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Government Subsidies and Green Innovation in Renewable Energy Enterprises: The Moderating Role of Financing Constraints

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ABSTRACT: Renewable energy enterprises are central to the low-carbon transition, yet their green innovation is constrained by high technological uncertainty, long payback periods, and limited access to external finance. Government subsidies are among the most widely used policy instruments for correcting the resulting under-investment, but whether they actually stimulate green innovation, and under what financial conditions they work best, remains unclear. Drawing on market-failure theory, information-asymmetry theory, and signaling theory, this study examines the effect of government subsidies on green innovation in Chinese renewable energy listed companies and tests the moderating role of financing constraints. Using an unbalanced panel of 186 A-share listed renewable energy firms observed from 2012 to 2023 (1,794 firm-year observations), two-way fixed effects estimates show that government subsidies significantly promote green innovation, and the result is robust to alternative measures, instrumental-variable estimation, and Poisson pseudo-maximum likelihood estimation. Financing constraints positively moderate this relationship: the marginal effect of subsidies is larger for firms facing tighter constraints, consistent with the view that subsidies compensate for scarce external funds and send positive signals to creditors. The promoting effect is also stronger in non-state-owned enterprises, small and medium-sized enterprises, and firms located in central and western China. These findings enrich the literature on the financial conditions under which industrial policy is effective and offer practical implications for designing targeted and differentiated subsidy schemes that support the green transformation of the renewable energy sector.

KEYWORDS: Government Subsidies; Green Innovation; Renewable Energy Enterprises; Financing Constraints; Moderating Effect

I. INTRODUCTION

In 2020, China announced its goals of reaching peak carbon emissions before 2030 and achieving carbon neutrality before 2060, and the transformation of the energy system toward low-carbon sources has since become a national priority. Renewable energy enterprises, including those engaged in solar photovoltaics, wind power, hydropower, biomass, and energy storage, are the main carriers of the technologies on which this transformation depends. Continued progress in cost reduction, grid integration, and energy storage rests heavily on green innovation, that is, technological innovation that saves energy, prevents pollution, and reduces carbon emissions. However, green innovation generates double externalities, namely knowledge spillovers and environmental benefits, so that private returns fall short of social returns (Arrow, 1962; Rennings, 2000). Its high technological uncertainty, long payback period, and large up-front investment also make external financing difficult to obtain (Hall and Lerner, 2010). Governments have therefore relied extensively on subsidies, including special funds, grants, and taxrelated support, to encourage firms in the sector to innovate. Do government subsidies genuinely promote green innovation in renewable energy enterprises? Existing evidence is mixed: some studies find that public support induces additional private innovation effort, whereas others find that it is captured for other purposes or merely substitutes for firms' own spending (Czarnitzki and Lopes-Bento, 2013; Boeing, 2016; Zúñiga-Vicente et al., 2014). One possible reason is that the effect of subsidies depends on the financial conditions of the recipients. If a firm is financially constrained, a subsidy relaxes a binding budget constraint and certifies project quality to outside investors, so its marginal contribution should be larger (Kleer, 2010; Meuleman and De Maeseneire, 2012). These considerations lead to two questions addressed in this paper: Do government subsidies promote green innovation in renewable energy enterprises? Does the effect depend on the degree of financing constraints? Theoretical significance: Existing studies have mainly examined the effects of subsidies on R&D expenditure or innovation in general, and few have focused on green innovation in the renewable energy sector or treated financing constraints as a boundary condition of subsidy effectiveness. This paper integrates the subsidy and corporate finance literatures by treating financing constraints as a moderator, thereby

contributing to research on the conditions under which industrial policy works. Practical significance: The findings can provide empirical evidence for improving the targeting of subsidies, for helping financially constrained firms sustain long-term green R&D, and for coordinating fiscal support with green finance. This paper uses A-share companies in the renewable energy sector listed on the Shanghai and Shenzhen stock exchanges from 2012 to 2023, measures green innovation by green patent applications, and employs two-way fixed effects models to examine the effect of government subsidies and the moderating role of financing constraints, there is further examined by ownership type, firm size, and region.

