Spanish Journal of Finance and Accounting / Revista Española de Financiación y Contabilidad

ISSN: 0210-2412 (Print) 2332-0753 (Online) Journal homepage: www.tandfonline.com/journals/refc20

The asymmetry of cost behaviour and green innovation: the moderating effect of government subsidies

Radwan Alkebsee, Ahsan Habib, Adeeb Alhebri, Tingting Wu & Shuai Wu

To cite this article: Radwan Alkebsee, Ahsan Habib, Adeeb Alhebri, Tingting Wu & Shuai Wu (03 Feb 2026): The asymmetry of cost behaviour and green innovation: the moderating effect of government subsidies, Spanish Journal of Finance and Accounting / Revista Española de Financiación y Contabilidad, DOI: 10.1080/02102412.2026.2613519

To link to this article: https://doi.org/10.1080/02102412.2026.2613519

SPANISH JOURNAL OF FINANCE AND ACCOUNTING / REVISTA ESPAÑOLA DE FINANCIACIÓN Y CONTABILIDAD
https://doi.org/10.1080/02102412.2026.2613519

Check for updates

The asymmetry of cost behaviour and green innovation: the moderating effect of government subsidies

Radwan Alkebsee[a], Ahsan Habib[b], Adeeb Alhebri[c], Tingting Wu[d] and Shuai Wu[d]

[a]Faculty of Business Administration, University of Tabuk, Tabuk, Saudi Arabia; [b]School of Accountancy, Economics and Finance, Massey University Auckland, New Zealand; [c]Accounting Program, Applied College at Muhayil, King Khalid University, Muhayil Assir, Kingdom of Saudi Arabia; [d]Business School, Xi'an International Studies University, China

ABSTRACT

This study examines the relationship between cost stickiness and green innovation. Using data from Chinese public firms spanning the period from 2009–2020, we find that cost stickiness negatively affects green innovation, indicating that firms with sticky costs are associated with fewer green innovation activities. Also, it explores the moderating impact of government subsidies on the relationship between cost stickiness and green innovation. The results highlight the crucial role of government subsidies in mitigating this negative impact. Specifically, firms that receive R&D and green subsidies can better cope with the adverse effects of increased cost stickiness for green innovation than firms that do not receive such subsidies. The results remain consistent after addressing potential endogeneity concerns. This study contributes to the understanding of how cost behaviour and government interventions influence green innovation, offering practical implications for corporate management, policymakers, and sustainability practices.

ARTICLE HISTORY
Received 28 December 2024
Accepted 5 January 2026

KEYWORDS
Green innovation; cost stickiness; cost asymmetry; government subsidies; China

JEL CLASSIFICATION
M41; Q56; Q55

1. Introduction

Our planet is facing a huge risk that includes, but is not limited to scorching climate to severe pollution and a collapsing ecosystem. This means we are all at risk of environmental issues. Green innovation has become no longer a luxury, it has become a compulsory tool to bridge the gap between economic growth and an eco-friendly environment. The term 'green innovation' refers to a process or product that combines conventional and ecological technical innovation to decrease environmental pollution and generate additional financial benefits (Xie et al., 2019). The literature has documented many determinants of green innovations such as firm characteristics, including firm size (Lin et al., 2019), corporate governance and firm growth (Amore & Bennedsen, 2016), stakeholders' characteristics (Peng & Lin, 2008), R&D investment (Zhang & Jin, 2021), CEO and top management team characteristics (He &

CONTACT Radwan Alkebsee Ralkebsee@ut.edu.sa Faculty of Business Administration, University of Tabuk, Tabuk, Saudi Arabia

Paper accepted by Jacobo Gomez-Conde

Jiang, 2019; Quan et al., 2021), the quality of the internal control environment (Chan et al., 2021; Li et al., 2019), financial constraints and economic policy uncertainty (Canepa & Stoneman, 2008; García-Quevedo et al., 2018). Surprisingly, the literature has overlooked the relationship between asymmetric cost behaviour or cost stickiness and green innovation. Accordingly, this study aims to fill this gap in the literature by investigating the impact of asymmetric cost behaviour on green innovation.

Cost stickiness refers to the tendency for costs to remain high even when the activity level declines (Anderson et al., 2003). Cost stickiness could hamper green innovation, given that cost stickiness stems from managerial decisions concerning resource adjustments. Particularly, in the context of our study, the adjustment costs associated with research and development (R&D) expenses are high due to the recruitment of highly skilled personnel (Zhang & Jin, 2021). Anderson et al. (2003) and Banker et al. (2013) contend the important role of labour adjustment costs in shaping the asymmetry of cost behaviour. Hence, managers may choose to retain surplus resources during economic downturns instead of adjusting their cost structures, driven by optimism about future business activity. However, this practice can restrict the availability of financial resources and human capital essential for supporting green innovation initiatives. Engaging in green innovation demands substantial financial resources including skilled labour, fixed assets, and R&D expenditures (Habib & Hasan, 2019; Hojnik & Ruzzier, 2016; Zhang & Jin, 2021), which complicates the decision-making process regarding green innovation in the presence of cost stickiness. Cost stickiness can hinder green innovation for several other reasons. First, cost stickiness increases financing costs, as creditors demand higher interest rates from sticky-cost firms, limiting resources available for green innovation (Homburg et al., 2019; Kim & Zhou, 2023). Second, firms with sticky costs often delay resource adjustments due to high adjustment costs, exacerbating financial constraints forcing managers to prioritise the firm's regular operations over green investments (Chen & Ma, 2021). Third, cost stickiness increases firm risk by raising the likelihood of losses and investment uncertainty, leading managers to adopt conservative approaches and reduce R&D spending (Ko et al., 2021; Tang, 2019). Thus, firms with higher cost stickiness are less likely to invest in green innovation. Consequently, we predict that firms with stickier costs are less likely to invest in green innovations.

As cost stickiness primarily leads to resource misallocation and financial constraints, it also increases firm risks, which influence managerial decisions on green innovation investment. External factors such as government support, particularly subsidies, may play a critical role in moderating firms' perspectives and ability to invest in green innovation. Government subsidies are a key mechanism for promoting green innovation in the capital market, as they alleviate financial constraints and reduce the risks associated with long-term investments (Almus & Czarnitzki, 2003; González & Pazó, 2008). In this study, we address the question of whether government subsidies play a beneficial role in mitigating the adverse effects of cost stickiness on green innovation. We expect that firms receiving government subsidies are better equipped to overcome the challenges posed by cost stickiness, thereby enabling greater investment in green innovation activities. Government subsidies are likely to strengthen the financial capacity of firms (Duan et al., 2024; Lyu et al., 2024; Zhao et al., 2024), allowing for more efficient resource allocation and reducing the risks associated with green innovation investments, which in turn decreases managerial risk aversion. Therefore, examining the moderating effect of government subsidies on the relationship between cost stickiness and green innovation is crucial for understanding how policy interventions can influence firms' operational behaviours and innovation strategies.

Using a sample of data from 2688 firms from China spanning the period from 2009 to 2020, we document a negative relationship between cost stickiness and green innovation. Economically, our estimations show that a one-standard-deviation increase in operating cost stickiness decreases green patents and green process innovation by 3.5% and 3%, respectively. We further find that government subsidies weaken the negative impact of cost stickiness on green innovation. Our main results remain consistent and robust after performing several endogeneity tests.

This study contributes to the literature as follows. First, this study extends the extant literature on green innovation (e.g. Amore & Bennedsen, 2016; Bai et al., 2019; Chan et al., 2021, Cuerva et al., 2014; Duan et al., 2024; He & Jiang, 2019; Hussain et al., 2024; Lin et al., 2019; Peng & Lin, 2008; Quan et al., 2021; Zhang & Jin, 2021) by adding a new determinant of green innovation; namely cost stickiness, as this study provides empirical evidence that stickier cost firms are less likely to engage in greener activities (products and processes). To our knowledge, this study is the first that uses cost stickiness as a contextual factor deterring green innovation. In addition, it augments the literature on cost stickiness (e.g. Agarwal, 2022; Caylor & Lopez, 2013; Ciftci et al., 2016; Costa & Habib, 2023; Hartlieb & Loy, 2022; He et al., 2020; Homburg et al., 2019; Tang et al., 2022; Weiss, 2010) by providing empirical evidence on the consequences of the cost stickiness on the environmental strategy of a firm. Habib and Hasan (2019) examine the impact of CSR activities on cost stickiness and find that CSR-related costs exhibit cost stickiness. However, they do not consider the impact of cost behaviour asymmetry on green innovation. Second, this study contributes to the government subsidies literature by demonstrating that government subsidies not only promote green innovation (e.g. Lyu et al., 2024; Zhao et al., 2024; An et al., 2025), but also eliminate the operational rigidity caused by cost stickiness, giving firms the ability to allocate resources more strategically towards green initiatives. By introducing cost stickiness as a constraint, our results reveal a new channel through which government subsidies enhance environmental innovation outcomes, offering novel evidence on the effectiveness of government intervention. This bears important implications for policymakers aiming to foster green transition, especially in firms facing rigid cost structures that hinder flexible resource allocation. Finally, this study bridges the gap between management accounting and environmental research by linking cost stickiness, a core concept in management accounting, to firms' green innovation strategies. By demonstrating how the behaviour of cost affects sustainability-oriented decision making, the study offers novel insights into the role of managerial frictions in shaping environmental outcomes.

The rest of the paper is organised as follows. In Section 2, we review the relevant literature and develop the hypotheses. In Section 3, we explain the research design issues. The empirical findings are reported in Section 4. Section 5 concludes the paper.

2. Literature and hypothesis development

2.1. Cost stickiness

Contrary to traditional cost accounting, which assumes that 'fixed and variable' costs behave linearly in response to sales volume changes, cost stickiness establishes a new understanding of cost behaviour (Cooper & Kaplan, 1992; Noreen, 1991). This new concept recognises that the underlying cost drivers stem from resource adjustment decisions made by managers in response to changes in the activity level (Banker et al., 2018). For instance, during economic downturns managers may think of dismissing employees but they need to be somewhat certain that this economic pessimism will persist because firing and then rehiring employees will be associated with substantial resource adjustment costs. Initial empirical evidence supporting the existence of cost stickiness was provided by Anderson et al. (2003), who document that selling, general and administrative (SGA) costs rise more when sales increase but decrease less when sales decrease. A subsequent literature extends and enriches the study of Anderson et al. (2003) by documenting cost stickiness for different cost categories (Balakrishnan & Gruca, 2008; Calleja et al., 2006; Cannon, 2014; Dierynck et al., 2012; Holzhacker et al., 2015).

An extensive body of literature has examined the determinants of cost stickiness (for a comprehensive review see Ibrahim et al. (2022) and Naoum et al. (2023). For instance, the quality of the audit (Liang et al., 2014), regulation changes (Holzhacker et al., 2015), corporate governance (Xue & Hong, 2016), state ownership (Prabowo et al., 2018), corporate social responsibility (Habib & Hasan, 2019), R&D strategy (Ko et al., 2021), political and economic policy uncertainty (Lee et al., 2020; Pan et al., 2022), tax avoidance (Xu & Zheng, 2020), and COVID-19 pandemic (Zhang & Li, 2025) are shown to affect cost stickiness. With respect to the consequences of cost stickiness, research has shown that cost stickiness has implications for earnings forecasts and equity valuation (Banker & Chen, 2006; Banker et al., 2013; Bu et al., 2015; Ciftci et al., 2016; Weiss, 2010), dividend policy (He et al., 2020), market reaction (Agarwal, 2022; Tang et al., 2022), firm value (Costa & Habib, 2023), executives compensation (Caylor & Lopez, 2013), financial reporting quality (Hartlieb & Loy, 2022), and the credit risk (Homburg et al., 2019).

