Corporate and Green Innovation in China: An Analysis of CEO Overconfidence, Equity Incentives, and Political Connections

By

Shuo Kang

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Declaration

This thesis is the result of the author’s original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.

Signed: 康硕

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Abstract

Corporate innovation is a critical engine for economic growth and firm sustainability. Within transitional economies such as China, its determinants are shaped by distinctive institutional features and the evolving interaction between market mechanisms and state influence. This thesis examines the drivers of innovation among Chinese listed firms through three complementary empirical studies on executive beliefs, internal incentive design, and political embeddedness. The first two studies analyse general corporate innovation, while the third focuses on green innovation, a policy-sensitive form of innovation that has become increasingly important during China's green transition.

The first study develops a holdings-based revealed-beliefs proxy of CEO overconfidence adapted to Chinese data by extending the intuition of the Holder 67 measure. It shows that CEO overconfidence is positively associated with patent citation outcomes, with a stronger association in state-owned enterprises, while the moderating effect of CEO duality is concentrated in utility model patent citations. The second study examines whether equity incentives promote innovation among Chinese listed companies following the 2006 regulatory reforms. It finds a significant positive association between equity incentives and corporate innovation. Option-based instruments are more strongly associated with higher-value invention outcomes, incentives targeted at core technical and business personnel are more effective than those targeted at executives, and the positive relation is stronger in non-state-owned firms and technology-intensive industries. The third study shifts the focus to green innovation and analyses how CEO political connections and local officials' promotion incentives jointly shape green innovation in Chinese private listed firms. The evidence shows that political connections significantly increase green invention patent output, while their effect on green utility model innovation is weaker and statistically insignificant. This positive effect is more pronounced in lower-level cities, in regions with stricter environmental regulation, and among heavily polluting firms, and it is further strengthened when mayoral promotion incentives are stronger in quasi-sub-provincial and ordinary prefecture-level cities.

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Chapter 1
General Introduction

1.1 Background and Motivation

In an era of accelerating global economic integration and technological change, corporate innovation has become a central source of sustained economic growth and long-term firm competitiveness (Aghion et al., 2005). Innovation is understood not merely as the introduction of new products, processes, or services, but more broadly as the generation, absorption, recombination, and commercialisation of knowledge in response to evolving technological opportunities and competitive conditions (Dosi, 1988; Cohen and Levinthal, 1990). For firms, innovation is therefore not an isolated technical activity; rather, it constitutes a strategic decision domain that shapes productivity, market positioning, and long-run development. At the same time, innovation differs from routine corporate investment because it typically entails substantial upfront commitment, long gestation periods, high uncertainty, and outputs that are often intangible and difficult to evaluate ex ante (March, 1991; Hall et al., 2010). These characteristics imply that corporate innovation outcomes depend not only on external conditions such as the macroeconomic environment, industry structure, and market opportunities, but also on how firms allocate decision authority, design incentive mechanisms, and translate managerial judgements into strategic action within a broader institutional environment.

Against this broader background, China, as one of the world's largest economies and an important arena for innovation activity, provides a particularly rich context for examining corporate innovation in a transitional economy. The Chinese economy is undergoing a profound shift from growth driven primarily by factor accumulation to growth led increasingly by innovation, and the government has placed the enhancement of indigenous innovation capabilities at the core of its national development strategy. Compared to mature market economies, China's institutional environment reflects the dual features of rapid development and systemic transition:

market-supporting institutions remain unevenly developed; the coexistence of state-owned and private enterprises gives rise to substantial differences in governance structures and incentive arrangements; and the government continues to play a significant role in resource allocation, industrial development, and the broader policy environment facing firms. This institutional configuration provides a rich and complex research context for understanding corporate innovation behaviour and suggests that theories developed in mature markets must be critically examined and appropriately adapted to the Chinese setting. Therefore, an investigation into the key drivers influencing the innovation performance of Chinese firms and their underlying mechanisms within this specific institutional framework not only holds significant theoretical value but also offers practical guidance for the innovation practices of Chinese enterprises and for relevant policymaking.

This thesis focuses specifically on China as a transitional economy, systematically examining several core factors that influence corporate innovation output, including both general and green innovation, from distinct yet complementary perspectives. Specifically, this research explores three dimensions: First, the individual traits and behavioural biases of executives, particularly how psychological factors (such as overconfidence) of Chief Executive Officers (CEOs), as the ultimate decision-makers for corporate strategy, shape firms' innovation outcomes under different ownership and governance arrangements. Second, internal incentive mechanisms within firms, especially how equity incentives, as an important corporate governance tool, shape corporate innovation across different incentive instruments, recipient groups, ownership structures, and industry contexts. Third, the interaction between firms and the external political and institutional environment, specifically how CEOs' political connections, influence corporate investment and performance in specific strategic areas such as green innovation against a backdrop of increasing emphasis on sustainable development. These three studies collectively revolve around the central theme of the drivers of corporate innovation in the Chinese context. They aim to reveal how individual, organisational, and external relational factors jointly shape corporate innovation behaviour and performance under specific governance structures, incentive frameworks, and institutional backgrounds.

The core motivation for this thesis lies in assessing the extent to which established theoretical explanations of corporate innovation retain explanatory power in the Chinese context, and in clarifying the mechanisms through which executive beliefs, organisational incentives, and political embeddedness shape innovation outcomes under China's institutional conditions. For instance, Upper Echelons Theory emphasises the profound influence of managerial characteristics on corporate decisions (Hambrick and Mason, 1984). However, when investigating the relationship between CEO psychological biases, such as overconfidence, and corporate innovation, measurement approaches developed primarily in mature markets are often difficult to implement directly in China because the relevant data are limited; moreover, the extent to which such belief distortions are translated into innovation outcomes may depend on local ownership structures and governance arrangements. Similarly, Agency Theory provides a theoretical foundation for equity incentives (Jensen and Meckling, 1976). Yet, with the gradual expansion of equity incentive plans among Chinese listed companies, it remains important to examine whether the established incentive-innovation relationship operates similarly in the Chinese market and how it varies across incentive instruments, recipient groups, ownership structures, and industry contexts. Furthermore, Resource Dependence Theory suggests that political connections may help firms obtain access to policy information, administrative support, and other strategic resources (Pfeffer and Salancik, 1978). However, under China's strategic orientation toward green transformation and high-quality development, whether such political embeddedness can be translated into green innovation outcomes in private firms, and how local officials' promotion incentives condition this process, remain insufficiently understood. Taken together, these considerations motivate the three studies in this thesis, each of which examines how a distinct but related mechanism shapes corporate innovation in China.

1.2 Overview of Three Studies

1.2.1 CEO Overconfidence and Corporate Innovation

A profound understanding of corporate strategic choices and behavioural patterns necessitates an examination of the characteristics of executives. As highlighted by

Upper Echelons Theory (Hambrick and Mason, 1984), managers' intrinsic values, personality traits, and cognitive structures are key forces shaping corporate strategy and performance. Among the various traits of executives, overconfidence, defined as an individual's tendency to systematically overestimate the accuracy of their own judgments or the likelihood of favourable future outcomes (Barber and Odean, 2001; Malmendier and Tate, 2015), has garnered considerable attention due to its profound impact on critical corporate decisions such as financing, investment, and mergers and acquisitions. Particularly in strategic areas related to corporate innovation, overconfidence is often considered a "double-edged sword" (Galasso and Simcoe, 2011): On the one hand, it may drive managers to commit more resources to uncertain, long-horizon innovation projects and to seize emerging opportunities more quickly (Hirshleifer et al., 2012). On the other hand, it can also lead to overinvestment, resource misallocation, and investment failures when managerial beliefs deviate too far from objective conditions (Malmendier and Tate, 2005a). Although a substantial body of literature has explored the economic consequences of CEO overconfidence, China's unique institutional and cultural context introduces particular complexities: this setting involves the coexistence of state-owned enterprises (SOEs) and private firms and distinct corporate governance structures (notably the CEO-chairperson duality), which contribute to potential conflicts between collectivist values and individual tendencies towards confidence. Therefore, how CEO overconfidence impacts corporate innovation within this specific environment, along with its underlying mechanisms and boundary conditions, still warrants further detailed analysis.

