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Government subsidy and corporate green innovation - Does board governance play a role?

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ABSTRACT

This study attempts to uncover the curvilinear relationship between government subsidies and corporate green innovation in China's new energy vehicle (NEV) industry, and investigate the moderating effect of board governance within this relationship. Using a strong balanced panel data from all NEV firms that have acquired government subsidy (GS) from 2013 to 2018, this study found government subsidy exhibit a U-shaped relationship to corporate green innovation (CGI). It also reveals that some facets of board governance (BG) significantly enhanced this U-shaped relationship, including board gender diversity, board age diversity, CEO duality and board educational level. Our study specifically suggests that policymakers should incorporate such diversity indicators as the proportion of female directors into investment evaluation standards (e.g. corporate governance, environmental, social and governance, and sustainable investment), in order to promote environmental benefits and societal equality and enhance women's empowerment.

1. Introduction

In the past few decades, the emission of greenhouse gases grew sharply from 31.78 billion tons in 1990 to 47.57 billion tons globally according to the announcement of the world resource institute (WRI, 2017), therein Carbon dioxide (CO2) accounts for about 75% of these greenhouse gases. Thanks to the Chinese leadership, great green transformation of many industries is happening within the country (Xia et al., 2020; Li et al., 2021a; Gao et al., 2021a & 2021b). And as the top one carbon emitter worldwide, China has also been endeavoring to play a responsible and leading role in alleviating CO2 emission. In September 2020, China pledged to achieve carbon emissions peak before 2030 and realize carbon neutrality before 2060 (Normile, 2020). Since the vehicle industry is a major contributor of CO2 emission in China, which emits CO2 at an average rate of 15% annually (Bai et al., 2019), China's policymakers have been pressured to design and implement measures to facilitate the replacement of traditional vehicles by battery electric, plug-in hybrid, and fuel cell vehicles (namely the NEVs, coined by the Chinese government). China proposed diverse measures, including subsidies, tax exemption and driving privileges, to boost the decarbonized process of its NEV industry and to guarantee the competitiveness of NEV firms, with lump-sum government subsidies being its dominant instrument.

China's NEV industry is featured with some vulnerable characteristics, such as immature technology, uncertain market demand and high imitation risk brought by CGI (Liu et al., 2017). Government subsidy is useful to provide NEV firms with extra income to address financial constraints and supplement green innovation resources (Almus and Czarnitzki, 2003; Tether, 2002). Previous literature has investigated the linkage between subsidy and corporate innovation, including stimulating (Bronzini and Piselli, 2016), inhibiting (Link and Scott, 2009), insignificant (Klette and Moen, 2012) and the non-linear (Dai and Cheng, 2015), but these studies failed to separate green innovation from non-green innovation and look into the effect of subsidy on green innovation which possesses a different feature of externality. Given that the positive and negative effects of subsidy on traditional innovation may coexist (Jiang et al., 2018), it is interesting and essential to examine this relationship.

In prior research, corporate green innovation has been a main concern for subsiding China's NEV firms, a number of studies explored that within different contexts, but the possible effect of government subsidy has rarely been examined. For example, Zeng et al. (2021) identified green innovation efficiency for 26 cities in Yangtze River Delta region; Yu et al. (2021) investigated the impact of financing

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constraints on green innovation in China. Bai et al. (2019) examined the influence of government subsidy on firms' green innovation in the energy-intensive industry but the linearly positive effect they found might not be same in the NEV industry (Costantini et al., 2015; Li et al., 2021b). Therefore, the relationship between government subsidy and green innovation in China's NEV firms is still missing, and this research thus strives to evaluate it.

Moreover, due to the advising and monitoring effect of board governance (Adams and Ferreira, 2007), the board of directors can play a pivotal role in assisting firms to design and plan strategies that are helpful in building and adjusting the macro mission, vision and direction (Benkraiem et al., 2021); factors including board gender diversity, age diversity, independence, educational level and CEO duality may be moderators that affect CGI in the industry. Collectively, this study attempts to answer the following two questions:

(i) What is the relationship between GS and CGI in the China's NEV industry?
(ii) Does BG matter within this relationship?

This study has several contributions academically and in terms of environmental policy. First, to the best of our knowledge, this study is the first attempt to investigate the relationship between government subsidy and green innovation in the China's NEV industry, and it thus enriches the literature under China's unique setting. Second, this study identifies board governance as an important moderator in a non-linear model, and then examines its effect on the GS-CGI relationship. Finally, the results indicate that the board governance of China's NEV firms strengthens the non-linear effect of GS on CGI. Specifically, board governance inhibits the negative partial effect and intensifies the positive partial effect.

The reminder of this study is constructed as follows. Section 2 reviews the relevant literature and meanwhile proposes the corresponding hypotheses. Additionally, research gaps and research motivations are demonstrated in subsection 2.3. Section 3 demonstrates the data and econometric models. The empirical results, discussion and robustness checks can be found in Section 4. Finally, Section 5 concludes this study.

2. Literature review and hypothesis development

2.1. Government subsidy and corporate green innovation

CGI refers to the innovations that aims at reducing environmental pollution and save natural resources and energy (Saunila et al., 2018). It is regarded as an effective approach to promote low-carbon economy and meanwhile move towards carbon neutrality. Bi et al. (2016) underlined that CGI has one remarkably characteristic compared with traditional innovation, namely the double externality; it can lead to positive externality through technology and knowledge spillover, and it can also bring about negative externality since firms have the motivation to emit than innovate when the cost of innovation is higher than that of emission. In the absence of macro intervention, firms could be reluctant to speed up CGI, and CGI investment might not be able to achieve an optimal level. When the cost of CGI is shouldered by firms, but the return cannot compensate that cost, their motivation to innovate will be hurt, especially in the situation where there is a lack of policy supports.

In the literature, much attention has been devoted to investigating the relationship between GS and traditional innovation. For example, Dai and Cheng (2015) found an inverted-U relationship between public subsidies and R&D investment in the manufacturing industry. Klette and Møen (2012) concluded that there is no obvious correlation between GS and innovation performance in high-tech industries. Link and Scott (2009) revealed that GS may hurt the commercialization of R&D activities in small business enterprises. Although these studies examined the impact of GS on traditional innovation within diverse contexts, how it affects green innovation may not be the same story. Given that GS can exert non-linear effect on firms' overall innovation (Li et al., 2021b) and the effect of subsidy on corporate innovation can be heterogeneous in different industries (Klaassen et al., 2005), the necessity of exploring another story (i.e. GS and CGI) in the China's NEV industry is outstood, which has not been properly explored before and thus inspires this study.

GS is widely regarded as an important incentive instrument to support CGI. Due to the double externality of CGI, private investment may not be able to reach the optimal level without effective policy intervention. However, despite of the fruitful studies that centered on GS and traditional innovation, the relationship between GS and CGI is still implicit in the literature so far. For example, Wang et al. (2017) found that GS can promote clean production innovation through designing a game theory model. Song et al. (2020) revealed that green product innovation can be contributed by green insurance subsidy. Yet, some scholars held opposed views. For instance, Antonelli and Crespi (2013) stressed that the effective control of GS is nearly impossible since firms may use GS to fund other business activities that are not directly relevant to CGI, since GS may encourage firms to invest more resources in unproductive rent-seeking activities (Tollison, 1997). Consequently, the risk of opportunistic behavior seems to be quite high. Besides, Shao et al. (2021) pointed out that the effect of GS on CGI behavior depends on the scale of GS. Collectively, in order to bridge these gaps, this study aims at providing the robust evidence to disclose the relationship between GS and CGI in China's NEV industry in parallel to these studies that focused on GS and traditional innovation.

Based on these above-mentioned discussions, this study speculates that GS may exhibit a non-linear effect in affecting the CGI performance of NEV firms. That is to say, this effect may be disparate before and after an inflection point. Specifically, when the scale of GS is insufficient, the driving power of CGI is not enough and the cost of green innovation activities cannot offset the received government subsidy, which further discourages corporate decision-makers to strive for more green innovation. Moreover, firms may lack the proactive incentive to engage R&D activities because of the potential free-riding or imitation behavior regardless of green or non-green innovation. In this light, it is more likely for firms to reduce their private CGI investment once their application for CGI funding is approved by government in the inadequate stage of subsidy (David et al., 2000). Jiang and Yan (2018) stated that GS to NEV firms may be misused for multiple objectives that is possibly opposite to promoting CGI. Besides, the innovation efficiency will decline when CGI is underfunded, but when the scale of GS reaches an inflection point, it may start to grow (Filipe and Carlos, 2012).

Indeed, this situation is bound to change with the increase of GS as the "certification effect" will gradually emerge (Jiang and Yan, 2018). External investors will consider these firms that has the ability to reap continuous and tremendous GS from government to have more tangible or intangible competitive strength, since these investors believe that governmental authorities have more valuable information than them. Thus, profit-oriented firms are pressured and encouraged to promote CGI with the purpose of maintaining or strengthening this certification effect. Furthermore, in the light of the tight association between CGI and corporate social responsibility, firms will find it easier to build a better corporate reputation as well as set up a well-known corporate image if they are dedicated to investing GS in CGI (Ghisetti and Rennings, 2014). Consequently, firms will gain more accesses to other external fundings through the accumulated effect of GS (Shao et al., 2021). In addition, it is becoming increasingly evident that the financing constraints and the uncertainty of CGI will be alleviated by the growing scale of GS.