The existing evidence shows that cost stickiness is a function of managerial resource adjustment decisions. Recent evidence shows that CSR investment triggers cost stickiness (Habib & Hasan, 2019). However, there is no evidence on the impact of cost stickiness on green innovation or environmental performance. Given the importance of cost stickiness in the financial performance of a firm, we believe that considering the impact of cost stickiness on green innovation is important and has a significant influence on managerial decisions regarding strategic investments.

2.2. Green innovation

Green innovation refers to technological advancements that promote resource efficiency and environmentally friendly production processes, helping firms achieve both economic and environmental goals (Wong, 2013). The advantages of green innovation are well-documented. For instance, it enhances the firm's reputation (Amores-Salvadó et al., 2014), competitive advantages (Chang, 2011), brand equity (Yao et al., 2021), and firm performance (Xie et al., 2019). Moreover, green innovation has been found to reduce idiosyncratic risk and lower the cost of equity in automotive firms (Lin et al., 2020). By attracting ethical investors, it also diversifies a firm's investor base (El Ghoul et al., 2011). Evidence from Chinese firms suggests that green innovation helps alleviate financial constraints (Zhang et al., 2020) and hence reduces the cost of equity (Alkebsee et al., 2023).

There exists an increased acknowledgement regarding the importance of green innovation for sustainable development. Scholars have increasingly explored the factors influencing green innovation. Scholars highlight that firm-specific attributes, such as size (Embong et al., 2012), growth (Amore & Bennedsen, 2016), and stakeholder characteristics (Peng & Lin, 2008), play a significant role in fostering green innovation. Additionally, the characteristics of CEOs and top management teams (He & Jiang, 2019; Quan et al., 2021) and the quality of internal control systems (Chan et al., 2021; Li et al., 2019) are also found to be critical determinants of green innovation. External factors like financial constraints and economic policy uncertainty (EPU) are linked to green innovation (Cui et al., 2023; García-Quevedo et al., 2018; Shen et al., 2021). Yet, no research yet examines the effect of cost stickiness on green innovation. Below we explain how cost stickiness affects green innovation activities.

2.3. Hypothesis development

2.3.1. Cost stickiness and green innovation

According to Anderson et al. (2003), cost stickiness refers to the asymmetric behaviour of costs in response to changes in activity levels. This phenomenon is attributed to managerial decisions to retain committed resources, such as skilled labour and fixed assets, during periods of declining demand, driven by adjustment costs and opportunistic behaviours (Anderson et al., 2003; Banker et al., 2013; Lee et al., 2020). This cost behaviour has a very important impact on firm strategic decisions such as green innovation. Green innovation typically requires significant investment in R&D, specialised human capital, and sustainable production technologies (Hojnik & Ruzzier, 2016; Zhang & Jin, 2021). When costs are sticky, firms have less flexibility to reallocate resources towards such discretionary and long-term innovation activities. Thus, firms with higher cost stickiness may find it more challenging to finance and execute green innovation projects.

However, the relationship between cost stickiness and green innovation may not be strictly unidirectional. On one hand, firms operating in China are expected to align with the national green agenda and the rising societal expectations on environmental responsibility. As a result, managers proactively invest in green initiatives such as environmental R&D and clean production processes. Such increases in costs are conventionally associated with corresponding increases in activity levels (Noreen, 1991). However, when managers encounter a decline in sales volume, they may face adjustment costs that prevent them from reducing green-innovation-related expenditures, which are difficult to retract once undertaken (Banker et al., 2013). The extant literature suggests that green investment itself can drive firms' cost structures in ways that increase cost stickiness. Habib and Hasan (2019) emphasise that CSR investments often involve long-term resource commitments, such as hiring well-qualified personnel, establishing R&D facilities, and acquiring environmentally friendly fixed assets. These investments increase fixed and semi-fixed costs, ultimately making it challenging to scale down these costs during downturns. Consequently, firms that engage more heavily in green innovation may end up with a more rigid cost structure, thereby exhibiting higher cost stickiness over time.

On the other hand, we argue that cost stickiness influences green innovation through several mechanisms as follows. First, cost stickiness leads to resource misallocation, as firms retain slack resources during economic downturns rather than adjusting their cost structures efficiently. This inefficiency limits the availability of financial and human capital that could otherwise be redirected towards green innovation initiatives. Given that green innovation depends on the continuous reallocation of resources to fund R&D activities and implement sustainable technologies (Sánchez-Sellero & Bataineh, 2022), the rigidity introduced by cost stickiness can be particularly detrimental to a firm's innovative capability. Consequently, firms encountering high-cost stickiness are likely to struggle to commit adequate resources to environmental initiatives, eventually decreasing green innovation. Second, cost stickiness intensifies financial constraints by heightening a firm's perceived risk and restricting its financial flexibility (Ahemed et al., 2025). For instance, Xiao (2023) documents a negative relationship between cost stickiness and cumulative abnormal returns in the season equity offerings, suggesting that investors view cost-sticky firms as riskier and therefore demand higher returns. Firms with sticky costs often encounter elevated borrowing costs and reduced access to external financing, as lenders perceive them as riskier and demand higher interest rates to offset the potential risk of financial distress (Kim & Zhou, 2023). As a result, these financial limitations hinder such firms' ability to obtain the substantial upfront capital necessary for green innovation, restricting their capacity to invest in sustainable technologies and R&D initiatives. Third, cost stickiness increases managerial risk aversion by increasing the potential for financial losses and exacerbating information asymmetry (Ntounis & Vlismas, 2025). Due to the increased financial risk and uncertainty associated with sticky costs, managers would be more cautious about committing resources to uncertain investments such as green innovation (Su et al., 2019; Tang, 2019). In firms characterised by sticky costs, managers tend to prioritise short-term financial stability over strategic and long-term sustainability objectives (Homburg et al., 2019). This reluctance to allocate resources towards green initiatives is primarily driven by concerns over uncertain returns and long investment horizons. Accordingly, this conservative decision-making approach further impedes firms' efforts to engage in green innovation, limiting their ability to develop and adopt sustainable technologies. Drawing on these arguments, although investing in green innovation may trigger cost stickiness, we contend that the predominant mechanism in our context is that cost stickiness constrains firms' ability to undertake green innovation. Accordingly, we develop the following hypothesis.

H1: ***Cost stickiness is negatively associated with green innovation.***

2.3.2. The moderating effect of government subsidies

Green innovation does not occur in isolation; rather, government support is essential for promoting its development (Wang et al., 2022). Government subsidies play a crucial role in fostering innovation in the capital market. Due to the uncertainty, externalities, and technological spillover risks associated with green innovation, firms often lack the motivation to innovate without government support (Duan et al., 2024; Karakaya & Sriwannawit, 2015). Financial constraints and resource limitations often hinder firms' ability to engage in green innovation, and government subsidies, especially those related to R&D, can help alleviate these limitations. By mitigating the risks associated with green innovation investments and bridging the funding gap, government subsidies stimulate firms' innovation enthusiasm (Hewitt-Dundas & Roper, 2010). Cost stickiness, as discussed above, poses a challenge to green innovation. Given that green innovation often requires substantial and sustained investment, firms facing cost stickiness may hesitate to allocate resources towards such initiatives. Government subsidies can serve as a mitigating factor by easing financial constraints and encouraging firms to invest in green technologies (Shao & Wang, 2023; Shao et al., 2021).

According to Keynesian economic theory, government intervention is necessary to address market failures, particularly in the innovation process. Relying solely on market mechanisms is not sufficient to prompt green innovation, highlighting the importance of government subsidies and policies as supportive mechanisms. Empirical research has shown that government subsidies play a vital role in promoting corporate green innovation by providing direct financial support, increasing R&D investment (Hall, 2002), alleviating financing constraints (Takalo & Tanayama, 2010), reducing R&D costs, and enhancing firms' risk-bearing capacity (Almus & Czarnitzki, 2003; González & Pazó, 2008). Recent evidence shows that government subsidies are positively related to green innovation (Duan et al., 2024; Lyu et al., 2024, Z. Wang et al., 2022; Zhao et al., 2024).

Building on this, we argue that government subsidies can weaken the negative impact of cost stickiness on green innovation for several reasons. First, subsidies help bridge the financial constraint caused by cost stickiness, reducing the risks associated with green innovation investments. Further, managers in firms that received government subsidies are likely to be less risk-averse, thereby they are likely to engage in green innovation initiatives. Second, targeted subsidies for green innovation and R&D send a positive signal to investors, improving firms' access to financial resources and alleviating financing pressures. Additionally, firms that receive government subsidies for innovation or R&D are often required to engage in green innovation activities to comply with subsidy objectives (Li et al., 2023). Taken together, government subsidies provide firms with greater flexibility in resource allocation decisions, particularly regarding R&D expenditures. For instance, subsidies can help firms offset the adjustment costs associated with retaining highly skilled personnel, ensuring the continuity of green innovation efforts. Moreover, firms receiving government support are better positioned to overcome the financial rigidity imposed by cost stickiness, enabling them to make the substantial investments necessary for advancing green innovation. Accordingly, we develop the following hypothesis.

H2: ***Government subsidies weaken the negative impact of cost stickiness on green innovation.***

3. Research design

3.1. Sample and data

Our sample is composed of all Chinese-listed firms on the Shenzhen and Shanghai stock exchanges over the period 2009 to 2020. We first exclude observations with missing data on green innovation, which leaves us with an initial sample of 18,569 observations. We then exclude firms with missing data on cost stickiness (2,587 observations), financial firms (442 observations), and control variables (3,298 observations). We end up with a final sample of 12,242 firm-year observations. We obtained data on green innovation from the National Intellectual Property Administration (NIPA) of China, while we retrieved the rest of the data from the China Stock Market and Accounting Research (CSMAR) database. We winsorise all non-dummy variables at the top and bottom 1% of their respective distributions to avoid the impact of outliers. Table 1 presents the distribution of our sample firms. In panel A, we find that the years 2017, 2019, and 2020 represent the majority of our sample firms, followed by 2016 and 2018. Panel B shows that the majority of our sample firms belong to the Manufacturing industry (63.22%), followed by Information technology (7.77%) and Wholesale and retail (5.35%) industries.

Table 1. Sample distribution.