Therefore, the initial study in this thesis focuses on this issue, systematically examining the impact of CEO overconfidence on the innovation output of Chinese A-share listed companies. It further investigates how enterprise ownership and corporate governance arrangements moderate this relationship. One of the core challenges of this study lies in the effective measurement of overconfidence. Metrics widely adopted in mature markets literature, such as those based on executive option exercising behaviour, have limited applicability in the Chinese context. This is primarily due to the less prevalent use of certain incentive tools like stock options in China's capital market, coupled with significant constraints on relevant data availability. Therefore, a key methodological contribution of this study is the development of a holdings-based revealed-beliefs proxy of CEO overconfidence specifically tailored to this Chinese environment. This measure adapts the identification spirit of the internationally recognised "Holder 67" concept to the compensation and data structure of Chinese listed companies. Specifically, it combines stockholding concentration, a normative portfolio-choice benchmark, a China-specific expected-return benchmark, and repeated non-selling behaviour, thereby aiming to capture persistent firm-specific over-optimism embedded in CEOs' stockholding behaviour. This measurement approach, which is better suited to the local context, furnishes a more feasible and operational analytical tool and empirical basis for subsequent research on executive psychological traits and corporate strategic decision-making in China and other emerging markets. Employing this localised measurement method and drawing on a large dataset spanning from 2005 to 2020, complemented by multiple robustness checks, this study thoroughly investigates the role of CEO overconfidence in Chinese corporate innovation, thereby revealing the complexity and context-dependency of its effects. Corporate innovation is primarily measured by subsequent patent citation counts, and subsequent robustness checks involve comparative analyses using alternative metrics such as R&D intensity and patent grant numbers. Overall, CEO overconfidence is found to be positively associated with subsequent corporate innovation outcomes, with this effect being particularly pronounced in SOEs. However, the moderating role of CEO-chairperson duality is not uniform across patent types: the interaction is mainly concentrated in utility model patent citations, whereas no robust weakening effect is identified for invention patents or for the aggregate citation measure. These findings not only address the call for enhancing the explanatory power of Upper Echelons Theory across diverse institutional settings, but also more specifically illuminate how particular Chinese ownership and governance factors shape the relationship between managerial belief distortions and corporate innovation.

1.2.2 Equity Incentives and Corporate Innovation

In addition to the psychological traits of decision-makers, well-designed internal incentive mechanisms within firms, particularly those arrangements aimed at aligning the interests of principals and agents, and fostering long-term value creation, are equally crucial for stimulating innovative vitality. Agency Theory (Jensen and Meckling, 1976) posits that by linking the interests of management and key employees to the long-term development of the firm, agency costs arising from goal incongruence can be effectively mitigated, thereby guiding them to strive for shareholder value maximisation. Equity incentives, as one of the core tools of modern corporate governance, are predicated on this logic. By linking a portion of compensation to future firm value, and in some cases granting residual claims, the aim is thereby to encourage them to undertake necessary risks and engage in innovative activities characterised by high uncertainty, long horizons, and potentially substantial rewards (Manso, 2011; Core and Guay, 1999). However, whether and how equity incentives effectively promote corporate innovation, particularly as their effects may vary across incentive scheme designs, recipient groups, and institutional contexts, remains a subject of ongoing debate. Some studies raise concerns that, if poorly designed, equity incentives might induce managerial short-termism or an excessive preference for incremental innovation (Manso, 2011). Conversely, other research underscores their potential to more effectively stimulate innovative drive, particularly in specific industries or when targeted at certain employee groups such as core technical and business personnel (Ittner et al., 2003).

Against this backdrop, the second study in this thesis conducts an examination of the actual impact of equity incentive schemes on the innovation output of Chinese A-share listed companies, following the implementation of the "Administrative Measures for Equity Incentives of Listed Companies (Trial)" by the China Securities Regulatory Commission (CSRC) in 2006. This study pays particular attention to China's unique institutional environment, including differences in property rights between SOEs and private enterprises, the efficacy of various types of equity incentive instruments, the heterogeneity of incentive recipients, and variation across industry contexts. Drawing upon a large dataset from 2007 to 2021, the study finds that equity incentives exhibit a significant positive association with corporate innovation, whether measured by plan adoption or by the intensity of incentives under implementation, and this positive pattern remains broadly consistent when alternative measures based on patent grants and R&D expenditure are considered. Moreover, the study further shows that option-based incentive instruments are more strongly associated with higher-value invention outcomes, that incentives directed at core technical and business personnel are more effective than those directed at executives, and that the positive relation is more pronounced in non-SOEs and technology-intensive industries. Consequently, this research not only furnishes robust and longitudinal empirical evidence supporting the prevailing view that equity incentives drive corporate innovation in the Chinese context but also contributes crucial insights regarding organisational-level incentive arrangements through its methodological rigour and its detailed analysis of incentive design specifics and firm contexts. These insights, in turn, advance the overarching goal of this thesis: to comprehensively elucidate the mechanisms driving corporate innovation in China.

1.2.3 Political Connections, Officials' Promotion Incentives, and Green Innovation

Following the preceding discussions on how executive traits and internal incentive mechanisms shape corporate innovation behaviour, this thesis further extends its research perspective to the interaction between firms and their external institutional environment, with a particular focus on the political environment. Against a backdrop in which Environmental, Social, and Governance (ESG) principles are increasingly recognised as core standards for assessing corporate sustainability and long-term value (Eccles et al., 2014; Friede et al., 2015), and with China elevating its green and low-carbon transition to a national strategic priority, corporate green innovation has emerged not only as a vital means of fulfilling social responsibilities and combating climate change, but also as an increasingly important strategic pillar for establishing future competitive advantages. However, green innovation typically entails substantial upfront investments, long development cycles, technological uncertainties, and a significant reliance on the policy and regulatory environment. Consequently, as firms endeavour to advance green technologies, their interactions with governmental and political systems become particularly crucial.

In the distinctive context of China, where the government maintains a substantial role in economic development and intricate relational networks remain highly salient, the political connections of corporate executives are regarded as a crucial non-market strategic resource. These connections are believed to facilitate firms' access to critical resources, mitigate policy uncertainty, and potentially secure regulatory advantages (Xin and Pearce, 1996; Faccio, 2006; Li et al., 2008). Although existing literature has investigated the potential "resource effect" or "rent-seeking effect" of political connections on corporate behaviour and innovation (Pfeffer and Salancik, 1978; Shleifer and Vishny, 1994), their precise role and the mechanisms through which they influence different types of green innovation output are not yet fully elucidated. Furthermore, the available empirical evidence frequently reveals complex, and at times, contradictory outcomes. More importantly, the distinctive "promotion tournament" among local officials in China (Li and Zhou, 2005), together with the increasing incorporation of environmental performance into cadre evaluation frameworks, introduces an additional critical dimension of political economy to the understanding of corporate green behaviour. While the career advancement incentives of local officials may affect the intensity of regulatory oversight and the level of support for firms' environmental practices within their jurisdictions, how these official-level incentives interact with firm-level political connections to collectively determine green innovation outcomes remains a nascent area of research demanding thorough investigation.

To this end, the third study in this thesis is dedicated to uncovering the impact of CEO political connections on the green innovation output of Chinese A-share listed private enterprises. Furthermore, it innovatively investigates the moderating role of local officials' promotion incentives within this dynamic. The study's core research questions are: Do CEO political connections drive firms to engage in green innovation? And under which institutional contexts (such as city administrative hierarchy, the stringency of local environmental regulations, and the pollution intensity of the firm's industry) is this effect more significant? A particularly significant theoretical contribution of this research is its novel approach of integrating firm-level political connections and the career promotion incentives of local government officials, two factors typically examined in isolation, into a unified analytical framework to assess their combined influence on corporate green innovation. Utilising long-span panel data and supported by additional checks addressing potential endogeneity concerns, this study undertakes a systematic empirical investigation of the aforementioned questions.

The core findings indicate that higher levels of CEO political connections significantly increase green invention patent output, whereas their effect on green utility model patent output is comparatively weaker and less robust across specifications. Consistent with contingency theory, the positive impact of political connections is more pronounced in cities with lower administrative levels, in regions subject to stricter environmental regulation, and among firms operating in high-pollution industries. Crucially, the study further shows that stronger mayoral promotion-window intensity significantly strengthens the positive relationship between CEO political connections and green invention patent output in quasi-sub-provincial and ordinary prefecture-level cities. Consequently, this study not only provides more granular empirical evidence on the role of political connections in advancing the green transition of Chinese enterprises, but, through its pioneering integration of a political economy perspective that uncovers the interaction between officials' career incentives and corporate political ties, it also offers significant theoretical insights into the intricate dynamics among political embeddedness, institutional incentives, and corporate sustainable development strategies within transitional economies. As such, it constitutes a component of the broader investigation within this thesis into the drivers of innovation in Chinese firms.

1.3 Structure of the Thesis

This thesis is organised into five chapters, structured as follows:

Chapter 1 is the general introduction, which elucidates the research background and motivation, outlines the principal content and contributions of the three empirical studies, and presents the overall structure of the thesis. Chapters 2 through 4 each correspond to one of the three empirical research studies, which are relatively independent yet thematically interconnected: Chapter 2 explores the impact of CEO overconfidence on corporate innovation; Chapter 3 analyses the differential effects of equity incentives on corporate innovation; and Chapter 4 focuses on how CEO political connections and the promotion incentives of local officials jointly influence corporate green innovation. Chapter 5 serves as the general conclusion, summarising the main findings from the three studies, discussing the theoretical and practical implications, and acknowledging the limitations of the research.

Chapter 2
CEO Overconfidence and Corporate Innovation: Evidence from China

2.1 Introduction

Corporate innovation is a key source of firm-level competitive advantage and, more broadly, an important driver of economic growth, while executives' personal traits exert profound influences on corporate strategic decisions (Barker and Mueller, 2002). Because many innovation projects are characterised by high uncertainty, long horizons, and skewed payoffs, managers exhibiting overconfidence may commit more resources to research and development (R&D) and pursue bolder innovative strategies, thereby increasing the likelihood that firms move earlier than rivals in exploiting emerging technological opportunities (Malmendier and Tate, 2005a; Malmendier and Tate, 2005b; Hirshleifer et al., 2012). However, the same bias may also lead to overinvestment, blind expansion, or resource misallocation when managerial beliefs deviate too far from objective conditions, especially in emerging markets where institutional and market imperfections can amplify behavioural distortions (Zhou et al., 2021; Li and Tang, 2010).

