98)		
$Invent_{t+1}$		1.110	
		(0.90)	
$Subsidy_t$* $Invent_{t+1}$		−2.111**	
		(-2.32)	
$Other_{t+1}$			0.422
			(0.78)
$Subsidy_t$* $Other_{t+1}$			−0.656***
			(-2.88)
$AdSubsidy_t$	−0.658**	−0.711***	−0.712***
	(-2.35)	(-2.74)	(-2.62)
$AdSubsidy_t$* $Patent_{t+1}$	0.439		
	(0.57)		
$AdSubsidy_t$* $Invent_{t+1}$		3.453	
		(1.52)	
$AdSubsidy_t$* $Other_{t+1}$			0.795
			(0.82)
CONTROL	Yes	Yes	Yes
Ind FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Obs	355	355	355
Adj. R^2	0.553	0.544	0.550

Panel B

Dep. Var.=	$Patent_{t+1}$ (1)	$Invent_{t+1}$ (2)	$Other_{t+1}$ (3)
$Subsidy_t$	0.026	0.008**	0.016
	(1.55)	(2.31)	(1.12)
$AdSubsidy_t$	0.014	0.003	0.009
	(0.38)	(0.24)	(0.28)
CONTROL	Yes	Yes	Yes
Ind FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Obs	355	355	355
Adj. R^2	0.316	0.248	0.287

Note: AdSubsidyt is defined as the total amount of subsidies received by firms minus the amount of R&D subsidies. The t-statistics in parentheses below the coefficient estimates are based on standard errors clustered at the firm and year level. ***, **, and * indicate 1%, 5%, and 10% significance, respectively.
Source: made by the author.

policymakers to build up a more market-oriented subsidy distribution system to inhibit the firms' rent-seeking behaviors and improve the examination procedures of subsidy use to focus more on the innovation quality measures, such as patent citations or the patent's market value, instead of the direct quantity indicators.

However, we need to bear in mind two important caveats when interpreting or generalizing our results. First, while our findings are consistent with the negative role of R&D subsidies induced by information asymmetry, we cannot rule out the possible positive role played by R&D subsidies and directly apply our findings to all industries. Second, due to data availability, we hardly capture the effect of R&D subsidies on innovation activities of non-listed firms. Future research can further investigate the innovation strategies of other industries and non-listed firms under government R&D subsidies.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes

1. Chinese local governments such as Zhejiang Province and Jiangsu Province have formulated the 'Regulations for Acceptance of Science and Technology Subsidy Projects' in 2008, requiring firms that have received subsidies to submit project expenditure sheets, scientific and technological achievements appraisal certificates, patent applications or patent authorization certificates and other supporting materials.
2. We obtain data on the number of patent applications that are successfully granted from CSMAR database which contains patent information from 2008 to 2018. According to the 'Patent Law of the People's Republic of China', the period between a patent's application and its grant is no more than three years and some patent applications filed in 2018 are still under review and have not been granted by 2021. Therefore, the final sample is during the period of 2008-2017.
3. The data comes from the World Bank's questionnaire on the extent of unfair competition for 12,400 companies in 120 cities.

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Appendix

Table A1. Variable definitions.

Variables	Definitions	References
Tobin's Q	The ratio of the total market value to the total asset value of a firm.	Zhou and Zhang (2016)
Patent	The number of patent applications that are successfully granted divided by revenues (per 10 million RMB).	Zhong (2018)
Invent	The number of invention patent applications that are successfully granted divided by revenues (per 10 million RMB).	
Other	The number of utility and design patent applications that are successfully granted divided by revenues (per 10 million RMB).	
Subsidy	The ratio of R&D subsidies to revenues (per 100 RMB).	Hu et al. (2021)
Size	The natural logarithm of a firm's total assets.	Hou et al. (2017);
Lev	The ratio of total liabilities to total assets.	Jiang and Chen (2018);
Cash	The net cash flow from operations divided by total assets.	Jiang and Yuan (2018)
Growth	The growth rate of revenues.	
ISHR	The proportion of shares held by institutional investors.	
FSHR	The proportion of shares held by the largest shareholder.	
R&D	The ratio of research and development expenditures to revenues (Per 100 RMB).	
Board	The proportion of independent directors in all directors at the end of year t.	
SOE	The value equals one if the firm is a state-owned enterprise and zero otherwise.	
Rent	The ratio of administrative expenses to revenues.	Cai et al. (2011)

Note: Table A1 presents the detailed definitions of all the variables and the references for measuring variables.
Source: made by the author.