Therefore, the following hypothesis are proposed to vividly demonstrate this curvilinear relationship between GS and CGI.

H1. there is a U-shaped relationship between GS and CGI in China's NEV industry. Specifically, the relationship between prior GS and CGI is negative at lower levels of GS, but tends to become positive at higher levels.

2.2. The moderating effect of board governance

2.2.1. The moderating role of board gender diversity

According to the principal-agent theory, the board plays an indispensable role in controlling managers and directing corporate decisions regarding strategy and operation. In 1983, Fama and Jensen (Fama and Jensen, 1983) stressed that the board exhibits the monitoring and controlling functions on firms, and these functions are further confirmed to be more effective if the board is featured with highly gender diversity

Board gender diversity is a hot topic in the field of board governance, and the extant studies evidenced the merit of female managers when managing firms compared with their counterparts. For example, Carter et al. (2003) stated that female directors are less likely to keep close connection to managers than male counterparts. Singh et al. (2008) underlined that males tend to rub shoulders with managers during their vocational career. In this regard, gender diversity can not only bring improved controlling effect for corporates but also leads to an effective reduction regarding agency cost and rent-seeking risk (Daily et al., 1999; Jurkus et al., 2011). As for China's NEV industry, GS is one of the most critical financial resource that provided by the government, which can be used to strengthen their competitiveness whilst developing and Ward and Forker (2017) stated that female directors can enable corporates to make the most of resources (e.g. GS). In addition, an increasing number of studies underscored the role played by female directors in protecting environment. For example, Liu (2018) found that female directors are more likely to concern social and environmental issues, such as climate change and global warming. More interestingly, Atif et al. (2021) noted that women may be more ethically sensitive than men, which intrinsically spurs them to support pro-social, pro-environmental activities (Kennedy and Dzialo, 2015). Thus, corporate board with high age diversity is posited to have more active oversight while voting for utilizing CGI to develop green product.

Therefore, hypothesis 2 (H2) is proposed to demonstrate the moderating role played by board gender diversity.

H2. Board gender diversity (BGDiv) enhances the curvilinear relationship between GS and CGI; specifically, the U-shaped relationship is stronger for corporate boards with high proportion of BDG and flatter for that with low proportion of BDG.

2.2.2. The moderating role of board age diversity

Age is an important background characteristic to predict management decisions (Hambrick and Mason, 1984). In fact, regardless of older managers or young managers, they all can play a positive role in contributing to corporate green innovation. On the one hand, the famous "age hypothesis" proposed by Fransson and Gärling (1999) demonstrated that younger generation is likelier to pay attention to addressing environmental problems. On the other hand, the literature held that older people are commonly more risk-averse than youngsters. For example, Bucciol and Miniaci (2011) found that getting older is accompanied with lower level of risk tolerance. Therefore, this study speculates that board members with higher age diversity are more equipped with comprehensive eco-friendly information and knowledge, and thus these firms are more likely to pump GS into pro-environmental investment.

Collectively, hypothesis 3 (H3) is proposed to demonstrate the moderating role played by board age diversity.

H3. Board age diversity (BADiv) enhances the curvilinear relationship between GS and CGI.

2.2.3. The moderating role of board independence

From the view of "career concerns", the positive correlation between stronger corporate governance and outstanding firm innovation is supported (Holmstrom, 1999). To be specific, top managers are generally concerned with their career and therefore hesitate or even refuse to engage innovation activities, since innovation is a complex process with uncertain outputs that may damage their long-term career prospects. In this light, a body of the literature emphasized the effectiveness of board independence in promoting innovation performance. For example, Aghion et al. (2013) noted that independent directors with strict scrutiny could incentivize managers to innovate. Balsmeier et al. (2017) stated that firms with more independent boards are more likely to advance innovation. Lu and Wang (2018) also found that high board independence can positively impact innovation. Coles et al. (2008) underscored the benefit of having more outside directors since they have practical experience or/and academic knowledge that can provide more insights for firms. Li et al. (2020) showed that the technical expertise of independent directors can help firms outperform than their rivals in the field of innovation. Furthermore, some studies also documented an intimate relationship between board independence and pro-environmental behavior. For instance, Bhuiyan et al. (2021) empirically evidenced that firms with more independent directors invest more in the environment. Wang and Dewhirst (1992) mentioned that firms with more independent boards pay closer attention to their long-term growth and thus are more prone to approve environmental investment. Considering that outside independent directors are not directly working under senior managers, this study assumes that they are likelier to behave more objectiveness and enthusiasm while voting for strategies that are associated with CGI.

Therefore, hypothesis 4 (H4) is proposed to demonstrate the moderating role played by board independence.

H4: Board independence (BIndep) enhances the curvilinear relationship between GS and CGI.

2.2.4. The moderating role of CEO duality

CEO duality happens when CEO plays a double role in corporates, namely, the president of the firm and the chairman of the board. In the literature, two dominant theories catalyze the debates on CEO duality. The agency theory underlines that the duality of chairman and CEO does harm to the board's monitoring and controlling functions and lead to conflicts of interests, and thus damages corporate financial performance (Jensen and Meckling, 1976). For example, the chair-CEO will dominate the board agenda and information flow so as to make questioning management lost its effectiveness (McNulty and Pettigrew, 1999). Hsu et al. (2021) revealed that CEO duality has a significantly negative impact on firm performance. Nevertheless, the stewardship theory has long held that CEO duality could contribute a clearer and stronger leadership for a firm and thereby allow for more effective and efficient decisions (Donaldson, 1990; Hsu et al., 2021), especially in a turbulent environment (Mutlu et al., 2018) such as highly uncertain economic policy (Chang et al., 2018). For instance, Mallin et al. (2013) found that CEO duality can not only positively affect the environmental performance but also improve the likelihood that corporates commit to engaging eco-friendly activities, and the potential reason may be attributed to the fact that CEO duality plays a strong monitoring role in limiting managerial opportunism and protecting shareholders' interests. Nonetheless, it is noteworthy that the policy uncertainty may spur managers to transfer resources (e.g. GS) for personal gains (Sena et al., 2018).

In order to echo the moderating effect of CEO duality, this study argues that CEO duality may not impose a burden to the relationship between GS and CGI, since CEO duality can be useful in eliminating information transferring and processing cost between managers and shareholders (Hsu et al., 2021), and in turn, these costs will rise if authority is divided (Yang and Zhao, 2014). Also, according to the stewardship theory (Donaldson, 1990) and resource dependence theory (Pfeffer, 1972), stronger and unified leadership will incentivize CEOs to make decisions that meet the interest of shareholders. Furthermore, in order to operate under government subsidy policy that served as a competitive and dynamic environment, firms need to rely on a unified leadership to mitigate coordination costs and enable more efficient and effective decision-making (Li et al., 2019). In addition, eco-friendly strategies could be formulated since powerful CEOs are more willing to share more pro-environmental information with other directors (Adams and Ferreira, 2007), which is beneficial for enhancing the relationship between GS and CGI.

Therefore, hypothesis 5 (H5) is proposed to demonstrate the moderating role played by CEO duality.

H5: CEO duality (CEO_dual) enhances the curvilinear relationship between GS and CGI.

2.2.5. The moderating role of board members' level of education

The upper echelons theory held that organizations' strategic performance could be predicted through the educational background of top executives (Hambrick and Mason, 1984). Indeed, the level of education is another important feature of board governance, since education is seen as a traditional human capital (Bruderl et al., 1992) and has the potential to affect board members' cognitive ability to make strategic decisions (Ma et al., 2019). In particular, education background is intimately correlated with CEOs' intellectual competence and innovative ability. In this sense, well-educated board members are more sensitive to environmental issues and thereby tend to pursue corporate goals beyond profitability and income. In turn, they are willing to buy in eco-friendly concept and concentrate on pro-environmental behaviors. For example, Lewis et al. (2014) and Tran and Pham (2020) evidenced that there is a positive relationship between leaders' educational background and corporate environmental performance. Likewise, Shahab et al. (2020) found that CEO's level of education is positively associated with firms' sustainability performance.

Therefore, hypothesis 6 (H6) is proposed to demonstrate the moderating role played by board members' level of education.

H6: Board members' level of education (BEdu) enhances the curvilinear relationship between GS and CGI.

2.3. Research gaps

Here we summarize the shortcomings of the existing research and propose the research gaps that this research would attempt to resolve. Previous studies have paid much attention into investigating the relationship between GS and traditional innovation and failed to separate green innovation from non-green innovation and look into the effect of GS on CGI. In addition, in the unique context of the China's NEV industry, the extant literature has well discussed the effect of GS on general innovation, but the possible effect of GS on CGI has rarely been examined, which may not be the same story. Furthermore, the moderating effect of board governance within the GS-CGI relationship is required to be evaluated. Therefore, this research aims to deal with these research gaps and propose crucial policy implications.