	Freq.	Percent	Cum.
Panel A: sample distribution based on Year			
2009	798	6.5%	6.5%
2010	807	6.6%	13.1%
2011	821	6.7%	19.8%
2012	853	7.0%	26.8%
2013	896	7.3%	34.1%
2014	926	7.6%	41.7%
2015	1,166	9.5%	51.2%
2016	1,183	9.7%	60.9%
2017	1,201	9.8%	70.7%
2018	1,191	9.7%	80.4%
2019	1,196	9.8%	90.2%
2020	1,204	9.8%	100.0%
Panel B: sample distribution based on industry			
Industry			
A: Agriculture and fishery	176	1.44	1.44
B: Mining industry	356	2.91	4.35
C: Manufacturing industry	7,740	63.22	67.57
D: Electricity, Water Production, and Supply Industry	359	2.93	70.50
E: Construction business	318	2.60	73.10
F: Wholesale and retail business	655	5.35	78.45
G: Transportation and Postal Service	361	2.95	81.40
H: Accommodation and catering	53	0.43	81.83
I: Information transmission and information technology services	951	7.77	89.60
K: Real Estate	508	4.15	93.75
L: Leasing Services	186	1.52	95.27
M: Scientific Research and Technology Services	96	0.78	96.05
N: Water Conservancy and Public Facilities Industry	182	1.49	97.54
Q: Health and social work	52	0.42	97.97
R: Culture and Entertainment	187	1.53	99.49
S: Comprehensive	62	0.51	100.00

Note: This table shows the distribution of the sample observations based on year and industry.

3.2. Variable measurement

3.2.1. Dependent variable

Green innovation (GIN) is our dependent variable. We use two proxies for GIN: green patents (GP) and green processes (GPP) (Alkebsee et al., 2023; Quan et al., 2022). We measure GP (GPP) as the natural logarithm of one plus the number of green patents (green processes) (Zhang et al., 2020).

3.2.2. Independent variable

Cost stickiness is our independent variable. Given that our objective is to investigate the consequences of cost stickiness, our empirical strategy is guided by the firm-level cost stickiness measure introduced by Weiss (2010) and further applied by Banker and Byzalov (2014). Specifically, Weiss (2010) defines a firm's cost stickiness in a given quarter (Q) as the difference in the slope of the cost function over the most recent four quarters (from q–3 to q), conditional on sales increasing in one quarter and decreasing in another. Below are equations used to calculate cost stickiness proxies, operating cost stickiness (OPCS) and selling, administrative, and general cost stickiness (SAGCS).

$$OPCS_{i,q} = Ln(\Delta OPCOST/\Delta SALES)_{i,\,T} - Ln(\Delta OPCOST/\Delta SALES)_{i,t}t,\ T, \in [Q \ldots Q-3] \quad (1)$$

$$SAGCS_{i,q} = Ln(\Delta SAGCOST/\Delta SALES)_{i,\,T} - Ln(\Delta SAGCOST/\Delta SALES)_{i,t}t,\ T, \in [Q \ldots Q-3] \quad (2)$$

where $OPCS_{i,q}$ refers to the proxy of stickiness in the cost of 'total operating costs' and $SAGCS_{i,q}$ refers to the proxy of stickiness in the cost of selling, administrative, and general costs (SA&G), T (t) is the most recent of the last four quarters with an increase (decrease) in sales,

$\Delta OPCOST = OPCOST_{i,Q} - OPCOST_{i,Q-1}$, $\Delta SALES = SALES_{i,Q} - SALES_{i,Q-1}$, and while $\Delta SAGCOST = SAGCOST_{i,Q} - SAGCOST_{i,Q-1}$.

Following prior studies (Costa & Habib, 2023), $OPCS_{i,q}$ gauges the variance in the slope of the cost function between the two most recent quarters within the last four quarters. We multiply Weiss's (2010) original measure by −1, thereby, a high value of $OPCS_{i,q}$ represents stickier cost behaviour. We obtained $OPCS_{i,t}$ by calculating the mean of $OPCS_{i,q}$ for total operating costs and $SAGCS_{i,q}$ for SA&G costs.

3.2.3. Moderator variable. Our moderator variable is government subsidies (SUBSIDIES) allocated for R&D and innovation received by a firm. In line with prior research (Duan et al., 2024; Wang et al., 2022), we measure SUBSIDIES as the natural logarithm of the total government subsidies granted to a firm per year.

3.3. Empirical model

To test the relationship between cost stickiness and green innovation, we employ the following ordinary least squares (OLS) regression model.

$$
\begin{aligned}
GIN_{i,t} = {} & \beta_0 + \beta_1 STICKY_{i,t} + \beta_2 BSIZE_{i,t} + \beta_3 BIND_{i,t} + \beta_4 BMEET_{i,t} + \beta_5 DUALITY_{i,t} \\
& + \beta_6 SIZE_{i,t} + \beta_7 ROA_{i,t} + \beta_8 BTM + \beta_9 LOSS_{i,t} + \beta_{10} DEBT_{i,t} \\
& + \beta_{11} MANOWN_{i,t} + \beta_{12} SOE_{i,t} + \beta_{13} FCDUM_{i,t} + \beta_{14} RD_{i,t} + YEAR \\
& + INDUSTRY + \varepsilon_{i,t}
\end{aligned} \tag{3}
$$

To examine the moderating role of government subsidies, we employ the following OLS model

$$
\begin{aligned}
GIN_{i,t} = {} & \beta_0 + \beta_1 STICKY_{i,t} + \beta_2 SUBSIDIES_{i,t} + \beta_3 SUBSIDIES{*}STICKY_{i,t} + \beta_4 BSIZE_{i,t} \\
& + \beta_5 BIND_{i,t} + \beta_6 BMEET_{i,t} + \beta_7 DUALITY_{i,t} + \beta_8 SIZE_{i,t} + \beta_9 ROA_{i,t} \\
& + \beta_{10} BTM + \beta_{11} LOSS_{i,t} + \beta_{12} DEBT_{i,t} + \beta_{13} MANOWN_{i,t} + \beta_{14} SOE_{i,t} \\
& + \beta_{15} FCDUM_{i,t} + \beta_{16} RD_{i,t} + YEAR + INDUSTRY + \varepsilon_{i,t}
\end{aligned} \tag{4}
$$

Where subscripts i and t represent the firm and year, respectively. GIN is the dependent variable that refers to green innovation proxies (GP and GPP). STICKY is the independent variable that refers to cost stickiness proxies (OPCS and SAGCS). SUBSIDIES is our moderator variable, representing government subsidies.

We include several control variables that prior research found to be likely determinants of green innovation. Following prior studies (e.g. Amore & Bennedsen, 2016, Quan et al., 2021; Zhang et al., 2020) we include board size (BSIZE) measured as the number of directors on the board, board independence (BDIND) measured as the proportion of independent directors on the board, board meeting (BMEET) measured as the number of board meetings held in a year t, and CEO duality (DUALITY) measured as an indicator variable coded 1 if the CEO is also the chairman of the board, and 0 otherwise. Moreover, we include some firm-level characteristics such as firm size (SIZE) measured as the natural log of total assets, return on assets (ROA) measured as the net profit scaled by total assets, book to market value (BTM) measured as total book value scaled by total market value, firm profitability (LOSS) measured as a dummy coded 1 if a firm incurred a loss, and 0 otherwise, firm leverage (DEBT) measured as total debts to total assets. We also control for ownership structure by including managerial ownership (MANOWN), measured as the ratio of the number of shares held by executives, state ownership (SOE), measured as a dummy variable coded 1 if the ultimate controller is the government, and zero otherwise. Abrahams and Sidhu (1998) find that R&D expenditure improves firm innovation. Thus, we include RD expenditures (RD) measured as the logarithm of R&D expenses.[1] Wang et al. (2022) document a significant relationship between financial constraints and green innovation, thus, we include financial constraints (FCDUM) coded as 1 if a firm is financially constrained and zero otherwise. Finally, we include year and industry-fixed effects. The standard errors are clustered at the firm level. All variables are defined in the Appendix.

Table 2. Descriptive statistics.

	N	Mean	SD	p25	Median	p75
GP	12,242	0.288	0.706	0.000	0.000	0.000
GPP	12,242	0.217	0.599	0.000	0.000	0.000
OPCS	12,242	0.019	0.343	0.000	0.002	0.055
SAGCS	12,242	0.026	0.229	0.000	0.004	0.104
BSIZE	12,242	8.761	1.752	8.000	9.000	9.000
BDIND	12,242	0.373	0.055	0.333	0.333	0.429
BMEET	12,242	10.205	3.990	7.000	9.000	12.000
DUALITY	12,242	0.262	0.440	0.000	0.000	1.000
SIZE	12,242	22.387	1.279	21.481	22.207	23.106
ROA	12,242	0.042	0.057	0.018	0.039	0.068
BTM	12,242	0.605	0.243	0.415	0.601	0.792
LOSS	12,242	0.073	0.260	0.000	0.000	0.000
DEBT	12,242	0.438	0.203	0.278	0.435	0.593
MANOWN	12,242	13.313	6.238	10.484	15.278	18.246
SOE	12,242	0.377	0.485	0.000	0.000	1.000
FCDUM	12,242	0.420	0.494	0.000	0.000	1.000
RD	12,242	16.019	4.766	16.11	17.565	18.519
SUBSIDIES	12,242	7.197	1.179	6.677	7.151	7.786

Note: This table reports the descriptive statistics for all variables used in this study.

4. Empirical results

4.1. Descriptive statistics

Table 2 reports the statistics of all variables of the model. The average GP and GPP are 0.288 and 0.217, respectively. Our statistics are close to prior studies; for instance, Alkebsee et al. (2023) reported average GP and GPP of 0.201 and 0.16, while Quan et al. (2021) reported an average GP of 0.20. The average OPCS and SAGCS are 0.019 and 0.026, respectively. The average board size (BSIZE) is 8.76 members, with approximately 37.3% being independent directors (BDIND). They get together around ten times a year, and around 26.2% of our sample firms have a CEO who is also the chairman of the board (DUALITY). The mean firm size is about 22.39, and the average return on assets (ROA) and (BTM) are 0.042 and 0.605, respectively. Around 7.3% of our sample firms reported a negative profit, while the mean firm leverage ratio (DEBT) is 0.438, suggesting that firms finance about 43.8% of their assets with debt. Regarding ownership structure, almost 13.313% of shares are owned by managers (MANOWN), and around 37.7% of the firms are state-owned enterprises (SOE). Around 42% of our sample firms are financially constrained (FCDUM). The average R&D expenditure is 16.016. Finally, the mean government subsidies is 7.197.

Table 3 presents the Pearson correlation results. The correlation coefficients between GP and GPP and OPCS are negative and significant (−0.028 and −0.024, respectively). The correlation coefficients between GP and GPP and SAGCS are negative and significant (−0.018 and −0.017, respectively). The correlation coefficient among the independent variables is below 0.60, implying that our model is relieved of multicollinearity. The results of the VIF test support our statement on the multicollinearity, as the highest VIF is 2.49 on the board independence, which is lower than the maximum value of 10.

Table 3. Correlation matrix.