II. LITERATURE REVIEW

A. Government Subsidies and Corporate Innovation

Research on government subsidies and corporate innovation is rooted in the market-failure argument. Because knowledge is partly non-excludable and innovation projects are risky, private firms under-invest in R&D relative to the social optimum (Arrow, 1962), and public support may be justified when adverse selection prevents good projects from being financed (Takalo and Tanayama, 2010). The empirical literature has focused on whether subsidies are additional to or crowd out private effort. Czarnitzki and Lopes-Bento (2013) provide microeconometric evidence on public R&D grants, and Zúñiga-Vicente et al. (2014) survey the evidence on the effect of public subsidies on firm R&D investment and conclude that the results depend on the context and on the empirical strategy. Howell (2017) shows that early-stage R&D grants raise the subsequent financing and patenting of recipients, with particularly large effects for firms that are financially constrained. From the signaling perspective, Kleer (2010) argues that subsidies can serve as a signal of project quality to private investors, and Meuleman and De Maeseneire (2012) find that R&D subsidies improve small firms' access to external financing. In China, Boeing (2016) documents that the allocation and effectiveness of R&D subsidies among listed firms vary systematically with firm characteristics, and Guo et al. (2016) show that government-subsidized R&D is associated with firm innovation output but that its effectiveness is conditional on firm features. In the renewable energy sector, Zhang et al. (2014) examine the roles of political connections and subsidies in the performance of renewable energy manufacturers, and Yu et al. (2016) study the relationship between government subsidies and R&D investment in renewable energy enterprises using panel data. Green innovation has distinctive features that strengthen the case for public support. Rennings (2000) emphasizes the double externality of eco-innovation, and Jaffe et al. (2005) describe a tale of two market failures in which environmental externalities and knowledge spillovers jointly depress investment in clean technology. Porter and van der Linde (1995) argue that well-designed environmental policy can stimulate innovation that partly offsets compliance costs. Popp (2002) shows that innovation responds to energy prices, and Acemoglu et al. (2012) demonstrate that, without policy intervention, technical change may remain directed toward dirty technologies. Johnstone et al. (2010) find that different types of renewable energy policies are associated with patenting in renewable technologies, and Cai and Li (2018) examine the drivers of eco-innovation in China. Existing studies, however, typically focus on environmental regulation or demand-side policies, and the interaction between direct subsidies and the financial position of renewable energy enterprises has received much less attention.

B. Financing Constraints and Corporate Green Innovation

Financing constraints play an important role in shaping corporate investment, particularly for innovation. Credit rationing arises when lenders cannot observe borrower quality (Stiglitz and Weiss, 1981), and information asymmetry makes external funds more costly than internal funds (Myers and Majluf, 1984). Fazzari et al. (1988) were among the first to examine the effect of financing constraints on corporate investment. Hall and Lerner (2010) review the financing of R&D and innovation and explain why intangible, risky projects are especially difficult to finance externally. Brown et al. (2009) show that R&D of young firms depends strongly on internal cash flow and external equity, and Hottenrott and Peters (2012) provide evidence that financing constraints restrict innovation activity. Common measures of financing constraints include the KZ index (Kaplan and Zingales, 1997), the WW index (Whited and Wu, 2006), and the SA index (Hadlock and Pierce, 2010). Hadlock and Pierce (2010) question the validity of the KZ index and propose the SA index, which relies only on firm size and age and is therefore less affected by endogenous financial variables. However, Farre-Mensa and Ljungqvist (2016) find that commonly used measures have difficulty identifying firms that are genuinely constrained, so researchers should choose indicators carefully and conduct robustness checks. Building on this literature, financing constraints may influence the effectiveness of government subsidies in at least three ways. First, a subsidy is a source of funds that is not subject to credit rationing, so its marginal value is higher for firms that cannot easily raise external funds. Second, because subsidies are awarded after government screening, they may certify project quality and reduce information asymmetry between firms and creditors (Kleer, 2010; Meuleman and De Maeseneire, 2012), which is especially valuable for firms that depend on external credit. Third, firms with severe constraints may use additional funds to meet immediate liquidity needs instead of long-term innovation, which could weaken the effect of subsidies on green innovation.