China provides a particularly relevant setting in which to examine this issue. The coexistence of state-owned enterprises (SOEs) and private firms, the continued importance of state support and intervention in innovation activities and marked differences in governance arrangements all shape how managerial traits are translated into firm-level decisions (Liu and White, 2001; Firth et al., 2006). On the one hand, policy support, resource availability, and market scale may create room for more ambitious innovation strategies. On the other hand, bureaucratic frictions, weaker market-oriented incentives, and concentrated decision authority may alter the way managerial beliefs affect innovation outcomes. In particular, SOEs possess relatively abundant resources and institutional protection, while CEO-chair duality concentrates strategic authority in a single individual and may therefore influence the extent to which personal beliefs are translated into innovation choices.

Against this background, this study focuses on Chinese A-share listed companies and examines how CEO overconfidence affects corporate innovation, while also considering whether enterprise ownership and CEO duality moderate this relationship. A central challenge in this setting is the measurement of overconfidence. To preserve the identification spirit of the mature-market literature while remaining feasible under Chinese data constraints, this study constructs a holdings-based revealed-beliefs proxy of CEO overconfidence. Specifically, the measure combines year-end stockholding concentration, a normative portfolio-choice benchmark, a China-specific expected-return benchmark, and repeated non-selling behaviour to infer persistent firm-specific over-optimism from observable holdings data, rather than relying on option exercise behaviour or on simple short-term shareholding changes alone (Malmendier and Tate, 2005a; Hall and Murphy, 2002; Liu et al., 2019). Corporate innovation is primarily measured by subsequent patent citation outcomes, and additional analyses use R&D intensity and patent grants as alternative innovation measures. Using data on Chinese listed firms from 2005 to 2020, this study finds that CEO overconfidence is positively associated with subsequent patent citation outcomes, and that this positive association is significantly stronger in SOEs. By contrast, the moderating role of CEO duality is not uniform across patent types: the interaction is concentrated in utility model patent citations, whereas no robust weakening effect is found for invention patents or for the aggregate citation measure. These findings underscore the importance of executive beliefs in corporate strategic decision-making while highlighting the institutional and governance contingencies of innovation in the Chinese context. The remainder of the chapter reviews relevant literature, develops hypotheses, introduces the data, variables, and methodology, presents the main empirical results and robustness checks, and concludes with a summary and discussion of the findings.

2.2 Literature Review and Hypothesis Development

As a widely studied psychological bias in behavioural science and management, overconfidence is broadly viewed as individuals' systematic tendency to hold overly favourable assessments of their own judgments or future outcomes (Barber and Odean, 2001; Malmendier and Tate, 2015). Importantly, the psychology literature suggests that overconfidence is not a single, monolithic construct but a family of related biases, often discussed as overestimation (overly high absolute assessments), overplacement (believing oneself to be better than others), and overprecision (excessive certainty regarding the accuracy of one's beliefs) (Moore and Healy, 2008). Consistent with this multifaceted nature, scholars have proposed multiple definitions of overconfidence, resulting in relatively mature yet distinct research perspectives. On the one hand, Weinstein (1980) characterises overconfidence as an unrealistic optimism about the future, whereby individuals tend to overestimate the probability of favourable events and underestimate that of adverse events. In this sense, forecasts may be systematically tilted towards desired outcomes, and optimism bias can arise even in settings that are objectively probabilistic (Langer and Roth, 1975). Related evidence also documents persistent "better-than-average" assessments in self-evaluations, which reflects a comparative component of overconfidence (Svenson, 1981). On the other hand, from a subjective probability standpoint, Lichtenstein et al. (1982) argue that overconfidence arises when individuals systematically misjudge the likelihood of uncertain events and the correctness of their own assessments. This line of research places particular emphasis on miscalibration in subjective probabilities and judgment accuracy, including the tendency to express extreme confidence that is not supported by actual performance (Fischhoff et al., 1977). Moreover, overconfidence is closely linked to how people process and weight evidence, as individuals may place disproportionate emphasis on salient or strength-based signals relative to the informational weight of the evidence, thereby generating excessive confidence (Griffin and Tversky, 1992). While the former perspective stresses directional optimism about outcomes, the latter focuses more on miscalibration and excessive certainty regarding probabilities and judgment precision; together, they point to systematic distortions in subjective assessments under uncertainty. In addition, Langer (1975) and Langer and Roth (1975) introduced the concept of "illusion of control", further explaining overconfidence as a tendency to overrate one's role in achieving success, even in intrinsically random or uncontrollable situations. This strong self-attribution of personal accomplishments is viewed in social psychology as meeting psychological needs for self-esteem and self-efficacy (Taylor and Brown, 1988). Because these mechanisms operate through subjective assessments, finance research typically frames overconfidence as overestimating the accuracy or precision of investment-related information or personal knowledge while underappreciating downside uncertainty and risk (Odean, 1998; Barber and Odean, 2000), with behavioural consequences such as excessive trading and under-diversification (Barber and Odean, 2001). Notably, such biases are not confined to lay individuals; empirical evidence suggests that even corporate decision-makers may exhibit systematic miscalibration (Ben-David et al., 2013). Overall, overconfidence, as a pervasive psychological and behavioural bias, can involve both an optimistic assessment of the external environment and an overestimation of one's own abilities; it manifests in multiple forms and is measured through diverse methods. Although scholars differ in definitions and focal points, they commonly acknowledge its potential influence on individual decisions and organisational performance (Odean, 1998; Camerer and Lovallo, 1999).

Building on this behavioural foundation, Hambrick and Mason (1984) propose Upper Echelons Theory, arguing that organisational outcomes can be understood as reflections of top executives' cognitive bases and values. A central premise is that strategic environments are complex and often characterised by ambiguity and incomplete information, such that decision-makers face bounded rationality and cannot fully observe, process, or interpret all relevant signals (Simon, 1955; March and Simon, 1958). In such settings, executives necessarily rely on simplifying cognitive frames and selective attention when forming expectations and evaluating strategic alternatives, which makes their internal values, personality traits, and cognitive structures particularly influential in shaping strategic choices and organisational behaviours (Carpenter et al., 2004; Hambrick, 2007). The role of executive characteristics is expected to be especially pronounced when managerial discretion is high and when outcomes are difficult to evaluate ex ante, because the informational and contractual constraints that would otherwise discipline decision-making are weaker (Hambrick and Finkelstein, 1987). Corporate innovation decisions fit this profile closely: they involve long horizons, uncertain technological trajectories, and substantial upside and downside tail risks, thereby leaving considerable scope for managerial judgment to affect both the direction and intensity of innovative activity. Within this theoretical framework, CEO overconfidence has gradually emerged as a major research focus in behavioural corporate finance, as it represents a systematic distortion in how decision-makers assess uncertain outcomes. From an economic perspective, choices under uncertainty reflect both managers' subjective beliefs about payoffs and their risk preferences; accordingly, observed "risk-taking" corporate policies can arise either because managers are more tolerant of risk or because they hold more optimistic or miscalibrated beliefs about success probabilities and downside uncertainty (Graham et al., 2013). The overconfidence literature primarily emphasises the latter channel, formalising overconfidence as biased beliefs or miscalibration in assessing future outcomes and risks (Odean, 1998; Malmendier and Tate, 2005a; Hackbarth, 2008; Ben-David et al., 2013). A growing body of evidence links CEO overconfidence to a range of discretionary corporate policies in which expectations and subjective assessments play a central role, including financing (Hackbarth, 2008), investment (Malmendier and Tate, 2005a), mergers and acquisitions (Hayward and Hambrick, 1997; Doukas and Petmezas, 2007; Malmendier and Tate, 2008), earnings forecasting (Hribar and Yang, 2016), and payout decisions (Deshmukh et al., 2013). These policy domains share an important feature: managers must form beliefs about future cash flows, competitive responses, and downside risks under uncertainty, and systematic distortions in such beliefs can materially affect corporate outcomes. Innovation strategy is similarly expectation-driven and discretion-intensive, and recent studies increasingly examine how managerial overconfidence is associated with innovative outcomes and the quality of inventive output (Hirshleifer et al., 2012; Galasso and Simcoe, 2011). This evidence aligns naturally with the Upper Echelons view that executive cognition and belief formation are key channels through which managerial traits translate into observable strategic actions.