Variables	VIF	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
GP		1.000																	
GPP		0.931*	1.000																
OPCS	1.09	−0.028*	−0.024*	1.000															
SAGCS	1.02	−0.018*	−0.017*	0.305*	1.000														
BSIZE	2.47	0.080*	0.081*	−0.021	0.018	1.000													
BDIND	2.49	0.094*	0.092*	−0.024*	0.005	0.562*	1.000												
BMEET	1.16	0.027*	0.024*	−0.009	−0.018	−0.044*	−0.007	1.000											
DUALITY	1.11	0.005	0.009	0.038*	−0.006	−0.187*	−0.127*	0.023*	1.000										
SIZE	2.28	0.241*	0.234*	−0.058*	0.026*	0.259*	0.309*	0.231*	−0.165*	1.000									
ROA	2.00	0.008	0.007	0.235*	0.103*	0.005	−0.011	−0.113*	0.025*	−0.063*	1.000								
BTM	1.71	0.096*	0.107*	−0.050*	0.023	0.174*	0.185*	0.104*	−0.131*	0.582*	−0.257*	1.000							
LOSS	1.61	−0.017	−0.014	−0.181*	−0.099*	−0.022	−0.013	0.027*	−0.010	−0.013	−0.568*	0.038*	1.000						
DEBT	1.86	0.091*	0.096*	−0.099*	0.009	0.166*	0.178*	0.243*	−0.131*	0.551*	−0.373*	0.443*	0.169*	1.000					
MANOWN	1.52	0.054*	0.046*	0.158*	0.057*	−0.164*	−0.155*	0.088*	0.213*	−0.197*	0.143*	−0.189*	−0.105*	−0.257*	1.000				
SOE	1.75	0.043*	0.042*	−0.067*	0.002	0.304*	0.294*	−0.077*	−0.277*	0.374*	−0.096*	0.267*	0.048*	0.310*	−0.548*	1.000			
FCDUM	1.02	−0.073*	−0.070*	−0.019	0.006	0.006	−0.015	0.055*	−0.072*	0.057*	−0.032*	0.043*	0.017	0.080*	−0.077*	0.089*	1.000		
RD	1.11	0.231*	0.204*	−0.017	0.014	−0.032*	−0.026*	−0.024*	0.077*	0.019	0.041*	−0.089*	0.010	−0.154*	0.192*	−0.173*	−0.094*	1.000	
SUBSIDIES	1.26	0.200*	0.185*	0.004	0.030*	0.127*	0.154*	0.067*	−0.051*	0.423*	0.032*	0.213*	−0.028*	0.177*	−0.025*	0.149*	−0.041*	0.138*	1.000

Note: this table presents the correlation matrix and the VIF statistics.* shows significance at the 0.01 level.

Table 4. The results of the relationship between cost stickiness and green innovation.

Variables	(1) GP	(2) GPP	(3) GP	(4) GPP
OPCS	−0.071***	−0.052***	–	–
	[−4.28]	[−3.90]	–	–
SAGCS	–	–	−0.128***	−0.100***
	-	–	[−4.92]	[−4.62]
BSIZE	0.006	0.007	0.007	0.007
	[0.58]	[0.75]	[0.60]	[0.77]
BDIND	0.015	0.008	0.015	0.008
	[0.53]	[0.35]	[0.51]	[0.33]
BMEET	−0.002	−0.002	−0.003	−0.002
	[−0.72]	[−0.69]	[−0.78]	[−0.74]
DUALITY	0.039	0.043*	0.038	0.042*
	[1.38]	[1.78]	[1.35]	[1.75]
SIZE	0.156***	0.127***	0.157***	0.127***
	[5.35]	[5.03]	[5.40]	[5.07]
ROA	−0.095	−0.004	−0.145	−0.039
	[−0.45]	[−0.02]	[−0.70]	[−0.24]
BTM	−0.096	−0.044	−0.103	−0.049
	[−1.33]	[−0.71]	[−1.42]	[−0.79]
LOSS	−0.068**	−0.037	−0.071**	−0.039
	[−2.21]	[−1.40]	[−2.28]	[−1.47]
DEBT	0.111	0.090	0.120	0.097
	[1.25]	[1.19]	[1.36]	[1.30]
MANOWN	0.010***	0.008***	0.009***	0.008***
	[5.00]	[4.59]	[4.91]	[4.53]
SOE	0.044	0.025	0.044	0.024
	[1.38]	[0.91]	[1.36]	[0.90]
FCDUM	−0.078***	−0.058***	−0.078***	−0.058***
	[−3.37]	[−3.05]	[−3.38]	[−3.06]
RD	0.019***	0.014***	0.019***	0.015***
	[8.27]	[6.96]	[8.48]	[7.12]
Constant	−3.843***	−3.124***	−3.858***	−3.135***
	[−6.67]	[−6.37]	[−6.71]	[−6.40]
Year&Industry	Yes	Yes	Yes	Yes
Observations	12,242	12,242	12,242	12,242
Adj.R2	0.15	0.13	0.15	0.13

Note: The table reports the impact of cost stickiness on green innovation. All variables (other than the categorical variables) are winsorised at the 1% and 99% levels. The numbers in the parentheses are t-statistics. ***, **, and * indicate statistical significance at 1%, 5% and 10% respectively. For a detailed description of variables, see the appendix.

4.2. Regression results

4.2.1. The impact of cost stickiness on green innovation

Table 4 reports the results of the relationship between cost stickiness and green innovation (H1). The coefficients on OPCS are negative and significant for GP (coefficient = −0.071, $p < 0.01$) (Column 1) and GPP (coefficient = −0.052, $p < 0.01$) (Column 2), indicating that higher levels of operating cost stickiness are associated with reduced green innovation activities. We observe similar negative coefficients for SAG cost stickiness, with coefficients for GP and GPP being −0.128 and −0.100, both significant at $p < 0.01$, respectively (Columns 3 and 4). This implies that cost stickiness, either in total operating or SAG costs, impedes green innovation activities, thus supporting H1. Economically, our estimations show that a one-standard-deviation increases in OPCS (SAGCS) lead to a decrease in green patents (GP) and green process (GPP) by 3.5[2]% and 3% (4.2% and 3.8%), respectively. Such findings highlight the significant impact of cost stickiness on firms' ability to engage in green innovation, which is critical for long-term sustainability and competitive advantage. Empirically, our findings align with prior research suggesting that inflexible cost structures compromise firms' flexibility to allocate resources towards innovative activities (e.g. Anderson et al., 2003; Banker et al., 2014). In terms of control variables (Column 1), we find that green innovation increases for large firms with high RD expenditures, and firms with high managerial ownership, while it decreases for firms with poor performance (LOSS) and financially constrained firms.

4.2.2. Mechanism analysis

To further validate the underlying mechanism behind the association between cost stickiness and green innovation, we conduct a cross-sectional analysis. Our theoretical argument posits that cost stickiness constrains firms' ability to adjust resources flexibly (Costa et al., 2021), thereby reducing the funds and managerial attention available for discretionary innovation activities. We test two potential channels: resource crowding-out. The resource crowding out channel, prior research suggests that financially constrained firms exhibit greater cost stickiness as managers prefer retaining resources rather than incurring the costs of reacquisition (Chen & Ma, 2021). Accordingly, we expect the negative effect of cost stickiness on green innovation to be more pronounced among financially constrained firms. We then re-estimate the baseline model separately for high- and low-constraint subsamples. Table 5 respots the results for this analysis. The results show that the negative association between cost stickiness and green innovation is significantly stronger for firms facing higher financial constraints where the coefficient on OPCS is negative and significant (coefficient = −0.096, −0.077, $p < 0.01$, column (1) (3)), compared with their unconstrained counterparts (−0.056, −0.036; $p < 0.05$, columns (2) and (4)). Regarding the SAG costs, the results show consistent outcomes. The coefficient on SAGCS is negative and significant (coefficient = −0.191, −0.151, $p < 0.01$, column (5) (7)), while their unconstrained counterparts are insignificant (columns (6) and (8)). This confirms that resource crowding-out amplifies the negative effect of cost stickiness on innovation.

4.2.3. The moderating effect of government subsidies

To test the hypothesis on whether the government subsidies granted to a firm moderate the negative impact of cost stickiness on green innovation, we use the interaction method. Table 6 reports the results of the moderating effect of government subsidies. The coefficient on OPCS remains negative and significant in Columns 1 and 2. The coefficient on SUBSIDIES is positive and significant (coefficient = 0.023 and 0.016, $p < 0.01$), suggesting that government subsidies promote green innovation. The coefficient on the variables of interest (SUBSIDIES*OPCS) is positive and significant (coefficient = 0.014 and 0.011, $p < 0.01$). Similarly, the coefficient on SUBSIDIES*SAGCS, in Columns 3 and 4, is positive and significant (coefficient = 0.040 and 0.028, $p < 0.01$). This suggests that government subsidies are likely to ease financial constraints and strengthen the ability of a firm to reallocate resources towards green innovation initiatives. These findings are in line with the prior studies that document that government subsidies enhance green innovation (Duan et al., 2024; Lyu et al., 2024, Wang et al., 2022; Zhao et al., 2024).

Table 5. The results of the resource crowding-out mechanism.

VARIABLES	(1) GP FCDUM = 1	(2) GP FCDUM = 0	(3) GPP FCDUM = 1	(4) GPP FCDUM = 0	(5) GP FCDUM = 1	(6) GP FCDUM = 0	(7) GPP FCDUM = 1	(8) GPP FCDUM = 0
OPCS	−0.096***	−0.056**	−0.077***	−0.036*	–	–	–	–
	[−4.28]	[−2.34]	[−4.25]	[−1.85]	–	–	–	–
SAGCS	–	–	–	–	−0.191***	−0.052	−0.151***	−0.039
	-	–	–	–	[−5.01]	[−1.44]	[−4.75]	[−1.31]
BOSIZE	−0.000	0.013	0.003	0.012	0.012	−0.000	0.009	0.003
	[−0.02]	[0.85]	[0.32]	[0.91]	[0.74]	[−0.03]	[0.74]	[0.30]
BOINDP	0.014	0.007	0.003	0.003	0.004	0.026	−0.002	0.019
	[0.41]	[0.17]	[0.11]	[0.09]	[0.10]	[0.83]	[−0.07]	[0.72]
BOMEETING	−0.002	−0.001	−0.001	−0.002	−0.006	0.001	−0.005	0.001
	[−0.75]	[−0.19]	[−0.37]	[−0.34]	[−1.55]	[0.28]	[−1.49]	[0.25]
DUALITY	−0.009	0.069*	0.012	0.063*	0.056	0.022	0.057	0.029
	[−0.28]	[1.78]	[0.46]	[1.87]	[1.30]	[0.80]	[1.52]	[1.28]
FIRMSIZE	0.060***	0.194***	0.039**	0.161***	0.158***	0.158***	0.126***	0.130***
	[2.82]	[5.00]	[2.17]	[4.77]	[4.81]	[3.93]	[4.41]	[3.80]
ROA	−0.094	−0.084	0.003	0.003	0.537*	−0.554*	0.480**	−0.354
	[−0.50]	[−0.25]	[0.02]	[0.01]	[1.93]	[−1.91]	[2.10]	[−1.52]
BTM	−0.039	−0.113	−0.001	−0.053	−0.246**	0.018	−0.153	0.038
	[−0.55]	[−1.09]	[−0.01]	[−0.58]	[−2.05]	[0.25]	[−1.49]	[0.60]
LOSS	−0.169***	0.012	−0.130***	0.035	−0.022	−0.099**	−0.003	−0.062
	[−4.87]	[0.26]	[−4.55]	[0.86]	[−0.52]	[−2.23]	[−0.07]	[−1.57]
DEBT	0.293***	−0.017	0.235***	−0.008	0.163	−0.099	0.138	−0.087
	[3.68]	[−0.13]	[3.65]	[−0.07]	[1.46]	[−0.85]	[1.46]	[−0.87]
MANOWN	0.008***	0.011***	0.007***	0.008***	0.010***	0.010***	0.008***	0.007***
	[3.94]	[3.72]	[4.11]	[3.24]	[3.64]	[4.41]	[3.68]	[3.72]
SOE	0.030	0.051	0.016	0.027	0.030	0.052	0.024	0.019
	[0.87]	[0.99]	[0.59]	[0.62]	[0.68]	[1.40]	[0.65]	[0.60]
FCDUM	–	–	–	–	–	–	–	–
	-	–	–	–	–	–	–	–
RD	0.016***	0.023***	0.012***	0.017***	0.019***	0.019***	0.014***	0.014***
	[8.65]	[5.88]	[7.89]	[4.90]	[7.88]	[5.86]	[6.99]	[4.84]
Constant	−1.812***	−4.717***	−1.272***	−3.902***	−3.937***	−3.762***	−3.143***	−3.094***
	[−4.28]	[−6.27]	[−3.55]	[−6.06]	[−6.14]	[−4.66]	[−5.67]	[−4.60]
Year&Industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,136	7,106	5,136	7,106	5,136	7,106	5,136	7,106
Adj.R2	0.10	0.17	0.08	0.16	0.15	0.15	0.12	0.14