3. Research method

3.1. Sample and data

In retrospect, this study lists the major subsidy policy events that targeted at China's NEV industry and their policy influences in Appendix A, and it is clear that three phases constitute this period, i.e. 2009-2012 (pilot phase), 2013–2015 (promoting phase) and 2016–2020 (post-subsidy phase). Then, this study has identified 70 China's NEV companies who have received government subsidies from 2013 to 2018. This specific period of time is selected under the following considerations: i) most of NEV firms in pilot phase actually took a wait-and-see attitude toward this subsidy policy as it seemed to be highly uncertain at that time. Additionally, the initial policy only supported NEV firms that provided public services. Thus, these observations cannot help to understand the real game between government subsidy and green innovation; ii) China's central government started to widely promote the policy of NEV subsidy since 2013, which means that a relatively large and stable sample can be acquired; iii) the subsidy policy was expected to end in 2020 yet has to be extended to 2022 due to some other external factors such as COVID-19 pandemic that outbroke since the end of 2019. Thus, our sample ends in 2018 lest the results would be contaminated. Nonetheless, our sample covered two core phases (promoting phase and post-subsidy phase), indicating a decent persuasiveness. The data are collected from the Chinese Research Data Services (CNRDS) and China Stock Market & Accounting Research (CSMAR) Database. To be specific, the financial data of these companies during 2013–2018 is collected from CSMAR, and correspondingly the data of green innovation is acquired from the database under CNRDS, that is, Green Patent Research Database (GPRD). According to the statement from GPRD, the green innovation applications and grants (used for robustness check in Section 4.3) are rigorously differentiated and measured based on the "Green Inventory of International Patent Classification (IPC)"[1], which was launched by the World Intellectual Property Organization (WIPO) in 2010 (Tang et al., 2021). The panel data set is strongly balanced, and the final sample size is 420 observations.

3.2. Measures

In this study, the dependent variable is firm's green innovation performance, and government subsidy is the independent variable. The moderating variable is five pillars of corporate governance, namely, board gender diversity, board age diversity, board independence, CEO duality and board member's educational level. Besides, several control variables are considered and discussed in this section.

3.2.1. Corporate green innovation

Traditionally, innovation performance is evaluated through R&D investment and patent applications, which respectively represents innovation input and output. However, in light of the difficulty of distinguishing firm's traditional R&D investment from green R&D investment, this study set green patent applications as a proxy of corporate green innovation. This measurement is in accordance with a great deal of studies, such as Bai et al. (2019), Yuan et al. (2021), Xu et al. (2021). These studies assessed firms' green innovation performance through the proxy of green patent applications.

3.2.2. Government subsidies

This study considers lump-sum government subsidies as the direct support to China's NEV firms, which is disclosed in NEV firms' income statement as "non-operating income". After collecting government subsidies by each NEV firm in each fiscal year, the natural logarithm is

[1] Interested readers can refer to: https://www.wipo.int/classifications/ipc/green-inventory/home.

used to process it. Given that subsidies may have a lagged effect on green innovation performance, this study delayed government subsidies one year later.

3.2.3. Board governance

In line with Atif et al. (2021), this study measures board gender diversity (BGDiv) by the proportion of female directors on the board. Board age diversity (BADiv) is determined by the ratio of the standard deviation of board age to mean of board age. Additionally, board independence (BIndep) is measured by the ratio of independent director on the board. With reference to Boyd (1995), CEO duality (CEO_dual) is coded as a dummy variable. Specifically, a firm in which CEO served as the chairperson was coded as one (1), otherwise, this dummy variable was equal to zero (0). After encoding educational background of each board of director, board members' educational level (BEdu) is attained by the average score. Detailly, the coding rule is as follows: technical high school or below = 1; technical college = 2; bachelor = 3; master = 4; doctoral degree = 5 (Cho et al., 2021).

3.2.4. Control variables

On the basis of extensive literature, this study control for some board and firm characteristics in order to eliminate the potential influence of these variables on green innovation performance. The size of a NEV firm may be associated with its green innovation performance, and this study thus used the natural logarithm of total assets (TotAsset) and revenues (Rev) to reflect it. ROA, the return on assets, is a key measure of profitability. Firm age (FirmAge) is measured by the numbers of years since firm established, and then this study takes the natural logarithm of this variable, thereby making it naturally distributed and balanced. In addition, firms are vulnerable to encounter financial risk, and firm leverage (Lvrg) plays a key role in controlling the financial risk of firms, and accordingly affects the decision-making process. Thus, this study measures firm leverage through the proportion of a firm's year-end asset-liability. Government is inclined to grant subsidies to sate-owned enterprise (SOE) because of the tight relationship between both of them (Wu, 2017), and Rong et al. (2017) evidenced that the presence of institutional ownership (IO) can enhance firm patenting. Therefore, these two variables are collected to reflect the proportion of stocks that are in possession of states and institutional investors respectively. Cantner and Kösters (2012) found that firms with higher R&D intensity (R&D) are more likely to receive government subsidies. In this light, R&D intensity is included into the control variables, which is measured through computing the natural logarithm of total R&D expenditure. Board size (BSize) is calculated by the number of board of directors, and Board meeting (BMeeting) is measured by the number of board meetings during a fiscal year. In addition, it is natural to observe the truth that the board member who holds the major shareholding (BTop) is more powerful to make corporate strategic decisions. BTop is measured by means of computing the shareholding ratio of major shareholders among board members[2]. In the light of the endogeneity, these variables are lagged one year.

3.3. Econometric models

3.3.1. The influence of GS on CGI (baseline model)

The following model is constructed to test the impact of government subsidy on green innovation performance:

$$CGI_{i,t} = \alpha + \beta_1 GS_{i,t-1} + \beta_2 GS^2_{i,t-1} + \sum_{j=1}^{n} \gamma_i CV_{j,i,t-1} + Fixed\ Effects + \varepsilon_{i,t} \tag{1}$$

where i denotes the company and t refers to the time period; CGI is the green innovation performance of each China's NEV firm; GS is the one-lump monetary subsidy provided by governments. CV contains all control variables including *TotAsset, Rev, FirmAge, ROA, Lvrg, SOE, IO, R&D, BSize, BMeeting, BTop*. Considering the lagged effect, this study tests the influence of GS on CGI one year later. Thus, $TotAsset_{i,t-1}$ and $Rev_{i,t-1}$ are the natural logarithm of total asset and revenue of a company i in year $t-1$, respectively; $FirmAge_{i,t-1}$ is the number of years since the establishment time to year $t-1$; $ROA_{i,t-1}$ is the return on assets of a company i in year $t-1$; $Lvrg_{i,t-1}$ is the leverage of a company i in year $t-1$; $SOE_{i,t-1}$ and $IO_{i,t-1}$ are the proportion of shares held by the state and institution to the total issued shares of a company i in year $t-1$, respectively; $R\&D_{i,t-1}$ denotes the natural logarithm of *R&D* expenditure of a company i in year $t-1$; $BSize_{i,t-1}$ is the number of board of directors of a company i in year $t-1$; $BMeeting_{i,t-1}$ is the number of board meetings of a company i in year $t-1$; $BTop_{i,t-1}$ is the major shareholding ratio among board members. Lastly, $\varepsilon_{i,t}$ refers to the random error term, and firm fixed effect and time fixed effect have been considered in Eq. (1).

3.3.2. The moderating role of board gender diversity

In order to examine the moderating effect of board gender diversity on the curvilinear relationship of GS and GIP, the following model is constructed on the basis of baseline model:

$$\begin{aligned} CGI_{i,t} = {} & \alpha + \beta_1 GS_{i,t-1} + \beta_2 GS^2_{i,t-1} + \beta_3 GS_{i,t-1} \times BGDiv_{i,t} + \beta_4 GS^2_{i,t-1} \times BGDiv_{i,t} \\ & + \beta_5 BGDiv_{i,t} + \beta_6 BADiv_{i,t} + \beta_7 BIndep_{i,t} + \beta_8 CEO\_dual_{i,t} + \beta_9 BEdu_{i,t} \\ & + \sum_{j=1}^{n} \gamma_i CV_{j,i,t-1} + Fixed\ Effects + \varepsilon_{i,t} \end{aligned} \tag{2}$$

where *BGDiv* refers to the moderator of board gender diversity, and the variables $GS_{i,t-1} \times BGDiv_{i,t}$ and $GS^2_{i,t-1} \times BGDiv_{i,t}$ are interactive items, which are added into the baseline model. Moreover, the coefficient β_3 and β_4 denote the influence of board gender diversity on the effect of government subsidy on green innovation performance. Firm fixed effect and time fixed effect have been controlled so as to avoid unobserved heterogeneity.

3.3.3. The moderating role of board age diversity

The following model is built to test the moderating effect of board age diversity on the curvilinear relationship of GS and CGI:

$$\begin{aligned} CGI_{i,t} = {} & \alpha + \beta_1 GS_{i,t-1} + \beta_2 GS^2_{i,t-1} + \beta_3 GS_{i,t-1} \times BADiv_{i,t} + \beta_4 GS^2_{i,t-1} \times BADiv_{i,t} \\ & + \beta_5 BADiv_{i,t} + \beta_6 BGDiv_{i,t} + \beta_7 BIndep_{i,t} + \beta_8 CEO\_dual_{i,t} + \beta_9 BEdu_{i,t} \\ & + \sum_{j=1}^{n} \gamma_i CV_{j,i,t-1} + Fixed\ Effects + \varepsilon_{i,t} \end{aligned} \tag{3}$$

where *BADiv* is the moderator of board age diversity, and the variables $GS_{i,t-1} \times BADiv_{i,t}$ and $GS^2_{i,t-1} \times BADiv_{i,t}$ are interactive items, and the coefficient β_3 and β_4 denote the influence of board age diversity on the effect of government subsidy on green innovation performance. Firm fixed effect and time fixed effect have been controlled in Eq. (3).