Whether financing constraints strengthen or weaken the effect of subsidies on green innovation in renewable energy enterprises therefore remains an empirical question. Examining this question can clarify the financial conditions under which subsidies are effective and whether they should be targeted at constrained firms. Howell (2017) shows that early-stage R&D grants raise the subsequent financing and patenting of recipients, with particularly large effects for firms that are financially constrained. From the signaling perspective, Kleer (2010) argues that subsidies can serve as a signal of project quality to private investors, and Meuleman and De Maeseneire (2012) find that R&D subsidies improve small firms' access to external financing.

III. RESEARCH HYPOTHESES

A. The Impact of Government Subsidies on Green Innovation

Government subsidies are an important policy instrument for promoting sustainable development and guiding resources toward strategic emerging industries. Renewable energy enterprises play a crucial role in China's energy transition and carbon neutrality strategy, but their innovation activities are characterized by high uncertainty, long investment cycles, and considerable initial costs. Compared with conventional projects, green innovation involves greater technological risk and a longer period before it generates financial returns, and its environmental and knowledge spillovers cannot be fully appropriated by the innovator. These characteristics lead to under-investment when firms rely only on market incentives (Arrow, 1962; Jaffe et al., 2005). Government subsidies can mitigate this problem through several channels. First, subsidies directly increase the funds available for research and development, equipment upgrading, and the commercialization of new technologies, and lower the cost of failure for risky projects. Second, subsidies reduce the private cost of innovation and raise its expected return, which encourages firms to undertake projects they would otherwise postpone. Third, the award of a subsidy sends a positive signal about the quality of the firm and its alignment with national industrial priorities, which may improve investor confidence and attract additional external capital (Kleer, 2010). Finally, subsidies tied to environmental objectives may strengthen managers' attention to energy-saving and low-carbon technologies. Of course, subsidies may also be used for rent-seeking or to substitute for firms' own spending (Boeing, 2016), but for a sector in which social returns are high and private financing is scarce, the positive effects are expected to dominate. Therefore, this study proposes the following hypothesis: **H1: Government subsidies significantly promote green innovation in Chinese renewable energy listed companies.**

B. The Moderating Role of Financing Constraints

Financing constraints are an important factor affecting corporate innovation decisions. Because of information asymmetry, high technological uncertainty, and long investment recovery periods, renewable energy enterprises may find it difficult to obtain sufficient external financing for green innovation, particularly when they lack collateral or stable cash flow (Stiglitz and Weiss, 1981; Hall and Lerner, 2010). When constraints are severe, firms may reduce R&D expenditure, postpone technological upgrading, or abandon potentially valuable projects. For such firms, an additional unit of subsidy has a higher marginal value because it relaxes a binding budget constraint, whereas unconstrained firms can finance promising projects through bank loans or capital markets and may treat subsidies as a substitute for funds they would have raised anyway. Subsidies also serve as a certification device: because they are granted after government evaluation, they reduce information asymmetry and improve constrained firms' access to bank loans and other financing (Meuleman and De Maeseneire, 2012; Howell, 2017). By easing funding shortages and supporting continuous investment in research and development, subsidies can therefore play a particularly important role for firms facing tighter financing constraints. The following hypothesis is proposed: **H2: Financing constraints positively moderate the relationship between government subsidies and green innovation; that is, the promoting effect of subsidies is stronger for renewable energy enterprises facing tighter financing constraints.**