Note: The table reports the results of the resource crowding out mechanism for the impact of stickiness in costs on green innovation, coefficients, and R2 across years and industries, T-value in brackets. For a detailed definition of variables, see Appendix. *, **, *** significant at 10, 5, and 1%, respectively.

4.3. Endogeneity

4.3.1. The fixed effect panel regression model

Some may argue that our model may suffer from a problem of omitted variables, resulting in biased findings. To address this concern, we use the fixed effect panel regression model with firm and year fixed effects and report the results in Table 7. The coefficient on OPCS in Columns 1 and 2, remains negative and significant (coefficient = −0.048 and −0.035, $p < 0.01$). Similarly, the coefficient on SAGCS is negative and significant (coefficient = −0.065 and −0.046, $p < 0.01$). The findings suggest that our main results are robust to the omitted variable concerns.

4.3.2. The two-stage least squares (2SLS) model

While our baseline results show that cost stickiness impedes green innovation by limiting resource allocation flexibility, heightening financial constraints, and increasing

Table 6. The results of the moderating effect of government subsidies on the relationship between cost stickiness and green innovation.

Variables	(1) GP	(2) GPP	(3) GP	(4) GPP
OPCS	−0.251***	−0.196***	–	–
	[−4.29]	[−3.78]	–	–
SUBSIDIES	0.023***	0.016***	0.022***	0.016***
	[5.23]	[4.52]	[5.01]	[4.33]
SUBSIDIES*OPCS	0.014***	0.011***	–	–
	[3.20]	[2.90]	–	–
SAGCS	–	–	−0.701***	−0.503***
	-	–	[−5.18]	[−4.62]
SUBSIDIES*SAGCS	–	–	0.040***	0.028***
	-	–	[4.29]	[3.75]
BSIZE	0.007	0.007	0.008	0.008
	[0.63]	[0.80]	[0.67]	[0.84]
BDIND	0.013	0.007	0.012	0.006
	[0.46]	[0.29]	[0.43]	[0.27]
BMEET	−0.002	−0.002	−0.003	−0.002
	[−0.71]	[−0.68]	[−0.76]	[−0.72]
DUALITY	0.038	0.043*	0.038	0.042*
	[1.37]	[1.77]	[1.35]	[1.75]
SIZE	0.134***	0.111***	0.134***	0.111***
	[4.98]	[4.77]	[4.99]	[4.79]
ROA	−0.129	−0.029	−0.169	−0.056
	[−0.61]	[−0.17]	[−0.82]	[−0.34]
BTM	−0.083	−0.034	−0.089	−0.039
	[−1.16]	[−0.56]	[−1.25]	[−0.64]
LOSS	−0.065**	−0.035	−0.064**	−0.035
	[−2.13]	[−1.32]	[−2.07]	[−1.30]
DEBT	0.110	0.089	0.122	0.099
	[1.26]	[1.20]	[1.40]	[1.33]
MANOWN	0.009***	0.007***	0.009***	0.007***
	[4.76]	[4.40]	[4.74]	[4.39]
SOE	0.042	0.022	0.041	0.022
	[1.30]	[0.84]	[1.29]	[0.84]
FCDUM	−0.075***	−0.056***	−0.076***	−0.057***
	[−3.29]	[−2.98]	[−3.32]	[−3.01]
RD	0.018***	0.014***	0.018***	0.014***
	[8.03]	[6.71]	[8.13]	[6.78]
Constant	−3.680***	−3.007***	−3.658***	−2.993***
	[−6.65]	[−6.37]	[−6.61]	[−6.35]
Year&Industry	Yes	Yes	Yes	Yes
Observations	12,242	12,242	12,242	12,242
Adj.R2	0.15	0.13	0.15	0.13

Note: The table reports the results of the moderating effect of government subsidies on the impact of cost stickiness on green innovation. All variables (other than the categorical variables) are winsorised at the 1% and 99% levels. The numbers in the parentheses are t-statistics. ***, **, and * indicate statistical significance at 1%, 5% and 10% respectively. For a detailed description of variables, see the appendix.

managerial risk aversion, we acknowledge that the causal relationship may be bidirectional. That is, firms engaging in green innovation, which often entails long-term investments in R&D and sustainable technologies, may lead to developing rigid cost structures, thereby exacerbating cost stickiness. This possibility of reverse causality introduces a critical endogeneity concern that cannot be overlooked. A recent study provides empirical evidence that CSR investments can increase cost stickiness (Habib & Hasan, 2019), suggesting that sustainability activities may inherently embed operating rigidity due to fixed long-term cost commitments. Therefore, the assumption of a one-way causal effect from cost stickiness to green innovation may be overly simplistic. To

Table 7. The results of the fixed effect panel regression model.

VARIABLES	(1) GP	(2) GPP	(3) GP	(4) GPP
OPCS	−0.048***	−0.035***	–	–
	[−3.82]	[−2.98]	–	–
SAGCS	–	–	−0.065***	−0.046***
	-	–	[−3.58]	[−2.72]
Other control variables	Yes	Yes	Yes	Yes
Constant	−0.486*	−0.535**	−0.569**	−0.596**
	[−1.81]	[−2.12]	[−2.13]	[−2.37]
Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Industry FE*	No	No	No	No
Observations	12,242	12,242	12,242	12,242
Adj.R2	0.25	0.27	0.25	0.28

*We excluded the industry-fixed effect from this model due to industry fixed effects would be fully absorbed by firm fixed effects, so including both would cause collinearity.

Note: The table reports the results of the firm-fixed effect. All variables (other than the categorical variables) are winsorised at the 1% and 99% levels. The numbers in the parentheses are t-statistics. ***, **, and * indicate statistical significance at 1%, 5% and 10% respectively. For a detailed description of variables, see the appendix.

address this issue, we use the 2SLS model. This model requires a valid instrument that must be correlated with the independent variable (OPCS and SAGCS) and not correlated with the dependent variable (green innovation proxies). We use the industry average of cost stickiness as an instrument because cost stickiness is basically affected by industry-level factors such as competition, technological intensity, and regulation. Such factors lead to common cost structures within industries (Anderson et al., 2003), suggesting a strong relationship between firm-level cost stickiness and the industry average. On the other hand, industry average cost stickiness is unlikely to be affected directly by the firm's green innovation activities, thereby satisfying the exclusion restriction. Table 8 presents the estimations for the 2SLS model. In Columns 1 and 5, we find the coefficient on OPCAINDUS and SAGCSINDUS positive and significant, supporting our assertion that our chosen instrument is correlated with the independent variable. In columns 2 and 6,

Table 8. The results of the 2SLS model.

VARIABLES	(1) OPCS	(2) GP	(3) GP	(4) GPP	(5) SAGCS	(6) GP	(7) GP	(8) GPP
OPCSINDUS	0.786***	0.288	–	–	–	–	–	–
	[10.06]	[1.33]	–	–	–	–	–	–
OPCS	–	−0.065***	−0.226**	−0.159*	–	–	–	–
	-	[−3.82]	[−2.37]	[−1.94]	–	–	–	–
SAGCSINDUS	–	–	–	–	0.562***	−0.081	–	–
	-	–	–	–	[18.45]	[−0.95]	–	–
SAGCS	–	–	–	–	–	−0.140***	−0.003	−0.026
	-	–	–	–	–	[−5.78]	[−0.03]	[−0.33]
Other control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.364***	−3.874***	−3.816***	−3.105***	0.072	−3.845***	−3.856***	−3.133***
	[4.41]	[−6.67]	[−24.73]	[−23.53]	[1.46]	[−6.68]	[−25.20]	[−23.93]
Year and Industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,242	12,242	12,242	12,242	12,242	12,242	12,242	12,242
Adj.R2	0.13	0.15	0.14	0.12	0.16	0.14	0.14	0.13
Stock-Yogo value			$F = 455.934$, $p = 0.000$				$F = 1142.39$, $p = 0.000$	

Note: The table reports the results of the 2SLS model. All variables (other than the categorical variables) are winsorised at the 1% and 99% levels. The numbers in the parentheses are t-statistics. ***, **, and * indicate statistical significance at 1%, 5% and 10% respectively. For a detailed description of variables, see the appendix.

we find that the coefficient on OPCAINDUS and SAGCSINDUS is insignificant, suggesting that our instrument is not correlated with our dependent variable, supporting the validity of our instrument. Furthermore, we perform a weak instrument test using the first-stage F-statistic and Stock-Yogo critical values. The F-statistic for our instruments (OPCSINDUS and SAGCSINDUS) is 455.934 and 1142.39, respectively, which is much greater than the value of the Stock-Yogo critical value threshold at 10% maximal IV size (16.38), suggesting that our instruments are strong. In Columns 3 and 4, the coefficient on OPCS is negative and significant (coefficient = −0.226 and −0.159, $p < 0.05$ and 0.10, respectively), implying that our main results are consistent and robust for causality concerns. However, we fail to find evidence for the SAG costs regarding the causality effect, as the coefficient on SAGCS is negative but insignificant (Columns 7 and 8).