3.3.4. The moderating role of board independence

The following model is built to test the moderating effect of board independence on the curvilinear relationship of GS and CGI:

$$\begin{aligned} CGI_{i,t} = {} & \alpha + \beta_1 GS_{i,t-1} + \beta_2 GS^2_{i,t-1} + \beta_3 GS_{i,t-1} \times BIndep_{i,t} + \beta_4 GS^2_{i,t-1} \times BIndep_{i,t} \\ & + \beta_5 BIndep_{i,t} + \beta_6 BGDiv_{i,t} + \beta_7 BADiv_{i,t} + \beta_8 CEO\_dual_{i,t} + \beta_9 BEdu_{i,t} \\ & + \sum_{j=1}^{n} \gamma_i CV_{j,i,t-1} + Fixed Effects + \varepsilon_{i,t} \end{aligned} \tag{4}$$

where *BIndep* is the moderator of board independence, and the variables

[2] The authors thank to one of the referees who points out this critical variable.

$GS_{i,t-1} \times BIndep_{i,t}$ and $GS^2_{i,t-1} \times BIndep_{i,t}$ are interactive items, and the coefficient β_3 and β_4 denote the influence of board independence on the effect of government subsidy on green innovation performance. Firm fixed effect and time fixed effect have been controlled in Eq. (4).

3.3.5. The moderating role of CEO duality

As shown below, Eq. (5) is constructed to verify the moderating role of CEO duality played on the relationship curvilinear relationship of GS and GIP:

$$CGI_{i,t} = \alpha + \beta_1 GS_{i,t-1} + \beta_2 GS^2_{i,t-1} + \beta_3 GS_{i,t-1} \times CEO\_dual_{i,t} + \beta_4 GS^2_{i,t-1} \times CEO\_dual_{i,t} + \beta_5 CEO\_dual_{i,t} + \beta_6 BGDiv_{i,t} + \beta_7 BADiv_{i,t} + \beta_8 BIndep_{i,t} + \beta_9 BEdu_{i,t} + \sum_{j=1}^{n} \gamma_i CV_{j,i,t-1} + Fixed\ Effects + \varepsilon_{i,t} \tag{5}$$

where *CEO_dual* denotes the moderator of CEO duality, and the variables $GS_{i,t-1} \times CEO\_dual_{i,t}$ and $GS^2_{i,t-1} \times CEO\_dual_{i,t}$ are interactive items, and the coefficient β_3 and β_4 denote the influence of CEO duality on the effect of government subsidy on green innovation performance. Eq. (5) has controlled firm fixed effect and time fixed effect.

3.3.6. The moderating role of board members' level of education

The following Eq. (6) is constructed to verify the moderating role of board members' educational level played on the relationship curvilinear relationship of GS and CGI:

$$CGI_{i,t} = \alpha + \beta_1 GS_{i,t-1} + \beta_2 GS^2_{i,t-1} + \beta_3 GS_{i,t-1} \times BEdu_{i,t} + \beta_4 GS^2_{i,t-1} \times BEdu_{i,t} + \beta_5 BEdu_{i,t} + \beta_6 BGDiv_{i,t} + \beta_7 BADiv_{i,t} + \beta_8 BIndep_{i,t} + \beta_9 CEO\_dual_{i,t} + \sum_{j=1}^{n} \gamma_i CV_{j,i,t-1} + Fixed\ Effects + \varepsilon_{i,t} \tag{6}$$

where *BEdu* denotes the moderator of board members' education level, and the variables $GS_{i,t-1} \times BEdu_{i,t}$ and $GS^2_{i,t-1} \times BEdu_{i,t}$ are interactive items, and the coefficient β_3 and β_4 denote the influence of board members' educational level on the effect of government subsidy on green innovation performance. Eq. (6) has controlled firm fixed effect and time fixed effect.

Table 1
Descriptive statistics.

	N	Mean	S.D	Min	Median	Max
CGI	420	0.41	0.77	0.00	0.12	4.16
GS	420	18.00	1.60	14.19	17.95	22.40
ROA	420	0.04	0.06	−0.24	0.04	0.14
Lvrg	420	0.49	0.18	0.09	0.49	0.95
IO	420	0.43	0.24	0.00	0.45	0.94
FirmAge	420	17.35	4.81	7.00	17.00	30.00
Rev	420	22.17	1.44	19.49	22.01	27.17
SOE	420	0.02	0.05	0.00	0.00	0.25
BSize	420	8.77	1.89	5.00	9.00	15.00
BGDiv	420	0.17	0.11	0.00	0.15	0.48
BIndep	420	0.37	0.05	0.33	0.33	0.50
TotAsset	420	22.69	1.22	20.37	22.57	26.75
BEdu	420	2.34	1.28	0.00	2.90	4.08
BADiv	420	0.19	0.04	0.09	0.19	0.27
CEO_dual	420	0.28	0.45	0.00	0.00	1.00
BMeeting	420	15.65	6.25	6.00	14.00	37.00
R&D	420	0.04	0.03	0.00	0.04	0.17
Top	420	0.35	0.16	0.09	0.32	0.74

4. Empirical results

4.1. Descriptive statistics and correlation analysis

In order to eliminate the abnormal effect of extreme values, this study winsorized all variables by 1%. Additionally, the Box-Cox transformation is used to mitigate the overdispersion for independent variable. Table 1 and Table 2 respectively report descriptive statistics and correlation coefficient matrix for the dependent variables, independent variables, moderating variables and all control variables. On average, China's NEV firms have a board with 8.77 members, and the proportion of female directors, independent directors is 17% and 37% respectively. Additionally, nearly half of China's NEV firms' board members failed to get a bachelor's degree (median = 2.9), and the highest educational level is 4.08, indicating a master's degree. In addition, Fig. 1 demonstrates that the education level of board members within full sample presents a relatively extreme distribution. Besides, board age diversity ranges from 0.09 to 0.27 in China's NEVs, and Fig. 2 demonstrates that most of directors in these firms are aged from 35 to 65. Among 70 NEV firms, twenty firms' CEOs serve dual roles. Besides, the number of meetings held by boards of China's NEV firms exhibits a great variation from 6 to 37 over the period from 2013 to 2018. According to Table 2, GS and CGI are positively correlated, indicating the statistical significance between these two variables. Additionally, there is a positive correlation between firm size and GS, partly because bigger firms prefer to conduct more R&D programs and therefore are more favored by government.

4.2. Regression results and discussion

As noted above, this study incorporates the fixed effect into the regression model so as to alleviate the heteroscedasticity, thereby improving the robustness of results. Table 2 reports the results using panel regression, and specification (1) reports the results for controlling firm and year fixed effects with all control variables. Specifications (2)–(7) in Table 3 respectively report the regression result of econometric models (1)–(6). It is noteworthy that the R^2 of these specifications are all greater than 0.5, indicating that these models have decent explanatory power.

In specification (2), it suggests that there is a U-shaped relationship between GS and CGI since the coefficients of linear and non-linear terms are (β=-5.254, $p < 0.01$) and (β=5.539, $p < 0.01$) respectively. In order to further approve this positive-U relationship, several additional tests are conducted as well. Therein, Table 4 reports the result of U-shape test, and the slope of lower bound is significantly negative while that of upper bound is significantly positive, which is in accordance with the test conclusion of Sasabuchi (1980). Moreover, the inflection point of GS (18.994) is within the domain of itself regardless of Fieller estimation (Fieller, 1954), indicating that a complete U-shaped curve can be observed. Overall, H1 is supported. These results indicate that a 1% rise in GS would decrease CGI by 5.254%, while the positive sign of squared GS term corroborates the linking of GS and CGI at high levels of subsidies in China's NEV industry. The evidence confirms that CGI decreases in an insufficient stage of GS, but finally grows when GS reached the inflection point. Interestingly, this finding is similar to previous studies that focused on the relationship between GS and traditional

Table 2
Correlation coefficient matrix.