Importantly, not all CEOs exhibit the same level or form of overconfidence. Prior research suggests that demographic and career attributes such as age, education, industry experience, and tenure are associated with systematic differences in confidence-related biases and strategic styles (Barker and Mueller, 2002). For example, younger or newly appointed CEOs may face stronger incentives to demonstrate ability and improve performance rapidly, which can coincide with more aggressive strategic postures in uncertain settings where success probabilities are difficult to assess objectively (Hambrick and Fukutomi, 1991; Serfling, 2014). In addition, internal promotion and selection mechanisms may reinforce these patterns over time: managers who adopt more aggressive strategies and experience interim success are more likely to advance, while those who underperform are disproportionately screened out, generating an endogenous selection of executives with particular behavioural tendencies (Goel and Thakor, 2008). In this context, actions that appear risk-increasing ex post need not reflect a stronger preference for risk; they can be consistent with standard risk aversion when decision-makers systematically overestimate the likelihood of favourable outcomes or underestimate downside uncertainty (Malmendier and Tate, 2005a; Hackbarth, 2008). Regarding the persistence of managerial overconfidence, theoretical work highlights that belief distortions can be reinforced through learning and self-attribution processes: when outcomes are noisy and feedback is imperfect, decision-makers may overweight personal skill in successful episodes and underweight the role of luck or external conditions, which can lead them to update their confidence upward and to become increasingly certain about the accuracy of their judgments (Daniel et al., 1998; Gervais and Odean, 2001). Consistent with this view, overconfidence has been documented to vary with market states and broader economic dynamics, often rising in booms and receding as conditions deteriorate (Scheinkman and Xiong, 2003). At the same time, empirical evidence suggests that certain components of miscalibration may be persistent at the individual level (Ben-David et al., 2013). Overall, the literature implies that overconfidence can exhibit a degree of persistence yet remain responsive to personal experiences and changing environments, reinforcing the relevance of examining how CEO characteristics and contexts jointly shape confidence-related biases and, in turn, major corporate decisions under uncertainty.

Overconfidence is commonly viewed as a double-edged sword in managerial decision-making, with particularly salient implications for corporate innovation (Galasso and Simcoe, 2011). On the one hand, when managers hold overly favourable assessments of their own judgment and the prospects of uncertain projects, they may be more willing to initiate and sustain high-uncertainty innovation activities that would otherwise be postponed or rejected. For instance, they may allocate substantial resources to R&D, pursue emerging technologies, and enter untapped markets where payoffs are highly skewed and difficult to evaluate ex ante (Hirshleifer et al., 2012).

Such managers may also act more decisively and rely less on external advisors or market feedback, thereby reducing internal procedural delays and accelerating project implementation, which can be valuable when speed and first-mover considerations matter in technological competition (Simon and Houghton, 2002). On the other hand, miscalibrated optimism can also lead to a systematic overestimation of expected returns and personal capabilities, together with an underappreciation of downside uncertainty, which may encourage overinvestment and inefficient allocation of scarce organisational resources (Heaton, 2002; Malmendier and Tate, 2005a). Under these conditions, managers may be insufficiently wary of failure, bypass essential feasibility evaluations, or discount critical external reviews, thus increasing the likelihood of costly experimentation and project collapse (Simon and Houghton, 2003). Moreover, excessive confidence may foster a tendency to discount disconfirming information and persist with poorly performing initiatives, a pattern closely related to escalation of commitment under uncertainty (Staw, 1976; Brockner, 1992). In innovation contexts, these behaviours may translate into higher failure costs and weaker innovation effectiveness, as resources can be diverted toward overambitious projects with fragile foundations rather than being deployed in a disciplined portfolio of experimentation and learning. Overall, overconfident managers can make it more difficult to balance exploration and exploitation, potentially tilting firms toward excessive exploration at the expense of incremental refinement and organisational learning (March, 1991). If decision-makers appropriately harness this inclination to explore new markets and products, they may achieve notable innovation performance; however, if they disregard external feedback and pursue unchecked expansion, they risk wasting resources and undermining innovation.

Beyond these direct effects, research increasingly emphasises that the innovation consequences of CEO overconfidence are contingent on organisational contexts that shape how individual-level belief distortions are translated into collective experimentation, learning, and resource allocation. A salient boundary condition is the firm's risk-taking climate and the broader cultural norms surrounding experimentation and failure. In organisations where trial-and-error learning is legitimate and failure is more readily tolerated, employees and middle managers are more willing to engage in exploratory activities and to support uncertain projects championed by top executives, thereby strengthening the extent to which CEO overconfidence can be channelled into innovative output (García-Granero et al., 2015; Tian and Wang, 2014; Tellis et al., 2009). By contrast, when internal norms prioritise caution, compliance, and consensus, confidence-driven initiatives are more likely to encounter scepticism and procedural frictions, which can constrain managerial discretion and attenuate the realised impact of overconfidence on innovation outcomes (Tang et al., 2015). Complementing the cultural channel, organisational structure and governance arrangements determine the intensity of monitoring and the quality of feedback embedded in strategic decision processes. Structures that concentrate authority at the top may accelerate project initiation and reduce coordination costs, yet they can also weaken internal challenge and amplify decision biases when leaders' judgments are systematically optimistic; more balanced structures, in contrast, may discipline optimistic beliefs through deliberation, staged investment, and clearer termination thresholds for low-quality projects (Finkelstein and D'Aveni, 1994; O'Reilly and Tushman, 2013). These contextual mechanisms are especially relevant in China, where corporate innovation unfolds within a hybrid environment that combines collectivist cultural norms stressing harmony and group consensus with strong policy and societal expectations for rapid technological upgrading and growth (Hofstede, 1980; Li and Atuahene-Gima, 2001). Chinese business leaders therefore face dual demands to maintain internal cohesion and legitimacy while simultaneously delivering visible performance and innovation outcomes (Zhou and Wu, 2010; Zhou et al., 2017). Under such pressures, CEO overconfidence may encourage the pursuit of ambitious, long-horizon innovation projects and greater persistence in the face of uncertainty (Li and Tang, 2010). However, when organisational controls and external constraints are insufficiently integrated into project selection and continuation decisions, the same confidence-related distortions can manifest as suboptimal innovation portfolio management, including escalation of commitment in weak projects or mis-timed termination of potentially valuable initiatives (Tang et al., 2015). Taken together, this implies that institutional and governance arrangements shaping resource availability, monitoring intensity, and leadership discretion are likely to be important boundary conditions for the overconfidence-innovation relationship.

Although the complex relationship between CEO overconfidence and corporate innovation has attracted substantial academic attention, existing findings remain mixed, particularly in institutional settings where innovation activities are jointly shaped by market forces, policy priorities, and governance constraints. In the Chinese context, one important source of heterogeneity lies in how CEO overconfidence is operationalised. Because overconfidence concerns distorted subjective beliefs rather than a direct preference for risk, different empirical proxies may capture different manifestations of belief distortion rather than the same underlying construct (Moore and Healy, 2008). Existing China-based studies have therefore employed several feasible but conceptually distinct measures, including simplified indicators based on executive shareholding changes (Rao and Wang, 2010), managerial forecast optimism (Huang et al., 2011), media tone and textual sentiment, and relative compensation (Li and Tang, 2010). While these approaches have advanced empirical research where canonical option-based measures are difficult to implement, some of them are more sensitive to short-horizon trading motives, disclosure incentives, or temporary market conditions. To reduce this measurement problem, the present chapter adopts a holdings-based revealed-beliefs proxy that is conceptually anchored in the Malmendier–Tate identification logic (Malmendier and Tate, 2005a). Rather than inferring overconfidence from a one-off increase in holdings, the measure asks whether a CEO persistently maintains concentrated firm-specific stock exposure under conditions in which a standard portfolio benchmark would imply lower exposure. Operationally, it combines year-end stockholding concentration, an implied-return calculation based on a normative portfolio-choice benchmark, a China-specific expected-return benchmark, and a repeated non-selling rule (Hall and Murphy, 2002; Liu et al., 2019). The resulting indicator is therefore intended to capture persistent firm-specific over-optimism revealed through observed holdings behaviour, while being less dependent on transitory trading noise. Using this measurement strategy, the chapter re-examines the innovation implications of CEO overconfidence in China through patent-based innovation outcomes.

Building on the double-edged nature of overconfidence discussed above, the theoretical predictions for innovation are inherently ambiguous. On the one hand, when CEOs hold systematically optimistic or overly certain beliefs about uncertain projects, they may be more willing to initiate innovative investments, tolerate interim setbacks, and sustain exploration in domains where objective evaluation is difficult ex ante (Malmendier and Tate, 2005a; Hirshleifer et al., 2012). Such belief-driven commitment can alleviate organisational inertia and reduce the tendency to underinvest in projects with long horizons and skewed payoffs. On the other hand, miscalibrated optimism may also lead to overinvestment, insufficient screening, and weak responsiveness to negative feedback, thereby increasing failure costs and lowering the effectiveness of innovation portfolios (Heaton, 2002; Malmendier and Tate, 2005a). These competing channels motivate two alternative hypotheses in the Chinese setting.

Hypothesis 1a: Overconfident CEOs promote corporate innovation.

Hypothesis 1b: Overconfident CEOs impede corporate innovation.

Beyond the average effect, institutional and organisational contexts are likely to shape whether CEO overconfidence is translated into realised innovation outcomes. This chapter focuses on firm ownership as an important boundary condition in China. Relative to non-state-owned enterprises (non-SOEs), state-owned enterprises (SOEs) often operate under distinctive constraints and privileges, including comparatively easier access to credit, policy support, and implicit guarantees that can soften the consequences of failure and relax financing constraints for long-horizon innovative investment (Kornai, 1986; Peng et al., 2016). Since innovation projects are typically difficult to finance externally due to severe information asymmetry and limited collateral value, the relaxation of financing frictions can materially affect whether managerial beliefs, whether optimistic or pessimistic, can be implemented through actual R&D and patenting activities (Hall and Lerner, 2010). In this sense, SOEs may provide an environment in which overconfident CEOs can more readily operationalise ambitious innovation strategies, and government support can further reinforce such beliefs by lowering perceived downside risks and providing resources for experimentation (Zhou et al., 2017). Therefore, conditional on overconfidence, the realised innovation outcomes are expected to be more responsive in SOEs.