4.3.3. The general moment method (GMM) approach

As our dependent variable (green innovation) is a dynamic variable, i.e. it is influenced by its own previous values. This would create a bias that may distort our main results. To address this potential bias, we use the GMM approach as it captures this persistence over time, allowing for a more accurate estimation of the dynamic relationship. Further, our model may contain unobserved firm-specific or time-specific factors that may be correlated with cost stickiness. The GMM approach accounts for this unobserved heterogeneity by using first differencing to remove fixed effects, ensuring that the estimates are not biased by these unobserved factors. To perform the GMM approach, we should include the lagged value of green innovation in our main model as an independent variable to control for endogeneity bias, as shown in the following model:

$$\begin{aligned} GIN_{i,t} = \beta_0 + \beta_1 L.GIN_{i,t} + \beta_2 STICKY_{i,t} + \beta_3 BSIZE_{i,t} + \beta_4 BIND_{i,t} + \beta_5 BMEET_{i,t} \\ + \beta_6 DUALITY_{i,t} + \beta_7 SIZE_{i,t} + \beta_8 ROA_{i,t} + \beta_9 BTM + \beta_{10} LOSS_{i,t} + \beta_{11} DEBT_{i,t} \\ + \beta_{12} MANOWN_{i,t} + \beta_{13} SOE_{i,t} + \beta_{14} FCDUM_{i,t} + \beta_{15} RD_{i,t} + YEAR \\ + INDUSTRY + \varepsilon_{i,t} \end{aligned} \tag{5}$$

The GMM approach provides several diagnostic tests; autocorrelation tests AR(1) and AR(2) (Arellano & Bond, 1991) that help detect the dynamic specifications of cost stickiness and green innovation. Further, the Sargan and Hansen tests assess the validity or exogeneity of the instrument set by examining over-identifying restrictions under the null hypothesis that the instruments are valid. That is, uncorrelated with the error term and properly excluded from the main equation. Table 9 reports the results of the GMM approach. In Columns 1 and 2, the coefficient on OPCS is negative and significant (coefficient = −0.062 and −0.078, $p < 0.05$ respectively). However, we fail to find evidence supporting the impact of SAG costs when accounting for dynamic and unobserved heterogeneity concerns, as the coefficient on SAGCS is negative but statistically insignificant in Columns 3 and 4. In Columns 1 and 2, AR (1) reveals a significant coefficient while AR(2) reveals an insignificant coefficient, suggesting that there is autocorrelation in the first

Table 9. The results of the GMM approach.

VARIABLES	(1) GP	(2) GPP	(3) GP	(4) GPP
	[31.43]	–	[50.36]	–
L.GPP	–	0.780***	–	0.791***
	-	[26.28]	–	[27.90]
OPCS	−0.062**	−0.078**	–	–
	[−1.97]	[−2.51]	–	–
SAGCS	–	–	−0.014	−0.018
	-	–	[−0.31]	[−0.43]
Other control variables	Yes	Yes	Yes	Yes
Constant	−0.231	−0.735	0.001	0.002
	[−0.40]	[−1.63]	[0.120]	[0.085]
Year&Industry	Yes	Yes	Yes	Yes
Observations	8,036	8,036	8,036	8,036
AR(1)	$z = -12.26$, $p = 0.000$	$z = -11.01$, $p = 0.000$	$z = -12.56$, $p = 0.000$	$z = -11.04$, $p = 0.000$
AR(2)	$z = 1.36$, $p = 0.169$	$z = 1.22$, $p = 0.221$	$z = 1.36$, $p = 0.166$	$z = 1.19$, $p = 0.233$
Sargan test	$chi^2 = 268.50$, $p = 0.023$	$chi^2 = 239.79$, $p = 0.000$	$chi^2 = 282.98$, $p = 0.000$	$chi^2 = 224.72$, $p = 0.003$
Hansen test	$chi^2 = 156.69$, $p = 0.603$	$chi^2 = 159.86$, $p = 0.681$	$chi^2 = 163.68$, $p = 0.601$	$chi^2 = 154.74$, $p = 0.777$

Note: The table reports the findings of the GMM approach. All variables (other than the categorical variables) are winsorised at the 1% and 99% levels. The numbers in the parentheses are t-statistics. ***, **, and * indicate statistical significance at 1%, 5% and 10% respectively. For a detailed description of variables, see the appendix.

difference, and the error terms in the level regressions are not correlated. Furthermore, the Sargan test's p-value in Table 8 is statistically significant, whereas the Hansen test is insignificant, indicating that our instruments are valid. Overall, our results demonstrate that our main findings are robust to endogeneity concerns, particularly for total operating costs.

4.3.4. Entropy balancing matching approach

Finally, we conduct an entropy balancing test to address endogeneity concerns arising from design choice issues. This method allows us to control for potential endogeneity arising from observable differences in firm-level characteristics between sticky and non-sticky cost firms. We split our sample firms into sticky and non-sticky cost firms using the median value of OPCS (SAGCS). If the observation's value exceeds the median value of OPCS (SAGCS), coded one (sticky cost firm 'treatment group'), zero otherwise. Entropy balancing, as described by Hainmueller (2012), is a method that reweights a dataset to achieve a covariate balance between treatment and control groups. This method is particularly effective in reducing model dependence and increasing the reliability of causal estimates. Our implementation of entropy balancing involves a group of covariates that are potential determinants ofcost stickiness. We set a tolerance threshold that determines the minimum level of covariate balance required before the balancing process stops adjusting control sample weights. A threshold of zero would result in an exact balance of moments between the two groups (McMullin & Schonberger, 2020).

Panels A and B of Table 10 present the covariate distributions before and after entropy balancing. The statistics for all covariates in the treatment and control samples are insignificant after balancing, indicating that the covariates are evenly distributed across both samples. Panel C of Table 9 reports the regression results using the entropy-

Table 10. The results of the entropy approach.

	Treatment before matching			Control before matching			Treatment after matching		
Panel A: Balancing process for OPCS									
	mean	variance	skewness	mean	variance	skewness	mean	variance	skewness
BOSIZE	8.812	3.581	1.100	8.745	2.906	0.796	8.812	3.581	1.100
BOINDP	3.256	0.424	1.756	3.216	0.366	1.627	3.256	0.424	1.756
BOMEETING	10.360	16.420	0.992	10.160	15.760	1.040	10.360	16.420	0.992
DUALITY	0.257	0.191	1.113	0.264	0.194	1.073	0.257	0.191	1.113
FIRMSIZE	22.470	1.821	0.777	22.360	1.576	0.825	22.470	1.821	0.777
ROAA	0.025	0.005	−2.113	0.048	0.003	−1.035	0.025	0.005	−2.113
BTM	0.621	0.063	−0.008	0.601	0.058	0.098	0.621	0.063	−0.008
LOSS	0.154	0.130	1.919	0.047	0.045	4.256	0.154	0.130	1.919
DEBT	0.447	0.043	0.071	0.436	0.041	0.114	0.447	0.043	0.071
MAOWN	12.340	51.180	−0.805	13.620	34.670	−1.150	12.340	51.180	−0.805
SOE	0.397	0.239	0.423	0.371	0.233	0.536	0.397	0.239	0.423
FCDUM	0.387	0.237	0.463	0.430	0.245	0.284	0.387	0.237	0.463
RD	16.790	10.930	−1.186	15.780	26.180	−2.110	16.790	10.930	−1.186
Panel B: Balancing process for SAGCS									
BOSIZE	8.721	3.197	0.950	8.772	3.035	0.880	8.721	3.197	0.950
BOINDP	3.230	0.395	1.755	3.225	0.377	1.645	3.230	0.395	1.755
BOMEETING	10.570	17.040	0.969	10.110	15.600	1.043	10.570	17.040	0.969
DUALITY	0.273	0.199	1.018	0.259	0.192	1.099	0.273	0.199	1.018
FIRMSIZE	22.440	1.719	0.759	22.370	1.615	0.833	22.440	1.719	0.759
ROAA	0.029	0.004	−2.109	0.046	0.003	−1.459	0.029	0.004	−2.109
BTM	0.610	0.060	0.058	0.604	0.059	0.078	0.610	0.060	0.058
LOSS	0.131	0.114	2.185	0.058	0.055	3.780	0.131	0.114	2.185
DEBT	0.453	0.043	0.005	0.435	0.041	0.130	0.453	0.043	0.005
MAOWN	13.220	42.920	−1.051	13.340	37.890	−1.079	13.220	42.920	−1.051
SOE	0.364	0.232	0.566	0.380	0.236	0.494	0.364	0.232	0.566
FCDUM	0.400	0.240	0.407	0.424	0.244	0.306	0.400	0.240	0.407
RD	16.520	17.310	−2.167	15.890	24.020	−2.131	16.520	17.310	−2.167
Panel C: The entropy balanced regression results									
			(1)			(2)	(3)		(4)
VARIABLES			GP			GPP	GP		GPP
OPCS			−0.059***			−0.047***	–		–
			[−3.29]			[−3.09]	–		–
SAGCS			–			–	−0.123***		−0.102***
			-			–	[−4.21]		[−4.24]

(*Continued*)

Table 10. (Continued).

	Treatment before matching	Control before matching	Treatment after matching	
Other control variables	Yes	Yes	Yes	Yes
Constant	−4.756***	−3.853***	−4.906***	−4.024***
	[−13.89]	[−12.81]	[−13.62]	[−12.75]
Year&Industry	Yes	Yes	Yes	Yes
Observations	12,242	12,242	12,242	12,242
Adj.R2	0.20	0.17	0.19	0.17

Note: The table reports the results of entropy balancing. All variables (other than the categorical variables) are winsorised at the 1% and 99% levels. The numbers in the parentheses are t-statistics. ***, **, and * indicate statistical significance at 1%, 5% and 10% respectively. For a detailed description of variables, see the appendix.

balanced sample. The coefficient on OPCS and SAGCS remains significantly negative. Overall, our findings imply that our baseline results are consistent and robust for endogeneity concerns arising from observable factors.

5. Conclusion

This study examines the impact of cost stickiness on green innovation and explores the moderating effect of government subsidies, offering valuable insights into corporate decision-making and policymakers. Using a sample of data from China over the period 2009–2020, we find that stickiness in total operating and SAG costs significantly refrains firms from allocating resources towards green innovation initiatives. Cost stickiness exacerbates financial constraints, increases managerial risk aversion, and limits firms' capacity to pursue sustainable innovation, ultimately acting as a barrier to green innovation. Furthermore, our results shed light on the critical role of government subsidies in mitigating the adverse effects of cost stickiness on green innovation. We document that firms that receive government subsidies, particularly R&D and green subsidies, encounter a positive association between cost stickiness and green innovation, as such subsidies reduce risks associated with green innovation and ease financial constraints, eventually reducing the firm's barriers to engaging in green innovation initiatives.

This study asserts the importance of understanding cost behaviour asymmetry as a critical determinant of green innovation. Additionally, the positive moderating role of government subsidies reveals the necessity of government intervention in mitigating the challenges caused by cost stickiness to support sustainable innovation. Considering cost stickiness and improving managerial decision-making would help firms to better align their operational strategies with long-term environmental and economic goals. Green innovation is a crucial factor in sustainable development and environmental sustainability. This study has a societal impact as it demonstrates how cost behaviour impacts environmental sustainability by demonstrating how cost stickiness can act as a barrier to green innovation. Further, addressing cost stickiness through enhanced government policy intervention can help firms contribute more effectively to environmental and social goals. Overall, this study not only augments the theoretical understanding of cost stickiness and green innovation but also provides actionable insights for policymakers and leaders. Future research could explore this relationship using across-country data for comparative perspectives and examining additional moderating factors to further deepen insights in this field.

Notes

1. We replace missing RD expenses with zero.
2. [{(coefficient of the OPCS/SAGCS)* (sd of the OPCS/SAGCS)}/SD of GP]*100. For example [{(0.071 × 0.343)}/0.706]*100 = 3.5%.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The authors extend their appreciation to the Deanship of Research and Graduate Studies at King Khalid University for funding this work through a large-group Research Project under grant number (RGP.2/141/46).