	CGI	GS	BADiv	BEdu	BGDiv	BIndep	CEO_dual	ROA	Lvrg	FirmAge	TotAsset	Rev	SOE	IO	R&D	BSize	BMeeting
CGI	1.000																
GS	0.525***	1.000															
	(0.000)																
BADiv	−0.014	−0.187***	1.000														
	(0.778)	(0.000)															
BEdu	0.173***	−0.089*	0.189***	1.000													
	(0.000)	(0.068)	(0.000)														
BGDiv	−0.079	−0.136***	0.124**	0.106**	1.000												
	(0.106)	(0.005)	(0.011)	(0.030)													
BIndep	0.246***	0.049	−0.026	0.082*	0.176***	1.000											
	(0.000)	(0.314)	(0.596)	(0.093)	(0.000)												
CEO_dual	0.128***	0.007	0.069	0.319***	0.174***	0.133***	1.000										
	(0.009)	(0.892)	(0.158)	(0.000)	(0.000)	(0.006)											
ROA	0.035	0.047	−0.072	0.101**	−0.025	−0.085*	0.109**	1.000									
	(0.474)	(0.339)	(0.142)	(0.038)	(0.614)	(0.082)	(0.025)										
Lvrg	0.280***	0.224***	−0.030	−0.273***	−0.252***	0.046	−0.096**	−0.343***	1.000								
	(0.000)	(0.000)	(0.540)	(0.000)	(0.000)	(0.350)	(0.050)	(0.000)									
FirmAge	0.093*	0.200***	−0.119**	−0.376***	−0.130***	−0.034	−0.197***	−0.114**	0.305***	1.000							
	(0.056)	(0.000)	(0.015)	(0.000)	(0.008)	(0.483)	(0.000)	(0.020)	(0.000)								
TotAsset	0.577***	0.748***	−0.162***	−0.230***	−0.203***	0.082*	−0.066	0.043	0.452***	0.317***	1.000						
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.092)	(0.180)	(0.377)	(0.000)	(0.000)							
Rev	0.540***	0.703***	−0.238***	−0.230***	−0.290***	0.064	−0.144***	0.140***	0.438***	0.280***	0.918***	1.000					
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.191)	(0.003)	(0.004)	(0.000)	(0.000)	(0.000)						
SOE	0.060	0.130***	−0.235***	0.005	−0.129***	0.044	−0.107**	−0.113**	0.116**	0.074	0.220***	0.252***	1.000				
	(0.221)	(0.007)	(0.000)	(0.916)	(0.008)	(0.371)	(0.028)	(0.021)	(0.017)	(0.132)	(0.000)	(0.000)					
IO	0.131***	0.227***	−0.227***	−0.292***	−0.194***	−0.112**	−0.145***	0.085*	0.264***	0.200***	0.407***	0.423***	0.193***	1.000			
	(0.007)	(0.000)	(0.000)	(0.000)	(0.000)	(0.022)	(0.003)	(0.081)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)				
R&D	0.082*	0.156***	−0.053	0.376***	0.052	0.090*	0.213***	0.017	−0.247***	−0.105**	−0.148***	−0.220***	−0.052	−0.103**	1.000		
	(0.095)	(0.001)	(0.275)	(0.000)	(0.289)	(0.066)	(0.000)	(0.722)	(0.000)	(0.031)	(0.002)	(0.000)	(0.284)	(0.034)			
BSize	−0.038	0.184***	−0.081*	−0.094*	−0.178***	−0.483***	−0.264***	0.008	0.075	0.083*	0.208***	0.156***	0.083*	0.236***	−0.073	1.000	
	(0.441)	(0.000)	(0.098)	(0.054)	(0.000)	(0.000)	(0.000)	(0.867)	(0.125)	(0.090)	(0.000)	(0.001)	(0.090)	(0.000)	(0.135)		
BMeeting	0.132***	0.087*	0.154***	0.140***	0.214***	0.103**	0.039	−0.094*	0.095*	−0.081*	0.154***	−0.006	−0.044	−0.039	0.035	0.076	1.000
	(0.007)	(0.074)	(0.001)	(0.004)	(0.000)	(0.035)	(0.420)	(0.055)	(0.051)	(0.098)	(0.002)	(0.909)	(0.373)	(0.428)	(0.477)	(0.119)	
Top	0.003	0.015	−0.196***	−0.254***	−0.227***	0.016	−0.207***	0.184***	0.108**	−0.014	0.188***	0.280***	0.004	0.642***	−0.101**	0.069	−0.078
	(0.947)	(0.753)	(0.000)	(0.000)	(0.000)	(0.743)	(0.000)	(0.000)	(0.026)	(0.767)	(0.000)	(0.000)	(0.929)	(0.000)	(0.039)	(0.161)	(0.109)

Note: p-values in parentheses. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

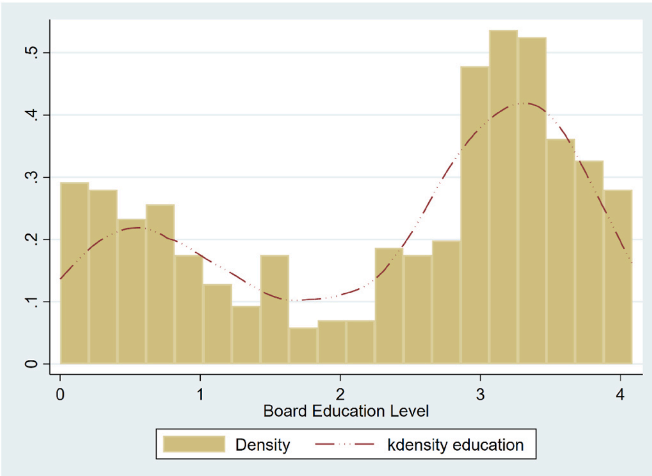

Fig. 1. Distribution of board education level in China's NEVs from 2013 to 2018.

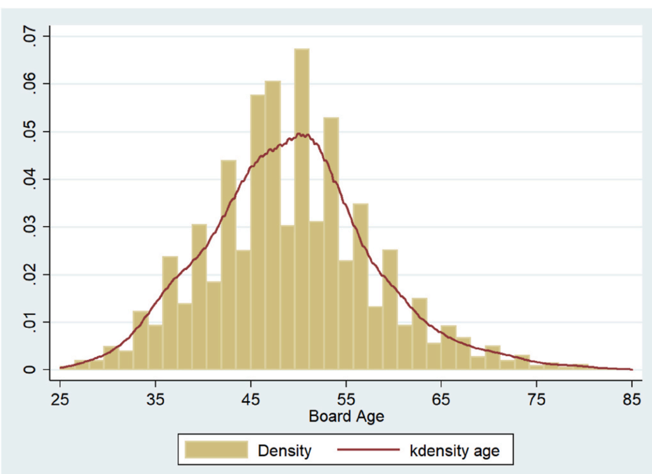

Fig. 2. Distribution of board average age in China's NEVs from 2013 to 2018.

innovation. For example, Jiang et al. (2018) argued that the positive and negative effects of government subsidies on traditional innovation may coexist, and Li et al. (2021b) also documented a complex nonlinear relationship between government subsidies and firms' traditional innovation output.

Furthermore, the left (negative) side of U shape indicates that China's NEV firms may shift government subsidies to other non-green innovation activities since the characteristic of double externalities does harm to their enthusiasm for developing CGI. In other words, the cost of green innovation is commonly higher than traditional innovation and the spillover effect of the former is more remarkable than the latter correspondingly (Bai et al., 2019), which makes it a threat to firms' competitive advantage in an insufficient stage of subsidies. On the other hand, benefit aside, investing innovation activities will inevitably face the risk of failure regardless green and non-green innovation, and it is inevitable that these risks will hurt firms' innovation motivation and performance (Yu et al., 2021). In this sense, China's NEV firms are likelier to take advantage of GS for other targets instead of developing green technologies, such as avoiding delisting risk (Yu et al., 2021). However, as government subsidies increases, GS-CGI relationship exhibits a sign of turning positive after an inflection point due to the certification effect of GS (Jiang and Yan, 2018). Specifically, accumulating government subsidies starts to signal stakeholders that these firms have abundantly unparalleled competitiveness in market. This certification or signal has been emphasized by venture capital institutions whilst making investment decision. Meanwhile, increasing government subsidies not only effectively reduce firms' risk of investing green innovation (Bai et al., 2019) but also enable them to achieve economies of scale in production (Yu et al., 2021). Thus, China's NEV firms are incentivized to pay closer attention to promote green innovation performance. Last but not least, although the median value of GS (17.95, see Table 1) is greater than the inflection point, indicating that more than half of China's NEVs observations entered the "positive" phase, the minimum value of GS (14.19) is lower than the inflection point, which means that some observations are still in the "negative" phase.

Specification (3)–(7) respectively examine the moderating effect of board governance on the U-shaped relationship between GS and CGI, including BGDiv, BADiv, BIndep, CEO_dual and BEdu, and it appears that these moderators indeed positively moderate or enhance GS-CGI relationship despite of CEO_dual. For example, BGDiv and BADiv significantly enhance the relationship (β=2.809, $p < 0.01$; $\beta = 1.289$, $p < 0.05$). Likewise, the relationship is strengthened when more independent directors are employed (β=1.813, $p < 0.05$) or when board members' educational level is high (β=1.215, $p < 0.05$). For providing parallel understanding of these coefficients, the relationship between GS and CGI under these moderators is mapped respectively in Fig. 3. Furthermore, the shadow area in Fig. 3 respectively indicates the enhanced effect brough by each board governance moderator. It appears that BGDiv serves as the most influential moderator in enhancing GS-CGI relationship, followed by BIndep, BAGiv and BEdu.

To sum up, H2, H3, H4 and H6 are supported while H5 is rejected and these phenomena can be explained as follows:

(i) The existence of linkage between innovation performance and board gender diversity is believed by many scholars and practitioners who focus on good corporate governance (Carter et al., 2003). The high level of gender diversity may improve controlling and monitoring effect of the board through saving agency cost and rent-seeking risk, which is in accordance with Daily et al. (1999) and Jurkus et al. (2011). Besides, prior studies argued that female directors are relatively more concerned about environment than their counterpart (Liu, 2018). Furthermore, female directors are likely to shoulder more environmental responsibility than their counterparts (Kassinis et al., 2016), and boards with diverse gender is less likely to be involved in unethical scandals (Boulouta, 2013). Thus, the enhanced effect of board gender diversity on GS-CGI relationship (135.029) is the most significant in comparison to other moderators.

(ii) Both older managers and young managers are characterized by distinct but beneficial properties that can contribute to cleaner environment, and thus boards with a high level of age diversity are likely to bend their efforts for green innovation development. This finding is consistent with Fransson and Gärling (1999) and Post et al. (2011).