Hypothesis 2: The positive effect of CEO overconfidence on corporate innovation is stronger in SOEs than in non-SOEs.

Finally, corporate governance arrangements determine the extent to which confidence-related belief distortions are disciplined or amplified in strategic decision processes. A central premise of governance theory is that separating decision management from decision control strengthens monitoring and reduces the risk that idiosyncratic managerial biases dominate corporate choices (Fama and Jensen, 1983; Jensen, 1993). When the CEO also serves as board chair, decision authority becomes more concentrated and internal challenge mechanisms may weaken, reducing the likelihood that overly optimistic assessments are scrutinised through independent oversight (Finkelstein and D'Aveni, 1994). While unified leadership can in principle facilitate coordination and speed, the innovation context places substantial weight on staged evaluation, disciplined termination, and learning from negative signals; weaker monitoring can therefore tilt the balance from productive exploration toward biased persistence or misallocation. In line with this reasoning, the beneficial component of CEO overconfidence is expected to be less pronounced when power concentration limits effective checks and balances, such that the net innovation gains from overconfidence are diminished under CEO duality (Adams et al., 2005).

Hypothesis 3: When the CEO also serves as board chair, the positive effect of overconfidence on corporate innovation is diminished.

2.3 Data, Variable Construction, and Methodology

2.3.1 Sample Selection and Data Sources

In this study, the sample covers non-financial firms listed on the Shanghai and Shenzhen A-share markets from 2005 to 2020. First, ST and *ST companies are excluded to avoid potential distortions arising from severe financial distress or abnormal reporting conditions. Second, firms in the financial industry are removed based on the 2012 CSRC (China Securities Regulatory Commission) industry classification, given their distinctive balance-sheet structures and regulatory environment relative to non-financial firms. Firm-level financial data, governance variables, executive information, and patent data are then matched, and observations with missing key variables are excluded. Firm-level financial variables are winsorised at the 1st and 99th percentiles to mitigate the influence of outliers. After these procedures, the final sample consists of 2,178 listed firms and 4,288 CEOs, forming an unbalanced panel of 13,120 firm-year observations. Firm-level financial statements, governance indicators, executive shareholding and compensation data, and patent grant and citation data are obtained from the CSMAR (China Stock Market and Accounting Research) database. The CEO overconfidence measure is constructed using executive stockholding information, annual cash compensation, monthly stock returns, risk-free rates, and the China-specific three-factor benchmark following Liu et al. (2019). The 2012 CSRC industry classification is used to identify industries. The period from 2005 to 2020 is selected because it spans several important institutional changes in China's capital market and corporate sector, including the split-share reform, the convergence of accounting standards with international practices, the launch of the ChiNext market, and the implementation of policies encouraging indigenous innovation. These developments provide a dynamic institutional environment well suited to examining firms' innovation behaviour and the role of managerial beliefs. Moreover, a sample period of approximately fifteen years makes it possible to observe patent-based innovation outcomes across different economic cycles while accommodating the lagged nature of corporate innovation.

2.3.2 Measurement of Corporate Innovation

Academic research frequently measures corporate innovation through two primary lenses: inputs and outputs. Inputs often refer to R&D expenditures, which gauge a firm's resource commitment to innovation activities. However, resource investment alone does not necessarily yield high-quality outcomes. By contrast, output indicators focus more on innovative achievements themselves, with patent counts and new product releases being the most common metrics. Some studies represent a firm's "invention" by the number of patents obtained, while measuring "innovation" through the number of announced new products (Artz et al., 2010). Among these metrics, patent output is widely employed due to its objective and quantifiable nature. Yet the sheer number of patents may fail to capture quality differentials, prompting many researchers to emphasise measures of patent quality. For instance, forward citation counts are regarded as a key proxy for a patent's technological impact and knowledge spillover (Hall et al., 2005; Alcácer and Gittelman, 2006), based on the notion that frequently cited patents often see extensive application in subsequent research and play a more significant role in advancing industry technologies (Jaffe et al., 1993).

Accordingly, this study employs patent forward citations as an indicator of innovation, namely the total forward citations received by patents applied for and ultimately granted in a given year (up to the end of 2021). Given the lagged nature of innovation activities, and to align CEO characteristics with subsequent observable innovation outcomes, the patent citation measures are constructed with a two-year lead in the panel. In the regression analysis, citation counts are logarithmically transformed to mitigate the right-skewness of their distribution and to reduce the influence of extreme observations. Under the Chinese patent system, the China National Intellectual Property Administration (CNIPA) distinguishes three patent types: invention patents, utility model patents, and design patents. Invention patents and utility model patents protect technical solutions, whereas design patents protect product appearance features that create an aesthetic effect rather than technological knowledge. The examination process also differs across patent types: invention patents are subject to substantive examination, while utility model and design applications follow a more streamlined procedure (CNIPA, n.d.). Given the focus of this chapter on technological innovation outcomes and knowledge spillovers, this study therefore excludes design patents and concentrates on invention patents and utility model patents. To clarify the influence of CEO overconfidence, this study differentiates between invention patents and utility model patents by calculating separate citation counts, as well as their combined total. While R&D investment and total patent counts remain informative proxies that reflect innovation inputs and the scale of codified outputs, respectively, patent forward citations provide an outcome-oriented indicator that captures the extent to which a firm's patented knowledge is subsequently drawn upon and diffused within the technological domain. To reinforce the robustness of the findings, subsequent analyses also incorporate R&D expenditure and total granted patents as alternative measures, thereby assessing whether the main results are sensitive to the choice of innovation proxy.

2.3.3 Measurement of CEO Overconfidence

Numerous established approaches for measuring executive overconfidence exist in psychology and finance, and they are commonly grouped into behaviour-based proxies and psychology- or belief-based proxies. In the corporate finance literature, the most influential behaviour-based measures are derived from managers' own portfolio decisions, especially their treatment of firm-specific equity exposure. Malmendier and Tate (2005a) introduced the widely used "Holder 67" and "Longholder" measures by exploiting the timing of executive stock option exercise. In their framework, a CEO is classified as overconfident when vested options remain unexercised by the fifth year after grant even after they have become at least 67% in the money. The logic is grounded in the rational exercise benchmark for risk-averse and underdiversified executives developed by Hall and Murphy (2002): once options are sufficiently deep in the money, continued delay is difficult to reconcile with a standard diversification motive and instead suggests that the executive assigns excessively favourable odds to future stock appreciation. In this sense, delayed option exercise is interpreted not merely as a willingness to bear risk, but more fundamentally as a revealed signal of overly optimistic or miscalibrated beliefs about the firm's future stock performance. For this reason, the Malmendier–Tate approach has become the canonical benchmark in the corporate finance literature.

Other commonly used proxies attempt to capture overconfidence more directly from expressed expectations and communication. Performance forecast bias is one representative approach. Lin et al. (2005), in their study of the Taiwanese market, show that managers who are excessively optimistic about firm prospects tend to generate repeated upward forecast errors. When managers systematically overpredict future earnings and upward forecast errors dominate downward ones, overconfidence can be inferred. Related studies draw on textual tone and public communication. By analysing earnings announcements, annual reports, public statements, and media portrayals, researchers infer the degree of optimism embedded in managerial narratives. Huang et al. (2014), for example, use the Loughran–McDonald finance dictionary to quantify optimistic language in corporate disclosures, while Malmendier and Tate (2009) suggest that external praise and public characterisations may reinforce overly positive managerial self-assessments. Survey-based evidence points in a similar direction. Ben-

David et al. (2013) document substantial miscalibration among senior executives and show that such miscalibration is associated with more aggressive corporate policies. The appeal of these measures is also consistent with the broader evidence in Malmendier and Tate (2005b), which shows that managerial overconfidence has first-order effects on corporate investment decisions.

Beyond portfolio-based and expectation-based proxies, another stream of research infers overconfidence from major strategic choices or broader executive characteristics. Roll (1986) proposed the hubris hypothesis, arguing that managers may systematically overestimate the value they can create through acquisitions. Building on this line of thinking, Haunschild (1994) shows that managers in acquisitive settings often rely on experience-based judgement rather than fully disciplined risk assessment, while Doukas and Petmezas (2007) interpret repeated acquisitive behaviour as consistent with managerial overconfidence. Hayward and Hambrick (1997), meanwhile, link CEO hubris to acquisition premiums and suggest that unusually strong executive self-belief can be reflected in strategic overreach. Other studies have used relative compensation, public recognition, or personal background traits as indirect indicators of inflated managerial self-assurance. Although these approaches each offer useful supplementary insights, the most influential measures in finance remain those that connect observed managerial behaviour to an explicit normative benchmark for rational decision-making under risk. This consideration becomes particularly important in settings where the direct transplantation of mature-market measures is constrained by data availability and institutional differences.