ORCID

Radwan Alkebsee http://orcid.org/0000-0003-3142-575X

References

Abrahams, T., & Sidhu, B. K. (1998). The role of R & amp;D capitalisations in firm valuation and performance measurement. *Australian Journal of Management*, *23*(2), 169–183. https://doi.org/10.1177/031289629802300203

Agarwal, N. (2022). Cost stickiness and stock price delay. *European Accounting Review*, 1–25. https://doi.org/10.2139/ssrn.4202674

Ahemed, A. M., Iqbal, U., & Atif, M. M. (2025). Asymmetric cost behavior and financial distress. *Economics Letters*, *247*, 112121. https://doi.org/10.1016/j.econlet.2024.112121

Alkebsee, R., Habib, A., & Li, J. (2023). Green innovation and the cost of equity: Evidence from China. *China Accounting and Finance Review*, *25*(3), 368–395. https://doi.org/10.1108/CAFR-06-2022-0075

Almus, M., & Czarnitzki, D. (2003). The effects of public R &D subsidies on firms' innovation activities: The case of Eastern Germany. *Journal of Business & Economic Statistics*, *21*(2), 226–236. https://doi.org/10.1198/073500103288618918

Amore, M. D., & Bennedsen, M. (2016). Corporate governance and green innovation. *Journal of Environmental Economics and Management*, *75*, 54–72. https://doi.org/10.1016/j.jeem.2015.11.003

Amores-Salvadó, J., Martín de Castro, G., & Navas-López, J. E. (2014). Green corporate image: Moderating the connection between environmental product innovation and firm performance. *Journal of Cleaner Production*, *83*, 356–365. https://doi.org/10.1016/j.jclepro.2014.07.059

An, J., He, G., Ge, S., & Wu, S. (2025). The impact of government green subsidies on corporate green innovation. *Finance Research Letters*, *71*, 106378. https://doi.org/10.1016/j.frl.2024.106378

Anderson, M. C., Banker, R. D., & Janakiraman, S. N. (2003). Are selling, general, and administrative costs "sticky"? *Journal of Accounting Research*, *41*(1), 47–63. https://doi.org/10.1111/1475-679X.00095

Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *The review of economic studies*, *58*(2), 277–297.

Bai, Y., Song, S., Jiao, J., & Yang, R. (2019). The impacts of government R &D subsidies on green innovation: Evidence from Chinese energy-intensive firms. *Journal of Cleaner Production*, *233*, 819–829. https://doi.org/10.1016/j.jclepro.2019.06.107

Balakrishnan, R., & Gruca, T. S. (2008). Cost stickiness and core competency: A note. *Contemporary Accounting Research, Forthcoming*, *25*(4), 993–1006. https://doi.org/10.1506/car.25.4.2

Banker, R. D., Byzalov, D., & Chen, L. T. (2013). Employment protection legislation, adjustment costs and cross-country differences in cost behavior. *Journal of Accounting and Economics*, *55*(1), 111–127. https://doi.org/10.1016/j.jacceco.2012.08.003

Banker, R. D., Byzalov, D., Fang, S., & Liang, Y. (2018). Cost management research. *Journal of Management Accounting Research*, *30*(3), 187–209. https://doi.org/10.2308/jmar-51965

Banker, R. D., & Chen, L. (2006). Predicting earnings using a model based on cost variability and cost stickiness. *The Accounting Review*, *81*(2), 285–307. https://doi.org/10.2308/accr.2006.81.2.285

Banker, R. D., & Byzalov, D. (2014). Asymmetric cost behavior. *Journal of Management Accounting Research*, *26*(2), 43–79.
Bu, D., Wen, C., & Banker, R. D. (2015). Implications of asymmetric cost behaviour for analysing financial reports of companies in China. *China Journal of Accounting Studies*, *3*(3), 181–208. https://doi.org/10.1080/21697213.2015.1062343
Calleja, K., Steliaros, M., & Thomas, D. C. (2006). A note on cost stickiness: Some international comparisons. *Management Accounting Research*, *17*(2), 127–140. https://doi.org/10.1016/j.mar.2006.02.001
Canepa, A., & Stoneman, P. (2008). Financial constraints to innovation in the UK: Evidence from CIS2 and CIS3. *Oxford Economic Papers*, *60*(4), 711–730. https://doi.org/10.1093/oep/gpm044
Cannon, J. N. (2014). Determinants of "sticky costs": An analysis of cost behavior using United States air transportation industry data. *The Accounting Review*, *89*(5), 1645–1672. https://doi.org/10.2308/accr-50806
Caylor, M. L., & Lopez, T. J. (2013). Cost behavior and executive bonus compensation. *Advances in Accounting*, *29*(2), 232–242. https://doi.org/10.1016/j.adiac.2013.08.001
Chan, K. C., Chen, Y., & Liu, B. (2021). The linear and non-linear effects of internal control and its five components on corporate innovation: Evidence from Chinese firms using the COSO framework. *European Accounting Review*, *30*(4), 733–765. https://doi.org/10.1080/09638180.2020.1776626
Chang, C.-H. (2011). The influence of corporate environmental ethics on competitive advantage: The mediation role of green innovation. *Journal of Business Ethics*, *104*(3), 361–370. https://doi.org/10.1007/s10551-011-0914-x
Chen, Y., & Ma, Y. (2021). Financing constraints, internal control quality and cost stickiness. *Journal of Business Economics and Management*, *22*(5), 1231–1251. https://doi.org/10.3846/jbem.2021.14878
Ciftci, M., Mashruwala, R., & Weiss, D. (2016). Implications of cost behavior for analysts' earnings forecasts. *Journal of Management Accounting Research*, *28*(1), 57–80. https://doi.org/10.2308/jmar-51073
Cooper, R., & Kaplan, R. S. (1992). Activity-based systems: Measuring the costs of resource usage. *Accounting Horizons*, *6*(3), 1–13.
Costa, M. D., & Habib, A. (2023). Cost stickiness and firm value. *Journal of Management Control*, *34*(2), 235–273. https://doi.org/10.1007/s00187-023-00356-z
Costa, M. D., Habib, A., & Bhuiyan, M. B. U. (2021). Financial constraints and asymmetric cost behavior. *Journal of Management Control*, *32*(1), 33–83. https://doi.org/10.1007/s00187-021-00314-7
Cui, X., Wang, C., Sensoy, A., Liao, J., & Xie, X. (2023). Economic policy uncertainty and green innovation: Evidence from China. *Economic Modelling*, *118*, 106104. https://doi.org/10.1016/j.econmod.2022.106104
Cuerva, M.C, Triguero-Cano, Á. & Córcoles, D. (2014). Drivers of green and non-green innovation: empirical evidence in Low-Tech SMEs. *Journal of cleaner production*, *68*, 104–113.
Dierynck, B., Landsman, W. R., & Renders, A. (2012). Do managerial incentives drive cost behavior? Evidence about the role of the zero earnings benchmark for labor cost behavior in private Belgian firms. *The Accounting Review*, *87*(4), 1219–1246. https://doi.org/10.2308/accr-50153
Duan, Y., Xi, B., Xu, X., & Xuan, S. (2024). The impact of government subsidies on green innovation performance in new energy enterprises: A digital transformation perspective. *International Review of Economics & Finance*, *94*, 103414. https://doi.org/10.1016/j.iref.2024.103414
El Ghoul, S., Guedhami, O., Kwok, C. C., & Mishra, D. R. (2011). Does corporate social responsibility affect the cost of capital? *Journal of Banking & Finance*, *35*(9), 2388–2406. https://doi.org/10.1016/j.jbankfin.2011.02.007
Embong, Z., Mohd-Saleh, N., & Sabri Hassan, M. (2012). Firm size, disclosure and cost of equity capital. *Asian Review of Accounting*, *20*(2), 119–139. https://doi.org/10.1108/13217341211242178

García-Quevedo, J., Segarra-Blasco, A., & Teruel, M. (2018). Financial constraints and the failure of innovation projects. *Technological Forecasting and Social Change*, *127*, 127–140. https://doi.org/10.1016/j.techfore.2017.05.029

González, X., & Pazó, C. (2008). Do public subsidies stimulate private R &D spending? *Research Policy*, *37*(3), 371–389. https://doi.org/10.1016/j.respol.2007.10.009

Habib, A., & Hasan, M. M. (2019). Corporate social responsibility and cost stickiness. *Business & Society*, *58*(3), 453–492. https://doi.org/10.1177/0007650316677936

Hadlock, C. J., & Pierce, J. R. (2010). New evidence on measuring financial constraints: Moving beyond the KZ index. *The Review of Financial Studies*, *23*(5), 1909–1940.

Hainmueller, J. (2012). Entropy balancing for causal effects: A multivariate reweighting method to produce balanced samples in observational studies. *Political Analysis*, *20*(1), 25–46. https://doi.org/10.1093/pan/mpr025

Hall, B. H. (2002). The financing of research and development. *Oxford Review of Economic Policy*, *18*(1), 35–51. https://doi.org/10.1093/oxrep/18.1.35

Hartlieb, S., & Loy, T. R. (2022). The impact of cost stickiness on financial reporting: Evidence from income smoothing. *Accounting & Finance*, *62*(3), 3913–3950. https://doi.org/10.1111/acfi.12910

He, J., Tian, X., Yang, H., & Zuo, L. (2020). Asymmetric cost behavior and dividend policy. *Journal of Accounting Research*, *58*(4), 989–1021. https://doi.org/10.1111/1475-679X.12328

He, X., & Jiang, S. (2019). Does gender diversity matter for green innovation? *Business Strategy and the Environment*, *28*(7), 1341–1356. https://doi.org/10.1002/bse.2319

Hewitt-Dundas, N., & Roper, S. (2010). Output additionality of public support for innovation: Evidence for Irish manufacturing plants. *European Planning Studies*, *18*(1), 107–122. https://doi.org/10.1080/09654310903343559

Hojnik, J., & Ruzzier, M. (2016). What drives eco-innovation? A review of an emerging literature. *Environmental Innovation and Societal Transitions*, *19*, 31–41. https://doi.org/10.1016/j.eist.2015.09.006

Holzhacker, M., Krishnan, R., & Mahlendorf, M. D. (2015). The impact of changes in regulation on cost behavior. *Contemporary Accounting Research*, *32*(2), 534–566. https://doi.org/10.1111/1911-3846.12082

Homburg, C., Hoppe, A., Nasev, J., Reimer, K., & Uhrig-Homburg, M. (2019). *How cost stickiness affects credit risk.*

Hussain, M. J., Gao Liang, T., Ashraf, A., & Alkebsee, R. H. (2024). Ceo's time perspective influence on green innovation. *Spanish Journal of Finance and Accounting/Revista Española de Financiación y Contabilidad*, *53*(3), 323–354. https://doi.org/10.1080/02102412.2023.2256082

Ibrahim, A. E. A., Ali, H., & Aboelkheir, H. (2022). Cost stickiness: A systematic literature review of 27 years of research and a future research agenda. *Journal of International Accounting, Auditing and Taxation*, *46*, 100439. https://doi.org/10.1016/j.intaccaudtax.2021.100439

Karakaya, E., & Sriwannawit, P. (2015). Barriers to the adoption of photovoltaic systems: The state of the art. *Renewable and Sustainable Energy Reviews*, *49*, 60–66. https://doi.org/10.1016/j.rser.2015.04.058

Kim, J.-B., & Zhou, J. (2023). Cost stickiness and bank loan contracting. *Advances in Accounting*, *61*, 100645. https://doi.org/10.1016/j.adiac.2023.100645

Ko, H., Chung, Y., & Woo, C. (2021). Choice of R & amp;D strategy and asymmetric cost behaviour. *Technology Analysis & Strategic Management*, *33*(9), 1022–1035. https://doi.org/10.1080/09537325.2020.1862786

Lee, W. J., Pittman, J., & Saffar, W. (2020). Political uncertainty and cost stickiness: Evidence from national elections around the world. *Contemporary Accounting Research*, *37*(2), 1107–1139.