(iii) The development status of China's NEV industry is still immature (Yu et al., 2021). Although China's government pumped a great deal of subsidies into NEV industry with the purpose of achieving long-term decarbonization, the practical effect is limited largely because NEV firms spontaneously tend to seek opportunism. In fact, some NEV firms even defrauded new energy subsidies for other uses instead of investing green technologies such as green battery. Considering this dilemma, the merit of board independence should be highlighted by reason of: 1) the career of outsider independent directors does not depend on CEO, which allows them to be free to intervene managers who show opportunism in acquiring and using GS; 2) independent board of directors generally insists a long-term vision, so short-term profitability aside, they intend to pursue sustainable development and thereby embrace CGI (Wang and Dewhirst, 1992); 3)

Table 3
Regression result: government subsidies, corporate green innovation and board governance.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
GS		−5.254***	−5.510***	−5.449***	−4.149***	−4.829***	−4.923***
		(-7.697)	(-7.864)	(-7.678)	(-6.117)	(-7.030)	(-7.186)
GS^2		5.539***	5.851***	5.803***	4.434***	5.151***	5.209***
		(7.929)	(8.165)	(7.951)	(6.390)	(7.330)	(7.476)
ROA	0.071	0.075	0.050	0.040	0.057	0.037	0.036
	(1.291)	(1.482)	(1.021)	(0.814)	(1.147)	(0.756)	(0.717)
Lvrg	0.077	0.110**	0.122**	0.108*	0.137**	0.119**	0.122**
	(1.293)	(1.984)	(2.290)	(1.913)	(2.549)	(2.250)	(2.197)
FirmAge	−0.110**	−0.097**	−0.007	−0.024	−0.029	−0.035	−0.019
	(-2.196)	(-2.120)	(-0.143)	(-0.501)	(-0.634)	(-0.757)	(-0.411)
TotAsset	0.371***	0.149	0.143	0.169	0.099	0.111	0.126
	(2.790)	(1.170)	(1.120)	(1.333)	(0.778)	(0.878)	(0.973)
Rev	0.260*	0.156	0.165	0.128	0.163	0.184	0.202
	(1.865)	(1.182)	(1.250)	(0.977)	(1.219)	(1.410)	(1.514)
SOE	−0.038	−0.062	−0.082*	−0.080*	−0.044	−0.040	−0.081*
	(-0.800)	(-1.412)	(-1.954)	(-1.920)	(-1.009)	(-0.932)	(-1.879)
IO	−0.013	−0.018	0.006	0.004	−0.001	0.017	0.005
	(-0.203)	(-0.300)	(0.100)	(0.064)	(-0.014)	(0.295)	(0.082)
R&D	0.141***	0.072	−0.022	−0.037	−0.008	−0.037	−0.003
	(3.058)	(1.558)	(-0.463)	(-0.782)	(-0.169)	(-0.780)	(-0.053)
BSize	−0.157***	−0.133***	−0.053	−0.042	−0.062	−0.036	−0.083
	(-3.419)	(-3.126)	(-1.085)	(-0.843)	(-1.265)	(-0.732)	(-1.566)
BMeeting	0.074	0.092**	0.028	0.032	0.034	0.031	0.045
	(1.461)	(1.971)	(0.624)	(0.700)	(0.756)	(0.694)	(0.993)
Top	−0.111*	−0.135**	−0.061	−0.063	−0.063	−0.046	−0.069
	(-1.833)	(-2.378)	(-1.088)	(-1.108)	(-1.098)	(-0.820)	(-1.197)
BADiv			0.020	−0.061	0.036	0.044	0.039
			(0.481)	(-1.171)	(0.865)	(1.066)	(0.919)
BEdu			0.238***	0.232***	0.214***	0.219***	0.229***
			(4.844)	(4.736)	(4.282)	(4.462)	(4.583)
BGDiv			0.111**	0.025	0.036	0.051	0.040
			(2.359)	(0.544)	(0.817)	(1.198)	(0.926)
BIndep			0.083*	0.094*	0.072	0.107**	0.082
			(1.683)	(1.949)	(1.476)	(2.238)	(1.642)
CEO_dual			0.049	0.051	0.059	0.101**	0.068
			(1.105)	(1.146)	(1.324)	(2.232)	(1.500)
BGDiv*GS			−2.744***				
			(-3.413)				
BGDiv*GS^2			2.809***				
			(3.476)				
BADiv*GS				−1.172**			
				(-2.457)			
BADiv*GS^2				1.289**			
				(2.420)			
BIndep*GS					−1.719**		
					(-2.377)		
BIndep*GS^2					1.813**		
					(2.495)		
CEO_dual*GS						−0.849	
						(-1.190)	
CEO_dual*GS^2						1.004	
						(1.406)	
BEdu*GS							−1.193**
							(-2.797)
BEdu*GS^2							1.215**
							(2.832)
Cons	−0.091	−0.021	1.834	2.749	−1.023	0.409	0.153
	(-0.03)	(-0.01)	(0.69)	(1.08)	(-0.40)	(0.17)	(0.06)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-square	0.404	0.502	0.554	0.571	0.564	0.583	0.558
N	420	420	420	420	420	420	420

Note: t statistics in parentheses (two-tailed test). $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

independent directors are prone to show social and environmental responsibility to stakeholders (Bhuiyan et al., 2021) and thus they are likelier to voting for investing CGI.

(iv) As noted, the GS policy not only catalyzed China's NEV industry but also forced NEV firms to operate under uncertain economic environment. However, according to the agency theory, CEO duality seriously deteriorates the board's monitoring and controlling functions (Jensen and Meckling, 1976), which make it easier for chair-CEO to use this policy uncertainty to transfer resources (e.g. GS) for personal gains (Sena et al., 2018) rather than invest CGI. In this case, the board agenda and information flow will be dominated, and the questioning mechanism will no longer work (McNulty and Pettigrew, 1999). Therefore, this study found there is an insignificant effect exerted by CEO duality on GS-CGI relationship.

(v) Highly educational level is closely related with directors' cognitive ability to make green investment decisions as well as impacts their attitude towards environmental issues, so well-educated

Table 4
The result of U-shape test.

GIP/GS	U-shape Test Result
Slope	Lower bound: −0.171*** Upper bound: 0.168***
Inflection point	18.994
Domain of GS	[14.189, 22.399]
Fieller estimation	[16.252, 19.019]

Note: The U-shape test is conducted based on unstandardized coefficients. ***p < 0.01, **p < 0.05, *p < 0.1.

directors are supposed to be more sensitive to environmental issues and behave extra pro-environmental behaviors. This observation is in line with some prior studies such as Ma et al. (2019) and Shahab et al. (2020).

(vi) Although the amount of received GS in left side is lesser than that of in right side, the top point of CGI is the opposite. Thus, despite the relief of external support (e.g. GS), the motivation crowding-out effect generally appears when the amount of GS exceeds a turning point (Dai and Cheng, 2015), in which GS will substitute firms' pro-environmental R&D investment and erode their motivation to innovate greenly (Dai and Cheng, 2015; Bronzini and Piselli, 2016). In this sense, excessive government support is likelier to be less effective or even ineffective to stimulate CGI performance especially in the post-subsidy era, that is, more is less. This finding is in keeping with Dai and Cheng (2015).

4.3. Robustness checks

4.3.1. Alternative variables

For verifying these obtained results, this study alters the prior proxy of dependent variable, namely, green application patents, to green granted patents. Besides, following the mainstream studies (e.g. Benkraiem et al., 2021), the proportion of female directors in the board is substituted by the number of female directors. These results can be found in Table 5.

It is clear that the curvilinear relationship between GS and CGI is still evident after alternating key variables, and despite of CEO duality other moderators, such as board gender diversity, board age diversity, board independence and board educational level, remains exhibiting significant and positive moderating effect on GS-CGI relationship.

4.3.2. Instrumental variable

Although alternating variables is effective to prove the robustness of our results, the endogenous nature of government subsidies and corporate green innovation should not be overlooked since firms with high level of green innovation may be likelier to be granted more government subsidies especially in post-subsidy era. Thus, 2SRI (two stage residual inclusion model) is considered to be utilized instead of 2SLS (two stage least square regressions) in this case, in that it is superior to 2SLS in estimating non-linear econometric model (Terza et al., 2008). The geographical distance between the registration address of firms and Beijing city is chosen as a suitable instrumental variable since it is of relevance and exogeneity. On the one hand, it is well-known that Beijing city is the political and cultural centre of China, and the distance may