In the Chinese market, however, the direct implementation of the Malmendier–Tate option-based approach is often infeasible. Although equity incentives have gradually developed in recent years, executive stock option data remain far less complete, standardised, and continuously observable than in the U.S. setting, particularly when one seeks to trace grant timing, vesting structure, exercise timing, and moneyness over long sample periods. As a result, the most widely used proxies in the Chinese literature tend to rely on managerial shareholding behaviour and forecast-based optimism rather than option exercise decisions. Among these, a representative approach is proposed by Rao and Wang (2010), who infer overconfidence from executives' shareholding choices when the firm's stock performs poorly relative to the broader market. The underlying intuition is straightforward: if a manager continues to hold or increase exposure to company stock even when market-adjusted performance is weak, such behaviour may reveal an excessively optimistic assessment of the firm's future prospects. In addition, some studies in the Chinese setting also use management earnings forecasts, performance guidance, or related disclosure-based indicators to capture overly optimistic expectations.

These proxies are practical under Chinese data constraints, but they also have limitations relative to the mature-market benchmark. Shareholding-change measures are less tightly linked to a formal diversification benchmark than the option-exercise framework of Malmendier and Tate (2005a). Forecast-based measures may likewise capture not only managerial beliefs, but also disclosure incentives and impression management. More generally, many China-based proxies rely on one-off annual observations, whereas the mature-market literature places greater weight on repeated behaviour that reveals persistent exposure to firm-specific risk. Accordingly, the key task in the Chinese context is not merely to find an observable proxy for managerial overconfidence, but to construct a measure that remains close to the identification logic of the mature-market literature while still being feasible under local data conditions. Guided by this principle, the following subsection develops a holdings-based measure that preserves the core intuition of Malmendier and Tate (2005a) while adapting its implementation to the institutional setting and data availability of Chinese listed firms.

Against this background, this study develops a holdings-based measure of CEO overconfidence that is designed to preserve the core identification logic of the mature-market literature while remaining feasible under Chinese data constraints. Rather than treating a simple increase or persistence in stockholding as sufficient evidence of overconfidence, the measure follows the underlying reasoning in Malmendier and Tate (2005a): a manager appears overconfident when the CEO persistently maintains firm-specific exposure under circumstances in which a standard diversification benchmark would imply a lower exposure. In the original Holder 67 and Longholder setting, this logic is implemented through stock option exercise behaviour and interpreted through the rational benchmark of Hall and Murphy (2002). In the present study, because detailed executive option grant and exercise data are unavailable, the same basic idea is translated into year-end stockholding behaviour. More specifically, the method begins from a maintained preference parameter, combines observed stock concentration with firm-specific return risk, and infers the level of subjective expected excess return required to rationalize the CEO's observed holdings. This implied subjective return is then compared with a rational benchmark return derived from the China-specific three-factor model, so that overconfidence is identified as behaviour consistent with excessive optimism about future firm-specific stock performance.

The construction of the measure is also informed by the broader logic of the Malmendier–Tate family of proxies. Similar to Net Buyer, the method treats the CEO's continued willingness to retain firm-specific exposure as behaviourally informative. At the same time, inspired by the Longholder approach, it does not classify a CEO as overconfident on the basis of a single isolated observation. Instead, the measure is designed to capture a repeated pattern of failure to reduce exposure, so that the final indicator reflects a more persistent behavioural tendency rather than a transitory annual fluctuation. To operationalise this idea in the Chinese setting, the procedure combines three elements: the optimism implied by the CEO's stock concentration, the absence of share reduction, and the repeated occurrence of such signals within a rolling window. In this sense, the proposed proxy is not intended as a mechanical replication of Holder 67, but as a China-specific adaptation of its identification spirit.

Guided by this framework, this study constructs a holdings-based revealed-beliefs proxy of CEO overconfidence by combining three elements: a normative portfolio-choice benchmark, a China-specific rational return benchmark, and a repeated non-de-risking rule. The construction follows the identification spirit of Malmendier and Tate (2005a), who interpret persistent failure to reduce firm-specific exposure as evidence of managerial overconfidence when such behaviour is evaluated against a rational benchmark for underdiversified and risk-averse executives derived from Hall and Murphy (2002). Rather than mechanically replicating the original Holder 67 measure, the present approach adapts its underlying logic to the Chinese setting by using observed year-end stockholdings and non-selling behaviour to infer the degree of firm-specific optimism embedded in the CEO's portfolio choice.

The starting point is the classic Merton portfolio-share benchmark (Merton, 1969, 1971). Under a standard two-asset framework with constant relative risk aversion, the optimal risky-asset share is increasing in expected excess return and decreasing in both risk aversion and return variance. Inverting this logic, one can recover the subjective excess return that would be required to rationalize an observed stockholding concentration. Let the year-end market value of the CEO's stockholding be denoted by $StockValue_{i,j,t}$, and let outside wealth be proxied by annual cash compensation multiplied by a constant κ. The CEO's portfolio concentration in company stock is then defined as:

$$\omega_{i,j,t} = \frac{StockValue_{i,j,t}}{StockValue_{i,j,t} + \kappa \cdot CashPay_{i,j,t}}. \tag{2-1}$$

Following the calibration spirit in Malmendier and Tate (2005a), this study fixes the coefficient of relative risk aversion at $\gamma = 3$, thereby treating preferences as maintained rather than estimated. Because total CEO wealth is unobservable, outside wealth is proxied as a cash-compensation-based benchmark commonly used in the executive-compensation literature. Hall and Murphy (2002) and Murphy (2013) adopt the greater of \$5 million or four times cash compensation, Cai and Vijh (2007) use three times prior-year cash compensation and six times annual salary and bonus, Armstrong et al. (2007) calibrate fixed wealth as five times salary and bonus plus SERP value, and Bakke et al. (2016) proxy outside wealth using the CEO's average salary and bonus over the previous five years. Guided by this literature, the baseline specification sets $\kappa = 5$. The implied subjective annual excess return required to rationalize the observed concentration is therefore written as:

$$\hat{\mu}^{subj}_{i,j,t} = \gamma \cdot \hat{\sigma}^2_{i,t} \cdot \omega_{i,j,t}, \tag{2-2}$$

where $\hat{\sigma}^2_{i,t}$ is the firm's annualised return variance estimated from rolling monthly excess returns. In economic terms, this equation asks how optimistic the CEO must be about future firm-specific returns in order for the observed degree of concentration in company stock to be consistent with a standard portfolio benchmark.

This implied subjective return is then compared with a rational benchmark expected excess return derived from the China-specific three-factor model of Liu et al. (2019). Using the firm's rolling factor exposures and the corresponding factor premia, the benchmark annual expected excess return is defined as:

$$\hat{\mu}_{i,t}^{CH3} = 12\big(\hat{\beta}_{i,t}^{MKT}\bar{MKT}_t + \hat{\beta}_{i,t}^{SMB}\bar{SMB}_t + \hat{\beta}_{i,t}^{VMG}\bar{VMG}_t\big). \tag{2-3}$$

The key comparison is then summarised by the CEO's implied alpha:

$$\hat{\alpha}_{i,j,t}^{impl} = \hat{\mu}_{i,j,t}^{subj} - \hat{\mu}_{i,t}^{CH3}. \tag{2-4}$$

A positive value of $\hat{\alpha}_{i,j,t}^{impl}$ indicates that, under the maintained preference assumptions and the China-specific rational benchmark, the CEO's observed stockholding concentration can only be rationalized if the CEO subjectively expects returns above the benchmark level. In this sense, a positive implied alpha is interpreted as a revealed signal of excessive optimism about the firm's future stock performance. The choice of CH-3 is particularly important in the present context because Liu et al. (2019) show that their China-specific three-factor model strongly outperforms a direct replication of the standard Fama–French procedure in the A-share market.

To ensure that the measure captures persistent optimism rather than a purely mechanical portfolio condition, the implied-alpha criterion is combined with an action-based filter. Specifically, a basic overconfidence event is recorded only when the implied alpha is positive, the CEO does not reduce stockholdings during the year, and year-end stock exposure remains strictly positive:

$$E_{i,j,t} = 1\{\hat{\alpha}_{i,j,t}^{impl} > 0,\ NoSell_{i,j,t} = 1,\ StockValue_{i,j,t} > 0\}. \tag{2-5}$$

The inclusion of the non-selling requirement follows the broader Malmendier–Tate logic that overconfidence is most plausibly revealed when executives remain exposed to firm-specific risk despite a diversification motive that would normally favour reducing such exposure. In this sense, the event indicator captures not merely optimistic beliefs, but optimistic beliefs that are acted upon through continued non-reduction of company-specific exposure.