Li, P., Shu, W., Tang, Q., & Zheng, Y. (2019). Internal control and corporate innovation: Evidence from China. *Asia-Pacific Journal of Accounting & Economics*, *26*(5), 622–642. https://doi.org/10.1080/16081625.2017.1370380

Li, Z., Liu, B., & Liu, Y. (2023). Does the presentation reform of R & amp;D expenses in China ease financial constraints in corporate innovation? *Journal of International Financial Management & Accounting*, *34*(3), 826–851. https://doi.org/10.1111/jifm.12169
Liang, S., Chen, D., & Hu, X. (2014). External auditor types and the cost stickiness of listed companies. *China Journal of Accounting Studies*, *2*(4), 294–322. https://doi.org/10.1080/21697213.2014.982004
Lin, W.-L., Cheah, J.-H., Azali, M., Ho, J. A., & Yip, N. (2019). Does firm size matter? Evidence on the impact of the green innovation strategy on corporate financial performance in the automotive sector. *Journal of Cleaner Production*, *229*, 974–988. https://doi.org/10.1016/j.jclepro.2019.04.214
Lin, W. L., Mohamed, A. B., Sambasivan, M., & Yip, N. (2020). Effect of green innovation strategy on firm-idiosyncratic risk: A competitive action perspective. *Business Strategy and the Environment*, *29*(3), 886–901. https://doi.org/10.1002/bse.2405
Lyu, H., Ma, C., & Arash, F. (2024). Government innovation subsidies, green technology innovation and carbon intensity of industrial firms. *Journal of Environmental Management*, *369*, 122274. https://doi.org/10.1016/j.jenvman.2024.122274
McMullin, J. L., & Schonberger, B. (2020). Entropy-balanced accruals. *Review of Accounting Studies*, *25*(1), 84–119. https://doi.org/10.1007/s11142-019-09525-9
Naoum, V.-C., Ntounis, D., Papanastasopoulos, G., & Vlismas, O. (2023). Asymmetric cost behavior: Theory, meta-analysis, and implications. *Journal of International Accounting, Auditing and Taxation*, *53*, 100578. https://doi.org/10.1016/j.intaccaudtax.2023.100578
Noreen, E. (1991). Conditions under which activity-based cost systems provide relevant costs. *Journal of Management Accounting Research*, *3*, 159-168.
Ntounis, D., & Vlismas, O. (2025). Exploring the predictive ability of cost asymmetry on bankruptcy. *The European Journal of Finance*, *31*(5), 553–593.
Pan, Z., Zhang, G., & Zhang, H. (2022). Political uncertainty and cost stickiness: Evidence from prefecture-city official turnover in China. *China Accounting and Finance Review*, *24*(2), 142–171. https://doi.org/10.1108/CAFR-02-2022-0007
Peng, Y.-S., & Lin, S.-S. (2008). Local responsiveness pressure, subsidiary resources, green management adoption and subsidiary's performance: Evidence from Taiwanese manufactures. *Journal of Business Ethics*, *79*(1–2), 199–212. https://doi.org/10.1007/s10551-007-9382-8
Prabowo, R., Hooghiemstra, R., & Van Veen-Dirks, P. (2018). State ownership, socio-political factors, and labor cost stickiness. *European Accounting Review*, *27*(4), 771–796. https://doi.org/10.1080/09638180.2017.1329659
Quan, X., Ke, Y., Qian, Y., & Zhang, Y. (2021). Ceo foreign experience and green innovation: Evidence from China. *Journal of Business Ethics*, 1–23.
Sánchez-Sellero, P., & Bataineh, M. J. (2022). How R &D cooperation, R&D expenditures, public funds and R&D intensity affect green innovation? *Technology Analysis & Strategic Management*, *34*(9), 1095–1108. https://doi.org/10.1080/09537325.2021.1947490
Shao, K., & Wang, X. (2023). Do government subsidies promote enterprise innovation?--evidence from Chinese listed companies. *Journal of Innovation & Knowledge*, *8*(4), 100436. https://doi.org/10.1016/j.jik.2023.100436
Shao, W., Yang, K., & Bai, X. (2021). Impact of financial subsidies on the R &D intensity of new energy vehicles: A case study of 88 listed enterprises in China. *Energy Strategy Reviews*, *33*, 100580. https://doi.org/10.1016/j.esr.2020.100580
Shen, F., Liu, B., Luo, F., Wu, C., Chen, H., & Wei, W. (2021). The effect of economic growth target constraints on green technology innovation. *Journal of Environmental Management*, *292*, 112765. https://doi.org/10.1016/j.jenvman.2021.112765
Su, K. (2019). Does religion benefit corporate social responsibility (CSR)? Evidence from China. *Corporate Social Responsibility and Environmental Management*, *26*(6), 1206–1221.
Takalo, T., & Tanayama, T. (2010). Adverse selection and financing of innovation: Is there a need for R &D subsidies? *The Journal of Technology Transfer*, *35*(1), 16–41. https://doi.org/10.1007/s10961-009-9112-8

Tang, L., Huang, Y., Liu, J., & Wan, X. (2022). Cost stickiness and stock price crash risk: Evidence from China. *Emerging Markets Finance and Trade*, *58*(2), 544–569. https://doi.org/10.1080/1540496X.2020.1787148

Tang, Q. (2019). Cost stickiness, corporate future losses and audit costs. *American Journal of Industrial and Business Management*, *10*(1), 110–134. https://doi.org/10.4236/ajibm.2020.101008

Wang, L., Long, Y., & Li, C. (2022). Research on the impact mechanism of heterogeneous environmental regulation on enterprise green technology innovation. *Journal of Environmental Management*, *322*, 116127. https://doi.org/10.1016/j.jenvman.2022.116127

Weiss, D. (2010). Cost behavior and analysts' earnings forecasts. *The Accounting Review*, *85*(4), 1441–1471. https://doi.org/10.2308/accr.2010.85.4.1441

Wong, S. K. S. (2013). Environmental requirements, knowledge sharing and green innovation: Empirical evidence from the electronics industry in China. *Business Strategy and the Environment*, *22*(5), 321–338. https://doi.org/10.1002/bse.1746

Xiao, H. (2023). Do cost behaviors affect cost of equity: Evidence from seasoned equity offering? *Asia-Pacific Journal of Financial Studies*, *52*(4), 565–608. https://doi.org/10.1111/ajfs.12441

Xie, X., Zhu, Q., & Wang, R. (2019). Turning green subsidies into sustainability: How green process innovation improves firms' green image. *Business Strategy and the Environment*, *28*(7), 1416–1433. https://doi.org/10.1002/bse.2323

Xu, S., & Zheng, K. (2020). Tax avoidance and asymmetric cost behavior. *Journal of Accounting, Auditing & Finance*, *35*(4), 723–747. https://doi.org/10.1177/0148558X18793757

Xue, S., & Hong, Y. (2016). Earnings management, corporate governance and expense stickiness. *China Journal of Accounting Research*, *9*(1), 41–58. https://doi.org/10.1016/j.cjar.2015.02.001

Yao, Q., Zeng, S., Sheng, S., & Gong, S. (2021). Green innovation and brand equity: Moderating effects of industrial institutions. *Asia Pacific Journal of Management*, *38*(2), 573–602. https://doi.org/10.1007/s10490-019-09664-2

Zhang, D., & Jin, Y. (2021). R &D and environmentally induced innovation: Does financial constraint play a facilitating role? *International Review of Financial Analysis*, *78*, 101918. https://doi.org/10.1016/j.irfa.2021.101918

Zhang, Y., Xing, C., & Wang, Y. (2020). Does green innovation mitigate financing constraints? Evidence from China's private enterprises. *Journal of Cleaner Production*, *264*, 121698. https://doi.org/10.1016/j.jclepro.2020.121698

Zhang, Z., & Li, M. (2025). Management expectations and operating cost responses to COVID-19: A study of Chinese listed enterprises. *Spanish Journal of Finance and Accounting/Revista Española de Financiación y Contabilidad*, *54*(2), 166–187. https://doi.org/10.1080/02102412.2024.2445994

Zhao, S., Abbassi, W., Hunjra, A. I., & Zhang, H. (2024). How do government R &D subsidies affect corporate green innovation choices? Perspectives from strategic and substantive innovation. *International Review of Economics & Finance*, *93*, 1378–1396. https://doi.org/10.1016/j.iref.2024.04.014

Appendix

Variable	Definition
GP	Refers to green innovation measured as the natural logarithm of one plus the number of green patents.
GPP	Refers to green innovation measured as the natural logarithm of one plus the number of green processes.
OPCS	Represents the degree of stickiness in total operating costs, which is calculated using Weiss's (2010) model as specified in Equation (3).
SAGCS	Represents the degree of stickiness in SA&G costs, which is calculated using Weiss's (2010) model as specified in Equation (3).
BSIZE	The number of directors on the board.
BDIND	The proportion of independent directors on the board.
BMEET	The number of board meetings held in a year t
DUALITY	An indicator variable coded 1 if the CEO is also the chairman of the board and 0 otherwise.
SIZE	The firm size is measured as the natural log of total assets.
ROA	A return on assets is measured by net profit scaled by total assets.
BTM	Book to market measured total book value scaled by total market value.
LOSS	A dummy coded 1 if a firm incurred a loss, and 0 otherwise.
DEBT	The firm's leverage is measured by total debts to total assets.
MANOWN	The ratio of shares held by executives.
SOE	A dummy variable coded 1 if the ultimate controller is the government, and zero otherwise.
FCDUM	A dummy variable refers to financial constraints (FC) which is coded as 1 if a firm is financially constrained and zero otherwise. The dummy variable constructed using the median value of SA index, if the firm-year observation has a value greater than or equal the median we coded it one, zero otherwise. The SA index (Hadlock & Pierce, 2010) is as follows SA= (−0.737*SIZE) + (0.043* $SIZE_2$) - (0.040*AGE). Where SIZE refers to the firm size measured as the total assets and AGE refers to the number of years a firm has been listed.
RD	Refers to R&D expenses measured as the logarithm of R&D expenses.
SUBSIDIES	Refers to government subsidies granted to a firm, we use it as the natural logarithm of total R&D and green subsidies granted to a firm in year t.