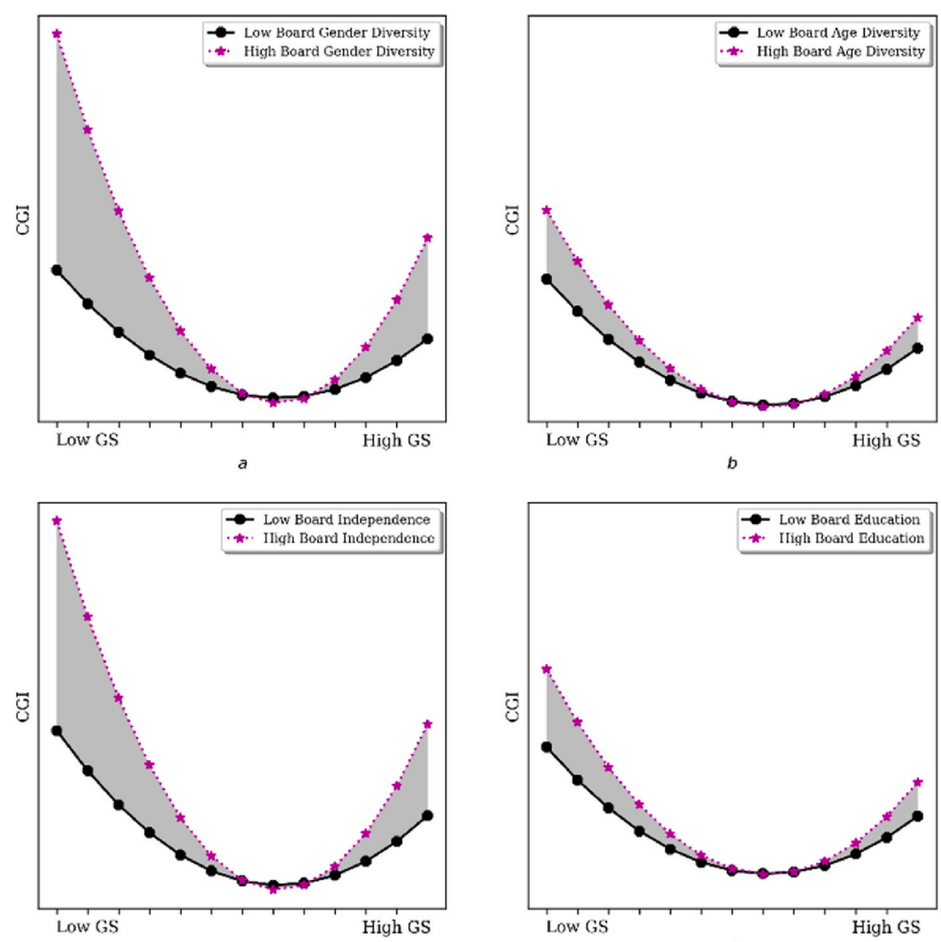

Fig. 3. (a) Moderating effect of board gender diversity; (b) moderating effect of board age diversity; (c) moderating effect of board independence; (d) moderating effect of board education.

Table 5
Robustness check by alternating variables.

	(1)	(2)	(3)	(4)	(5)	(6)
GS	−4.704***	−5.580***	−6.702***	−3.297***	−5.324***	−4.529***
	(-6.399)	(-7.950)	(-9.868)	(-4.721)	(-8.176)	(-6.363)
GS^2	4.965***	5.963***	7.146***	3.560***	5.669***	4.791***
	(6.598)	(8.307)	(10.230)	(4.982)	(8.509)	(6.619)
ROA	−0.036	−0.041	−0.028	−0.015	−0.035	−0.073
	(-0.657)	(-0.836)	(-0.591)	(-0.287)	(-0.763)	(-1.419)
Lvrg	0.045	0.020	0.031	0.064	0.048	0.011
	(0.752)	(0.383)	(0.577)	(1.166)	(0.965)	(0.191)
FirmAge	−0.130***	−0.046	−0.083*	−0.087*	−0.108**	−0.065
	(-2.634)	(-1.013)	(-1.819)	(-1.816)	(-2.493)	(-1.338)
TotAsset	0.058	0.033	0.128	−0.049	−0.113	−0.051
	(0.427)	(0.260)	(1.052)	(-0.373)	(-0.944)	(-0.382)
Rev	0.296**	0.309**	0.171	0.289**	0.402***	0.449***
	(2.086)	(2.337)	(1.364)	(2.093)	(3.247)	(3.234)
SOE	−0.062	−0.064	−0.073*	0.017	0.033	−0.076*
	(-1.309)	(-1.512)	(-1.831)	(0.384)	(0.804)	(-1.690)
IO	−0.073	−0.033	−0.066	−0.084	−0.057	−0.042
	(-1.136)	(-0.573)	(-1.185)	(-1.381)	(-1.032)	(-0.687)
R&D	0.137***	0.046	−0.005	0.071	0.019	0.082
	(2.745)	(0.957)	(-0.119)	(1.438)	(0.419)	(1.603)
BSize	−0.092**	0.028	0.046	0.012	0.083*	−0.065
	(-2.005)	(0.582)	(0.972)	(0.246)	(1.805)	(-1.181)
BMeeting	0.104**	0.010	0.026	0.030	0.026	0.051
	(2.079)	(0.224)	(0.585)	(0.637)	(0.620)	(1.073)
Top	−0.104*	−0.016	−0.000	−0.004	0.025	−0.021
	(-1.695)	(-0.289)	(-0.006)	(-0.069)	(0.461)	(-0.355)
BADiv		0.120***	−0.160***	0.141***	0.138***	0.146***
		(2.831)	(-3.235)	(3.277)	(3.510)	(3.322)
BEdu		0.161***	0.163***	0.101*	0.122***	0.137***
		(3.282)	(3.469)	(1.953)	(2.615)	(2.638)
BGDiv		0.150***	−0.058	0.006	0.005	−0.007
		(3.177)	(-1.337)	(0.141)	(0.134)	(-0.149)
BIndep		0.148***	0.108**	0.111**	0.133***	0.092*
		(3.018)	(2.350)	(2.204)	(2.936)	(1.775)
CEO_dual		0.078*	0.064	0.110**	0.212***	0.107**
		(1.733)	(1.502)	(2.393)	(4.952)	(2.272)
BGDiv*GS		−4.680***				
		(-5.809)				
BGDiv*GS^2		4.919***				
		(6.079)				
BADiv*GS			−4.830***			
			(-7.567)			
BADiv*GS^2			5.121***			
			(7.968)			
BIndep*GS				−1.737**		
				(-2.333)		
BIndep*GS^2				1.990***		
				(2.660)		
CEO_dual*GS					−4.466	
					(-1.601)	
CEO_dual*GS^2					4.774	
					(1.049)	
BEdu*GS						−2.317***
						(-3.361)
BEdu*GS^2						2.471***
						(3.587)
Cons	−0.009	1.508**	1.606***	−0.564	0.313	0.092
	(-0.012)	(2.194)	(2.562)	(-0.821)	(0.515)	(0.133)
R-square	0.374	0.504	0.578	0.486	0.567	0.459
N	420	420	420	420	420	420

Note: t statistics in parentheses (two-tailed test). $^*p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

affect the policymakers' decision to subsidy firms. On the other hand, the distance is generally exogenous owing to objective condition. Then, with reference to Chen et al. (2018a), a DWH (Durbin-Wu-Hausman) test is conducted to ensure the validity of instrumental variable (Durbin chi-squared = 0.496, p = 0.780; Wu-Hausman F = 0.239, p = 0.787). As shown in Table 6, the results are highly stable and remain consistent with those in Table 3.

5. Conclusion, policy implications and limitations

5.1. Conclusion

Unlike most of studies that concentrate on the linear effect of public subsidy on innovation, this study sheds light on how corporate green innovation is affected in pace with the growth of government subsidies in China's NEV industry. Although GS-CGI relationship is intuitively positive (i.e. subsidy encourages green innovation), this study argues that different concurrent and opposite forces may overturn this

Table 6
Robustness check by using 2SRI.

	(1)	(2)	(3)	(4)	(5)	(6)
GS	−5.256***	−5.463***	−5.476***	−4.145***	−4.805***	−4.920***
	(-7.690)	(-7.801)	(-7.746)	(-6.120)	(-7.027)	(-7.200)
GS^2	5.541***	5.805***	5.831***	4.429***	5.124***	5.203***
	(7.921)	(8.104)	(8.020)	(6.390)	(7.325)	(7.487)
ROA	0.068	0.017	−0.003	0.026	−0.008	−0.001
	(1.244)	(0.306)	(-0.058)	(0.487)	(-0.152)	(-0.024)
Lvrg	0.031	−0.251	−0.388	−0.217	−0.395	−0.300
	(0.118)	(-0.937)	(-1.461)	(-0.828)	(-1.523)	(-1.128)
FirmAge	−0.120	−0.115	−0.167*	−0.133	−0.187**	−0.143
	(-1.335)	(-1.295)	(-1.882)	(-1.508)	(-2.123)	(-1.599)
TotAsset	0.444	1.523	1.998**	1.414	2.025**	1.690*
	(0.452)	(1.556)	(2.069)	(1.472)	(2.121)	(1.737)
Rev	0.367	1.166	1.459**	1.119	1.576**	1.344*
	(0.518)	(1.629)	(2.059)	(1.588)	(2.250)	(1.876)
SOE	−0.094	−0.235**	−0.282**	−0.189*	−0.249**	−0.255**
	(-0.817)	(-2.041)	(-2.483)	(-1.663)	(-2.227)	(-2.205)
IO	−0.027	−0.034	−0.050	−0.041	−0.038	−0.042
	(-0.402)	(-0.522)	(-0.777)	(-0.624)	(-0.596)	(-0.637)
R&D	0.219	0.661	0.869*	0.644	0.911*	0.774
	(0.452)	(1.370)	(1.823)	(1.357)	(1.934)	(1.608)
BSize	−0.118*	0.029	0.070	0.016	0.079	0.006
	(-1.807)	(0.385)	(0.912)	(0.217)	(1.061)	(0.077)
BMeeting	0.077	−0.043	−0.062	−0.032	−0.066	−0.034
	(1.151)	(-0.630)	(-0.928)	(-0.483)	(-1.006)	(-0.506)
Top	−0.222	−0.467	−0.601**	−0.449	−0.609**	−0.529*
	(-0.762)	(-1.606)	(-2.092)	(-1.573)	(-2.145)	(-1.827)
BADiv		0.020	−0.073	0.034	0.042	0.036
		(0.480)	(-1.407)	(0.825)	(1.014)	(0.865)
BEdu		0.238***	0.230***	0.214***	0.218***	0.228***
		(4.857)	(4.700)	(4.276)	(4.459)	(4.582)
BGDiv		0.116**	0.026	0.040	0.057	0.044
		(2.464)	(0.578)	(0.917)	(1.340)	(1.021)
BIndep		0.101**	0.113**	0.086*	0.128***	0.095*
		(1.991)	(2.308)	(1.731)	(2.623)	(1.886)
CEO_dual		0.062	0.068	0.072	0.120***	0.082*
		(1.362)	(1.488)	(1.576)	(2.617)	(1.780)
BGDiv*GS		−2.634***				
		(-3.265)				
BGDiv*GS^2		2.711***				
		(3.349)				
BADiv*GS			−1.207*			
			(-1.817)			
BADiv*GS^2			1.334**			
			(1.993)			
BIndep*GS				−1.649**		
				(-2.278)		
BIndep*GS^2				1.746**		
				(2.401)		
CEO_dual*GS					−0.841	
					(-1.184)	
CEO_dual*GS^2					1.008	
					(1.417)	
BEdu*GS						−1.270*
						(-1.914)
BEdu*GS^2						1.300*
						(1.960)
Xuhat	−0.436	−2.049	−2.715*	−1.953	−2.844**	−2.325
	(-0.303)	(-1.423)	(-1.911)	(-1.381)	(-2.023)	(-1.622)
Cons	−0.011	1.604	2.510	−1.225	0.045	−0.131
	(-0.000)	(0.612)	(0.981)	(-0.483)	(0.024)	(-0.052)
R-square	0.501	0.555	0.572	0.564	0.584	0.559
N	420	420	420	420	420	420