Finally, the indicator is designed to capture a repeated behavioural tendency rather than a one-off annual event. Drawing on the Longholder intuition that overconfidence is better identified through habitual failure to diversify than through a purely transitory episode, this study counts the number of basic events within a rolling five-year window:

$$N_{i,j,t} = \sum_{s=t-4}^{t} E_{i,j,s}. \tag{2-6}$$

A CEO is first classified as overconfident in the year when such an event occurs for at least the second time within the rolling five-year window. Let

$$H_{i,j,t} = 1\{E_{i,j,t} = 1,\ N_{i,j,t} \geq 2,\ N_{i,j,t-1} < 2\} \tag{2-7}$$

denote the trigger year. The final overconfidence indicator is then treated as absorbing:

$$OC_{i,j,t} = 1\left\{\sum_{u \leq t} H_{i,j,u} \geq 1\right\}. \tag{2-8}$$

Accordingly, once a firm-CEO pair crosses the second-event threshold, the CEO is classified as overconfident from that year onward. This repeated-event and absorbing-state design inherits two central features of the Malmendier–Tate framework: first, overconfidence is inferred from persistent failure to reduce firm-specific exposure rather than from a single observation; second, the resulting measure is intended to capture a relatively stable behavioural tendency rather than a purely time-varying annual shock.

In sum, the proxy combines a formal portfolio benchmark from Merton, the underdiversified-executive logic emphasised by Hall and Murphy and Malmendier and Tate, a China-specific expected-return benchmark from Liu, Stambaugh, and Yuan, and a repeated non-selling filter inspired by the Longholder tradition. The resulting variable is therefore constructed to capture persistent firm-specific over-optimism revealed through concentrated and insufficiently reduced stockholding exposure in the Chinese institutional setting.

2.3.4 Moderating Variables: Ownership Structure and CEO Duality

When examining the influence of CEO overconfidence on corporate innovation, differences in governance structures stemming from various ownership backgrounds may play a critical moderating role. Compared with private enterprises, SOEs often exhibit more complex administrative intervention, distinct performance evaluation systems, and a higher tendency toward risk avoidance (Megginson and Netter, 2001). These factors may either amplify or weaken the impact of CEOs' personal traits on innovation decisions. On the one hand, SOEs possess resource endowments and policy support that may enable overconfident CEOs to pursue large-scale innovation projects. On the other hand, the more complex approval and accountability procedures in SOEs can partially constrain CEO autonomy, thereby affecting how overconfidence translates into innovative behaviour. In this study, ownership structure is incorporated as a dummy variable for moderating effects: enterprises are coded SOE = 1 if they are state-owned and 0 otherwise, to investigate how this distinction shapes the link between CEO overconfidence and corporate innovation.

When the CEO also serves as board chair, decision-making authority becomes more concentrated, potentially altering the balance between board monitoring and managerial discretion (Fama and Jensen, 1983). Under CEO duality, the CEO may exert greater influence over strategic planning and resource allocation, so that individual behavioural biases are more likely to be translated into firm-level decisions rather than being moderated by board oversight or alternative viewpoints (Finkelstein and D'Aveni, 1994). Accordingly, CEO duality may shape the extent to which managerial overconfidence affects corporate innovation. Consistent with the literature, this study defines CEO duality (DUAL) as a dummy variable equal to 1 if the CEO simultaneously serves as board chair, and 0 otherwise. The interaction term between CEO overconfidence and DUAL is then introduced into the regression model to examine whether a more concentrated power structure moderates the relationship between CEO overconfidence and innovation.

In summary, incorporating these two moderating variables helps clarify how CEO attributes influence corporate innovation under different ownership conditions and power arrangements, and thus enriches the literature on behavioural finance and corporate governance by providing further evidence on the differentiated effects of executive behaviour.

2.3.5 Control Variables

To more accurately identify the impact of CEO overconfidence on corporate innovation, this study incorporates a series of control variables in the regression model. These variables have been extensively validated in previous research as being related to firms' innovation performance. The selection of control variables is primarily based on three perspectives: firm-level characteristics, corporate governance factors, and individual attributes. Specifically, this study includes firm size, return on assets, leverage, firm age, Tobin's Q, the Herfindahl-Hirschman Index (HHI), board independence, and CEO age, gender, and tenure.

Total Assets: Larger firms typically possess greater resources and scale to support R&D investment (Cohen and Klepper, 1996). At the same time, large established firms may face interpretive barriers and organisational rigidities that can slow more novel or breakthrough innovation (Dougherty, 1992; Ahuja and Lampert, 2001).

Return on Assets: Firms with stronger profitability often have greater internally generated funds and more flexibility in financing R&D, which can facilitate sustained innovation investment (Hall, 2002; Brown et al., 2009). However, if a firm prioritises short-term profit maximisation, it may reduce investment in long-horizon innovation.

Debt-to-Asset Ratio: High leverage implies greater financial risk. Studies show that companies with substantial debt loads face pressure to meet repayment obligations, which can constrain their ability to invest in high-risk, high-return innovation projects (Myers, 1977). Moreover, heavily leveraged firms may have lower bargaining power in external financing markets, further limiting continuous R&D spending.

Firm Age: Younger firms tend to seize market opportunities and aggressively pursue innovation but have limited resources. Mature firms, on the other hand, benefit from established management systems and resource accumulation, yet they may suppress breakthrough innovation due to overreliance on existing paths or organisational inertia (Sørensen and Stuart, 2000).

Tobin's Q: A higher Tobin's Q is commonly interpreted as reflecting stronger market valuation and richer growth opportunities, which are generally associated with greater incentives to invest in future-oriented projects and firm growth (Lang et al., 1989; Lang et al., 1996). In favourable market conditions, firms may also find it easier to obtain financing, which can further support innovation activity.

Herfindahl-Hirschman Index (HHI): An overly concentrated market (high HHI) may reduce the incentive to innovate, because dominant firms lack sufficient competitive pressure. Conversely, although a market with very low HHI may spur the desire to innovate, intense competition can undermine returns (Aghion et al., 2005). Thus, controlling for industry competition is necessary when examining firms' innovation decisions.

Board Independence: A high proportion of independent directors can enhance oversight of the CEO and prevent reckless expansion or excessive risk-taking (Fama and Jensen, 1983). Independent directors can offer more objective input on R&D project selection and performance monitoring, thereby influencing the firm's innovation strategy.

CEO Age and Gender: These variables relate to personal characteristics and risk preferences. Prior research suggests that CEO age is negatively associated with corporate risk-taking, with older CEOs generally pursuing more cautious policies (Serfling, 2014). In innovation decisions, older CEOs may prefer to maintain existing business structures and avoid major uncertainties. Gender may also affect decision-making styles and risk tolerance. Female executives are often more cautious in investment and financial decisions, whereas male CEOs may display stronger risk-taking behaviour in certain contexts (Barber and Odean, 2001; Huang and Kisgen, 2013).

CEO Tenure: Longer-serving CEOs generally possess greater authority and resource-allocation capacity within the firm. They also have deeper familiarity with operations, allowing for systematic changes. However, long tenures can lead to cognitive rigidity, making managers less receptive to disruptive innovation (Hambrick and Fukutomi, 1991).

Beyond the observed firm, governance, and CEO characteristics, the baseline specification includes industry and year fixed effects to absorb persistent cross-industry heterogeneity and common time-varying influences in corporate innovation. Innovation outcomes depend not only on firm-level attributes but also on industry-specific technological opportunity sets, appropriability conditions, competitive structure, and sectoral innovation norms, together with annual shocks related to macroeconomic conditions, financing environments, regulatory change, and innovation policy. These industry- and time-specific factors are unlikely to be orthogonal to CEO overconfidence or to patent-based innovation outcomes. Because forward citations are observed only through the end of 2021, year fixed effects additionally absorb cohort-level variation in observed citation accumulation arising from differences in effective citation exposure across patent years. The coefficient on CEO overconfidence is thus estimated from cross-firm variation after netting out average differences across industries and years, conditional on the included firm, governance, and CEO controls. This specification is consistent with standard empirical practice in related corporate finance and innovation studies (Malmendier and Tate, 2005a; Galasso and Simcoe, 2011; Hirshleifer et al., 2012). Standard errors are clustered by industry and year to allow for residual dependence among firms subject to common industry conditions and among observations exposed to the same annual environment. This follows established panel-data practice in finance and econometrics, which recommends multiway cluster-robust inference when error dependence may arise along more than one dimension (Petersen, 2009; Cameron et al., 2011; Thompson, 2011). Subsequent interaction specifications examine whether the overconfidence-innovation relation varies with ownership structure and CEO power concentration, while reverse-causality tests, propensity-score matching, and alternative-measure analyses are reported separately as robustness exercises.

Table 2-1. Variable definitions

Variable	Description
CiteI	Natural logarithm of forward citations of invention patents applied for and granted, aligned with a two-year lead (t+2).
CiteU	Natural logarithm of forward citations of utility model patents applied for and granted, aligned with a two-year lead (t+2).
CiteIU	Natural logarithm of forward citations of invention and utility model patents applied for and granted, aligned with a two-year lead (t+2).
OC	A dummy variable equal to 1 if the CEO is classified as overconfident, and 0 otherwise.
TA	Natural logarithm of total assets.
ROA	Return on assets, calculated as net income divided by total assets.
D/A	Debt-to-asset ratio, calculated as total liabilities divided by total assets.
AGE	Natural logarithm of firm age.
Q	Tobin's Q, calculated as market value divided by total assets
HHI	Herfindahl-Hirschman Index, calculated using individual firm revenue to determine its market share within the industry.
IND_DIR	Proportion of independent directors on the board.
CEO_AGE	Natural logarithm of CEO age.
CEO_GEN	Gender of the CEO, equal to 1 for male and 0 for female.
TENURE	Natural logarithm of CEO tenure (measured in months).
SOE	A dummy variable equal to 1 if the firm is a State-owned enterprise, and 0 otherwise.
DUAL	A dummy variable equal to 1 if the CEO also serves as board chair, and 0 otherwise.
OC2	A dummy variable equal to 1 if the CEO is classified as overconfident based on earnings forecasts, and 0 otherwise.
RD_INT	R&D intensity, calculated as R&D expenditure divided by operating revenue.
PatIU	Natural logarithm of the number of invention and utility model patents applied for and granted, aligned with a two-year lead (t+2).