C. Heterogeneous Effects of Government Subsidies

The impact of government subsidies may vary according to enterprise ownership, firm size, and regional financial development. These differences reflect variations in access to financial resources and in the marginal value of public funds. State-owned enterprises (SOEs) generally maintain closer relationships with government institutions and state-owned banks and enjoy implicit guarantees, so they face softer budget constraints. For them, subsidies are less critical to financing green innovation and may be used for other objectives such as capacity expansion. Non-state-owned enterprises, by contrast, face greater difficulty in obtaining external financing, so a subsidy has a larger marginal effect on their innovation. Second, enterprise size matters. Large enterprises generally have more collateral, stronger creditworthiness, and better-established relationships with financial institutions, whereas small and medium-sized enterprises (SMEs) face tighter constraints and have fewer internal resources, so they should benefit more from subsidies. Third, regional financial conditions differ substantially. Eastern China has a more developed financial system and a richer supply of alternative funding sources, whereas firms in central and western China have

limited access to credit and capital markets and therefore depend more on public support. Accordingly, the positive effect of subsidies may be stronger where alternative financing is scarcer. Based on these arguments, this study proposes the following hypotheses: **H3a: The positive effect of government subsidies on green innovation is stronger in non-state-owned enterprises than in state-owned enterprises. H3b: The positive effect of government subsidies on green innovation is stronger in small and medium-sized enterprises than in large enterprises. H3c: The positive effect of government subsidies on green innovation is stronger in central and western China than in eastern China.**

IV. RESULT ANALYSIS

A. Descriptive Statistics and Correlation Analysis

This section reports the empirical results. The sample consists of A-share listed renewable energy companies (solar photovoltaics, wind power, hydropower, biomass and waste-to-energy, energy storage, and related new-energy equipment) observed from 2012 to 2023. Financial data and green patent data are drawn from standard firm-level databases, and subsidy data are collected from the government-grant items disclosed in annual reports. After excluding financial firms, firms under special treatment (ST/*ST), firms with missing key variables, and firms observed for fewer than three consecutive years, an unbalanced panel of 1,794 firm-year observations covering 186 firms is obtained, and all continuous variables are winsorized at the 1st and 99th percentiles. The explained variable is green innovation (GI), measured as the natural logarithm of one plus the number of green patent applications filed in the year. The core explanatory variable is government subsidies (SUB), the natural logarithm of one plus the amount of government subsidies recognized in the year. The moderator is financing constraints (FC), measured by the SA index of Hadlock and Pierce (2010), for which larger (less negative) values indicate tighter constraints. The controls are firm size (Size), leverage (Lev), return on assets (ROA), firm age (Age), R&D intensity (RD), revenue growth (Growth), ownership concentration, cash holdings (Cash), and a state ownership dummy (SOE). Table 1 presents the descriptive statistics.

Table 1. Descriptive Statistics of Main Variables

Variable Name	Obs	Mean	Std. Dev.	Min	Max
GI	1794	1.846	1.208	0.000	5.386
SUB	1794	16.742	1.563	10.309	20.884
FC	1794	-3.742	0.261	-4.498	-2.874
Size	1794	22.318	1.286	19.527	26.104
Lev	1794	0.531	0.187	0.082	0.921
ROA	1794	0.026	0.054	-0.213	0.187
Age	1794	2.412	0.548	0.693	3.401
RD (%)	1794	3.614	2.873	0.000	16.420
Growth	1794	0.132	0.287	-0.512	1.634
Top1 (%)	1794	33.241	14.386	8.730	72.150
Cash	1794	0.118	0.093	0.004	0.512
SOE	1794	0.436	0.496	0.000	1.000

Green innovation differs considerably across firms: GI has a mean of 1.846 and ranges from 0.000 to 5.386, indicating substantial room for improvement in the sector's green technology capability. SUB has a mean of 16.742, corresponding to about RMB 18.7 million of subsidies per firm-year, with a standard deviation of 1.563, so subsidy intensity varies widely across firms. FC has a mean of −3.742 and a standard deviation of 0.261, and about 43.6% of the observations belong to SOEs. The core explanatory variable is government subsidies (SUB), the natural logarithm of one plus the amount of government subsidies recognized in the year. The moderator is financing constraints (FC), measured by the SA index of Hadlock and Pierce (2010), for which larger (less negative) values indicate tighter constraints. SUB is positively correlated with GI ($r = 0.221$, $p < 0.01$), while FC is negatively correlated with GI ($r = -0.118$, $p < 0.01$). The largest variance inflation factor is 2.47, so multicolored not a concern.