Note: t statistics in parentheses (two-tailed test). $*p < 0.10$, $**p < 0.05$, $***p < 0.01$.

intuition, such as the double externality and certification effect. The corresponding shows that GS exhibits a U-shaped curvilinear relationship to CGI. In other words, GS fails to prompt CGI when GS is insufficient, while it shows that CGI can be enhanced once GS attains an inflection point.

Besides, since board governance generally plays an advising and monitoring role in affecting China's NEVs firms' decision to improve CGI through GS. This study further examines the moderating role of board governance in GS-CGI relationship, and the findings demonstrate that board governance weaken the negative impact of GS on CGI before inflection point as well as inhibit the positive role of GS in contributing to CGI after inflection point, including board gender diversity, board age diversity, board independence and board educational level. To address endogenous issues and ensure the robustness of results, key variables alternation and 2SRI model are conducted.

5.2. Policy implications

In 2020, the China's central government distributed its *NEV Industry Development Plan (2021–2035)* which has proposed its national strategic measures for the further promotion of the industry during this period. The plan has highlighted the advancements of green innovation from a technical perspective as one of the key drivers that encourage the development of the industry, but it fails to consider the managerial problems, for instance, from an angle of corporate governance. Currently, the incumbent Chinese policy has not yet incorporated board governance issues, though prior research has already pointed out that in order for firm efficiency to be enhanced there is a need for governance mechanisms in China and the government should enact policies to encourage board diversity (Ali et al., 2021). Our study more specifically demonstrates that legislations for board diversity in the NEV industry is urgent due to its effect on green innovation performance.

Our results highlight that gender diversity can enhance the CGI performance in China's NEV firms, indicating female members can promote CGI in the industry. This also points out that the UN's sustainable development goals of gender equality and environmental protection can go hand in hand. Recent years have witnessed the louder voices of Chinese women both online through social media platforms and offline in the workplace and industries. Although we target at the imbalance of female directors, it must be pointed out that this inequality on the board is generally an epitome of the reality of whole industry. To resolve this problem, this study suggests policymakers should incorporate such indicators as the proportion of female directors into investment assessment standards (e.g. corporate governance, environmental, social and governance, and sustainable investment), in order to promote gender equality and women's empowerment in the industry. As our findings imply, with an aim of the realization of the net-zero carbon goal in China, female leadership can be of great significance for a sustainable and greenly innovative future.

In addition, this research finds age diversity can improve CGI in China's NEV firms. Compared to gender diversity, age diversity issues have not yet been questioned as widely and frequently by the Chinese public within recent years, perhaps because Chinese people are historically and naturally convinced that older and more experienced ones *should* take the leading and managing roles. Our results demonstrate that in China board with younger members can boost the performance of CGI; this could be due to the facts that (i) younger people are more sensible to innovative strategies; and (ii) they could be more aware of environmental issues rather than economic profits merely. This study thus suggests age diversity criteria should also be integrated into investment standards. In 2020, Nasdaq submitted a proposal to the U.S. Securities and Exchange Commission to call for the adoption of new listing rules regarding board diversity and information disclosure, requiring most Nasdaq-listed companies to have at least two different directors. Thus, China could consider similar movements to boost board age and gender diversity, in the NEV industry for both environmental benefits and societal (intergenerational and gender) equality and equity.

Our research also implies that board education can promote green innovation performance, which support the results of He et al. (2021) that demonstrate the academic background of senior management plays a key role in CGI in China. This implies the need for NEV firms to enhance their governance systems and support those with higher-level education to serve as board members. Besides, this research provides another reason for practicing board independence in China, in addition to the reasons including improving firm performance (Li et al., 2015; Liu et al., 2015), and improving the quality of board monitoring by reducing the occurrence of connected transactions and violations (Wu and Li, 2015). Also, different from the finding of Chen et al. (2018b) with a sample of China's top 100 listed companies, showing that board independence does not affect CGI, our research identifies that board independence can significantly affect CGI in the China's NEV industry, indicating that encouraging board independence in the specific industry is needed.

5.3. Limitations

This study has two main limitations that would be addressed in future research. First, green innovation input is not analyzed because of the difficulty of differentiating it from traditional innovation input in China. To resolve this requires more engagement in relevant data collection and transparency. Second, although this study included the majority shareholder of the board shareholding as a key control variable, it is worthwhile exploring its main effect for future studies.

Author contributions

Li Xia: Conceptualization, Methodology, Data curation, Writing – original draft, Visualization. Shuo Gao: Conceptualization, Formal Analysis, Writing – original draft. Jiuchang Wei: Funding acquisition, Methodology, Supervision, Writing – review & editing. Qiying Ding: Funding acquisition, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. The timeline of government subsidy policy in China's NEV industry

Phase	Policy Event	Year	Reference	Policy Influence
Subsidy pilot phase	The Ministry of Finance of China issued the notice on *carrying out the pilot work of demonstration and promotion of energy-saving and NEV*.	2009	http://www.gov.cn/zwgk/2009-02/05/content_1222338.htm (in Chinese)	Subsidies will be given to pilot cities for the purchase of NEV in the field of public services.
	⋮	⋮	⋮	⋮
	The State Council of China issued the notice on *the development plan of energy saving and NEV industry (2012–2020)*.	2012	http://www.gov.cn/gongbao/content/2012/content_2182749.htm (in Chinese)	The cultivation and development of NEV industry during the planning period (2012–2020) will be further accelerated.
Subsidy promoting phase	The Ministry of Finance of China, the Ministry of Science and Technology of China, the Ministry of Industry and Information Technology of China and the National Development and Reform Commission jointly issued the notice on *continuing the promotion and application of NEV*.	2013	http://www.gov.cn/zwgk/2013-09/17/content_2490108.htm (in Chinese)	The scope of subsidies will be extended from the pilot to the whole country, as well as from the public services to the privately commercial vehicles.

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(*continued*)

Phase	Policy Event	Year	Reference	Policy Influence
	⋮	⋮	⋮	⋮
Post-subsidy phase	The Ministry of Finance of China, the Ministry of Science and Technology of China, the Ministry of Industry and Information Technology of China and the National Development and Reform Commission issued the notice on *the 2016–2020 financial support policy for the promotion and application of NEV*.	2016	http://www.gov.cn/xinwen/2015-04/29/content_2855040.htm (in Chinese)	The subsidy standard will be mainly based on the effect of energy conservation and emission reduction. Meanwhile, the subsidy is phasing out.
	⋮	⋮	⋮	⋮
	The Ministry of Finance of China, the Ministry of Science and Technology of China, the Ministry of Industry and Information Technology of China and the National Development and Reform Commission issued the notice on *further improving the financial subsidy policy for the promotion and application of NEV*.	2019	http://www.gov.cn/xinwen/2019-03/27/content_5377123.htm (in Chinese)	The amount of subsidy for new energy passenger vehicles, new energy buses, and new energy trucks will be reduced by up to 60%.
	The Ministry of Finance of China, the Ministry of Science and Technology of China, the Ministry of Industry and Information Technology of China and the National Development and Reform Commission issued the notice on *improving the financial subsidy policy for the promotion and application of NEV*.	2020	http://www.gov.cn/zhengce/2020-12/31/content_5575908.htm (in Chinese)	Influenced by multiple factors such as the epidemic, the period for subsiding NEV will be extended to the end of 2022.

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Corrigendum

Corrigendum to "Government subsidy and corporate green innovation - Does board governance play a role?" [Energy Pol. 161 (February 2022) 112720]

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The authors regret that there is an error in the 'Abstract' of this published article. The text currently reads "It also reveals that some facets of board governance (BG) significantly enhanced this U-shaped relationship, including board gender diversity, board age diversity, CEO duality and board educational level." Instead, the correct statement should be "It also reveals that some facets of board governance (BG) significantly enhanced this U-shaped relationship, including board gender diversity, board age diversity, board independence and board educational level." The authors would like to apologize for any conveniences caused.

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