B. Baseline Regression Results

To test H1, this paper estimates the following two-way fixed effects model:

$$GI_{it} = \alpha + \beta \cdot SUB_{it} + \gamma \cdot Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \qquad (1)$$

where i and t denote firm and year, GI_{it} is green innovation, SUB_{it} is government subsidies, and $Controls_{it}$ is the vector of control variables. μ_i and λ_t are firm and year fixed effects, which absorb time-invariant firm characteristics and common shocks, and ε_{it} is the error term. H1 is supported if β is significantly positive. Table 2 reports the results.The core explanatory variable is government subsidies (SUB), the natural logarithm of one plus the amount of government subsidies recognized in the year. The moderator is financing constraints (FC), measured by the SA index of Hadlock and Pierce (2010), for which larger (less negative) values indicate tighter constraints. The controls are firm size (Size), leverage (Lev), return on assets, firm age, R&D intensity (RD), revenue growth (Growth), ownership concentration, cash holdings (Cash), and a state ownership dummy SOE.

Table 2. Baseline Regression Results

Variable	(1) GI	(2) GI	(3) GI
SUB	0.074***	0.059***	0.052***
	(0.019)	(0.017)	(0.017)
Size	-	0.121***	0.108***
		(0.031)	(0.032)
Lev	-	-0.118*	-0.103*
		(0.062)	(0.062)
ROA	-	0.287**	0.264**
		(0.131)	(0.133)
Firm and Year FE	Yes	Yes	Yes
Industry × Year FE	No	No	Yes
Obs	1794	1794	1794
Adj. R^2	0.612	0.634	0.661

Note: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors clustered at the firm level are reported in parentheses.

Column (1) controls only for firm and year fixed effects, and the SUB coefficient is 0.074 ($p < 0.01$). After adding controls in column (2), it falls to 0.059 but remains significant at the 1% level. Column (3) further includes industry-by-year fixed effects, and the coefficient is 0.052 ($p < 0.01$): a one-standard-deviation increase in SUB (1.563) raises GI by about 0.081, which is 6.7% of one standard deviation of GI and corresponds to roughly 8.5% more green patent applications. Larger and more profitable firms innovate more, whereas highly leveraged firms innovate less, as expected. These results support H1.

C. Moderating Effect of Financing Constraints

To test H2, FC (the SA index) is standardized and interacted with SUB, so the interaction coefficient is the change in the effect of subsidies per one-standard-deviation increase in financing constraints. The following model is estimated:

$$GI_{it} = \alpha + \beta_1 \cdot SUB_{it} + \beta_2 \cdot FC_{it} + \beta_3 \cdot SUB_{it} \times FC_{it} + \gamma \cdot Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

where FC_{it} is the standardized financing constraint and the other variables are as defined in Equation (1). H2 is supported if β_3 is significantly positive. Column (3) additionally includes industry-by-year fixed effects, and columns (4) and (5) re-estimate Equation (1) for firms with FC below and above the sample median, respectively (Table 3).

Table 3. Moderating Effect of Financing Constraints

Variable	(1) Main	(2) Interaction	(3) Strict FE	(4) Low FC	(5) High FC
SUB	0.056***	0.058***	0.051***	0.029	0.081***
	(0.017)	(0.017)	(0.017)	(0.021)	(0.022)
FC	-0.085**	-0.081**	-0.074*	-	-
	(0.037)	(0.037)	(0.038)		

SUB × FC	-	0.034*** (0.012)	0.029** (0.012)	-	-
Controls & FE	Yes	Yes	Yes	Yes	Yes
Obs	1794	1794	1794	897	897
Adj. R^2	0.637	0.641	0.668	0.598	0.652

Note: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors clustered at the firm level are reported in parentheses. Controls & FE: control variables and firm and year fixed effects are included.

In column (1), SUB remains significantly positive (0.056, $p < 0.01$) and FC is significantly negative (−0.085, $p < 0.05$), showing that tighter constraints inhibit green innovation. In column (2), the interaction SUB × FC is 0.034 ($p < 0.01$): a one-standarddeviation increase in financing constraints raises the marginal effect of subsidies from 0.058 to 0.092, an increase of about 59%, whereas for firms one standard deviation below the mean the marginal effect falls to 0.024. The interaction remains significantly positive after industry-by-year fixed effects are added (0.029, $p < 0.05$). The subsample results agree: the SUB coefficient is small and insignificant (0.029) among firms with low constraints but 0.081 ($p < 0.01$) among highly constrained firms, and a Fisher permutation test with 1,000 replications confirms that the difference is significant ($p = 0.024$). These results indicate that subsidies are most valuable where external funds are scarce, consistent with the funding-substitution and certification arguments. H2 is supported.

D. Heterogeneity Test by Ownership

The sample is divided into state-owned enterprises (782 observations) and non-state-owned enterprises (1,012 observations), and SUB × SOE is added to the pooled sample (Table 4).

Table 4. Heterogeneity Test by Ownership

Variable	**(1)** **SOE**	**(2)** **Non-SOE**	**(3)** **Pooled**
SUB	0.031 (0.022)	0.071*** (0.020)	0.069*** (0.020)
SUB × SOE	-	-	-0.043* (0.023)
Controls & FE	Yes	Yes	Yes
Obs	782	1012	1794
Adj. R^2	0.573	0.628	0.649

Note: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors clustered at the firm level are reported in parentheses. Controls & FE: control variables and firm and year fixed effects are included.

The SUB coefficient is small and insignificant (0.031) in SOEs but 0.071 ($p < 0.01$) in non-SOEs. A Fisher permutation test with 1,000 replications confirms that the difference is significant ($p = 0.037$), and the interaction term in column (3) is −0.043 ($p < 0.10$). SOEs enjoy easier access to state bank credit and implicit government support, so subsidies are less binding for their green innovation and may be directed to other uses such as capacity expansion, whereas non-state firms convert additional funds into green patents more effectively. H3a is supported.

E. Heterogeneity Test by Firm Size and Region

To test H3b and H3c, the sample is split by firm size (large firms, whose total assets exceed the annual industry median, 902 observations; SMEs, 892 observations) and by region (eastern China, 1,106 observations; central and western China, 688 observations). Column (5) pools the full sample and adds SUB × Large and SUB × East (Table 5).

Table 5. Heterogeneity Test by Firm Size and Region

Variable	**(1)** **Large**	**(2)** **SME**	**(3)** **East**	**(4)** **Central & West**	**(5)** **Pooled**
SUB	0.033 (0.024)	0.076*** (0.022)	0.036* (0.019)	0.085*** (0.027)	0.092*** (0.029)

SUB × Large	-	-	-	-	-0.036* (0.020)
SUB × East	-	-	-	-	-0.039* (0.022)
Controls & FE	Yes	Yes	Yes	Yes	Yes
Obs	902	892	1106	688	1794
Adj. R^2	0.587	0.619	0.601	0.644	0.652

Note: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors clustered at the firm level are reported in parentheses. Controls & FE: control variables and firm and year fixed effects are included.

The SUB coefficient is insignificant in large firms (0.033) but 0.076 ($p < 0.01$) in SMEs, and the difference is significant (Fisher permutation test, $p = 0.041$). Likewise, the coefficient is 0.036 ($p < 0.10$) in eastern China but 0.085 ($p < 0.01$) in central and western China ($p = 0.033$). In the pooled model, both SUB × Large (−0.036, $p < 0.10$) and SUB × East (−0.039, $p < 0.10$) are negative. Large firms have more collateral and well-established bank relationships, and firms in the better developed financial markets of the east have a richer menu of alternative funding, so public funds are less decisive for their green innovation. The pattern is consistent with the moderating role of financing constraints documented above. H3b and H3c are supported.

F. Robustness Tests

Several robustness tests support the baseline results. First, replacing GI with the logarithm of one plus green invention patent applications gives a SUB coefficient of 0.047 ($p < 0.01$), and using granted green patents gives 0.041 ($p < 0.01$). Second, because patent counts are non-negative and skewed, a Poisson pseudo-maximum likelihood model with raw patent counts (Santos Silva and Tenreyro, 2006) yields a coefficient of 0.058 ($p < 0.01$). Likewise, the coefficient is 0.036 ($p < 0.10$) in eastern China but 0.085 ($p < 0.01$) in central and western China ($p = 0.033$). In the pooled model, both SUB × Large (−0.036, $p < 0.10$) and SUB × East (−0.039, $p < 0.10$) are negative. Large firms have more collateral and well-established bank relationships, and firms in the better developed financial markets of the east have a richer menu of alternative funding, so public funds are less decisive for their green innovation. The pattern is consistent with the moderating role of financing constraints documented above. H3b and H3c are supported. Third, to mitigate reverse causality, SUB is lagged by one year, giving 0.043 ($p < 0.01$); in addition, two-stage least squares using the leave-one-out mean of subsidies received by other firms in the same city and year as the instrument gives a second-stage coefficient of 0.083 ($p < 0.05$), with a first-stage F-statistic of 27.4. Fourth, replacing the SA index with the WW index (Whited and Wu, 2006) and the KZ index (Kaplan and Zingales, 1997) gives interaction coefficients of 0.027 ($p < 0.05$) and 0.022 ($p < 0.10$), respectively, which alleviates the concern of Farre-Mensa and Ljungqvist (2016) that a single index may misclassify constrained firms and that the SA index is mechanically related to size and age. The subsample results agree: the SUB coefficient is small and insignificant (0.029) among firms with low constraints but 0.081 ($p < 0.01$) among highly constrained firms, and a Fisher permutation test with 1,000 replications confirms that the difference is significant ($p = 0.024$). These results indicate that subsidies are most valuable where external funds are scarce, consistent with the funding-substitution and certification arguments. H2 is supported. Several robustness tests support the baseline results. Fifth, clustering standard errors at both the firm and year levels (Petersen, 2009) leaves the significance of the main results unchanged. Finally, excluding the pandemic years 2020 and 2021 gives a SUB coefficient of 0.050 ($p < 0.01$).

CONCLUSIONS

Using firm-level data on Chinese A-share listed renewable energy companies from 2012 to 2023, this paper examines the effect of government subsidies on green innovation and the moderating role of financing constraints. The main findings are as follows. First, government subsidies significantly promote green innovation: a one-standard-deviation increase in subsidies raises green innovation by about 6.7% of its standard deviation, and the result survives alternative patent measures, Poisson pseudo-maximum likelihood, lagged and instrumental-variable estimation, and other robustness checks. Second, financing constraints positively moderate this relationship: the marginal effect of subsidies is about 59% larger for firms one standard deviation more constrained, and the effect is concentrated among highly constrained firms. Third, the promoting effect is stronger in non-state-owned enterprises, small and medium-sized enterprises, and firms in central and western China, that is, where alternative sources of finance are scarcer. Based on these findings, several implications follow. Policymakers should shift from uniform subsidies to targeted ones that give priority to financially constrained firms, SMEs, and non-state-owned enterprises in the renewable energy sector, and should link subsidy disbursement to verifiable green innovation outputs to limit rent-seeking and crowding-out.

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Subsidies should be coordinated with green credit, green bonds, and other green finance instruments so that the certification effect of subsidies helps firms obtain long-term external financing, and support for central and western regions should be strengthened. Firms should use subsidies for long-term, high-quality green R&D rather than short-term liquidity needs and should build stable relationships with financial institutions. This study has limitations. Financing constraints are measured by indices built from firm size and age, and green patent applications capture innovation output only partly. Future research could use project-level subsidy records, loan-level data, and measures of green innovation quality to identify the channels more precisely, and extend the analysis to renewable energy firms in other emerging economies.

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