2.4 Descriptive Statistics and Preliminary Analysis

2.4.1 Descriptive Statistics

Table 2-2 presents the descriptive statistics of the main variables in this study, encompassing 13,120 observations. Regarding the dependent variables, the mean values of CiteI, CiteU, and CiteIU (log-transformed) are 1.482, 1.990, and 2.425, respectively, with standard deviations exceeding 1.6. This indicates substantial variation in subsequent patent citation outcomes across firms. When looking at the medians, CiteU exceeds 1, suggesting that, overall, utility model patents tend to receive relatively high citation counts in this sample. Turning to the key independent variable OC, the mean is approximately 0.167, implying that about 16.7% of the sample observations can be categorised as featuring overconfident CEOs. This figure also highlights clear heterogeneity in confidence-related managerial characteristics across firms.

As for the control variables, total assets (log-transformed) average 22.163, indicating that while many firms in the sample are relatively large, the distribution remains fairly spread out. ROA averages 0.037, with a median of 0.033, suggesting moderate profitability for most firms, although the minimum reaches -0.195, signalling that some firms face considerable losses. D/A, with an average of 0.476, suggests a medium debt ratio for the sample overall. Firm age averages 15.517 years, ranging from 3 to 51, covering both relatively young enterprises and long-established mature companies. Tobin's Q has a mean of 1.937, peaking at 6.507, indicating that certain firms enjoy relatively strong market recognition and growth expectations. The HHI (Herfindahl-Hirschman Index) averages 0.115, and can reach as high as 1.000, reflecting high industry concentration in some cases and uneven competition among firms. Concerning CEO and governance characteristics, the proportion of independent directors averages 0.366, while CEO age averages 48.769 years. The CEO gender variable has a mean of 0.948, indicating that 94.8% of the CEOs in the sample are male, which reflects the gender imbalance among top executives in A-share listed firms. CEO tenure, measured in months, averages 48.595, with a standard deviation of 36.921. The large gap between the minimum and maximum values reveals that some CEOs have very short tenures while others remain in office for extended periods. SOE averages 0.570, indicating that state-owned enterprises account for a substantial proportion of the sample. DUAL averages 0.178, indicating that a relatively limited but non-negligible proportion of CEOs simultaneously serve as board chair and therefore exercise a higher degree of authority concentration.

Overall, these descriptive statistics reveal the distributional characteristics of the major variables within the sample. Firms exhibit significant variation in terms of innovation performance, financial profiles, corporate governance structures, and CEO attributes; however, the distributions of these variables are generally stable, thus laying a robust data foundation for subsequent empirical analysis.

Table 2-2. Summary Statistics

This table reports summary statistics for the main variables in the final regression sample, which consists of 13,120 firm-year observations from 2,178 non-financial companies listed on the Shanghai and Shenzhen A-share markets during 2005–2020. CiteI, CiteU, and CiteIU denote the natural logarithms of forward citations to invention patents, utility model patents, and their combined total, respectively, and are measured with a two-year lead (t+2). The key independent variable, OC, is a dummy variable equal to 1 if the CEO is classified as overconfident. The control variables cover firm characteristics, corporate governance factors, and CEO demographic attributes, including firm size, profitability, leverage, firm age, Tobin's Q, industry concentration, board independence, and CEO age, gender, and tenure. For ease of interpretation, AGE, CEO_AGE, and TENURE are reported in their original units in this table, whereas their logarithmic forms are used in the regression analysis as defined in Table 2-1. Firm-level financial variables are winsorised at the 1st and 99th percentiles. Detailed variable definitions are reported in Table 2-1.

VarName	Obs	Mean	SD	Min	Median	Max
CiteI	13120	1.482	1.689	0.000	1.099	9.868
CiteU	13120	1.990	1.891	0.000	1.946	9.066
CiteIU	13120	2.425	1.992	0.000	2.565	9.900
OC	13120	0.167	0.373	0.000	0.000	1.000
TA	13120	22.163	1.247	19.592	22.010	25.229
ROA	13120	0.037	0.054	-0.195	0.033	0.171
D/A	13120	0.476	0.203	0.071	0.483	0.915
AGE	13120	15.517	5.299	3.000	15.000	51.000
Q	13120	1.937	1.126	0.929	1.552	6.507
HHI	13120	0.115	0.122	0.016	0.077	1.000
IND_DIR	13120	0.366	0.053	0.133	0.333	0.800
CEO_AGE	13120	48.769	6.399	27.000	49.000	81.000
CEO_GEN	13120	0.948	0.222	0.000	1.000	1.000
TENURE	13120	48.595	36.921	0.000	41.000	244.000
SOE	13120	0.570	0.495	0.000	1.000	1.000
DUAL	13120	0.178	0.382	0.000	0.000	1.000

2.4.2 Correlation Matrix

Table 2-3 presents the Pearson correlation coefficients among the main variables, providing a preliminary view of the direction and magnitude of pairwise associations before turning to the multivariate regressions. Overall, except for the naturally strong correlations among the three patent citation measures, most pairwise correlation coefficients are moderate in magnitude, suggesting that severe multicollinearity is unlikely to be a major concern in the subsequent regressions. Focusing first on the key independent variable, CEO overconfidence (OC) is positively correlated with CiteIU (0.14), CiteU (0.14), and CiteI (0.09), indicating a positive preliminary association between CEO overconfidence and subsequent patent citation outcomes. In addition, OC is positively correlated with CEO duality (DUAL) (0.19) but negatively correlated with SOE (-0.21), suggesting that overconfidence is more likely to be observed in private firms and in settings where managerial power is relatively more concentrated. Moreover, OC is negatively correlated with leverage (D/A) (-0.08) and positively correlated with CEO tenure (TENURE) (0.31), implying that overconfident CEOs are more often observed in firms with lower debt pressure and in situations where CEOs remain in office for longer periods.

Regarding the control variables, TA shows a significant positive correlation with all three patent citation measures (CiteI, CiteU, and CiteIU), indicating that larger enterprises typically possess greater resources to support innovation activities. TA is also positively correlated with SOE, reinforcing the common pattern that state-owned enterprises tend to be larger in scale. Profitability (ROA) is positively correlated with CiteI, CiteU, and CiteIU, reflecting a positive association between firm profitability and innovation outcomes. Meanwhile, D/A is strongly negatively correlated with ROA (-0.39), which is consistent with the general financial intuition that heavier debt burdens are associated with weaker profitability. Notably, firm age (AGE) is negatively correlated with CiteI (-0.10) but displays weaker and less consistent correlations with CiteU and CiteIU, suggesting that firms at different stages of development may exhibit different patterns in invention-oriented and utility-model-oriented innovation. Finally, Q is negatively correlated with TA (-0.41), which is broadly consistent with the view that larger firms may receive relatively lower market-to-book type valuations than smaller firms with stronger growth expectations. These pairwise correlations are only descriptive in nature, and the corresponding relationships are examined more rigorously in the regression analyses that follow.

To further investigate how ownership structure and CEO power concentration differ across various dimensions, this study conducts subgroup analyses based on whether the enterprise is state-owned and whether the CEO also serves as board chair. Next part compares the mean values of key variables and conducts t-tests; the results are shown in Tables 2-4 and 2-5.

Table 2-3. Correlation Matrix

This table presents Pearson correlation coefficients among the main variables based on 13,120 firm-year observations from a panel of 2,178 non-financial firms listed on the Shanghai and Shenzhen A-share markets during 2005–2020. CiteI, CiteU, and CiteIU are the natural logarithms of forward citations to invention patents, utility model patents, and their combined total, respectively, each measured with a two-year lead (t+2). OC is a dummy variable indicating whether the CEO is classified as overconfident. Control variables include firm size, return on assets, leverage, firm age, Tobin's Q, industry concentration, board independence, and CEO characteristics such as age, gender, and tenure. * indicates significance at the 5% level.

	CiteI	CiteU	CiteIU	OC	TA	ROA	D/A	AGE	Q	HHI	IND_DIR	CEO_AGE	CEO_GEN	TENURE	SOE	DUAL
CiteI	1															
CiteU	0.66*	1														
CiteIU	0.85*	0.92*	1													
OC	0.09*	0.14*	0.14*	1												
TA	0.30*	0.38*	0.36*	0.08*	1											
ROA	0.13*	0.09*	0.13*	0.07*	0.08*	1										
D/A	0.04*	0.03*	0.01	-0.08*	0.37*	-0.39*	1									
AGE	-0.10*	0.06*	-0.00	0.11*	0.19*	-0.03*	0.06*	1								
Q	-0.00	-0.08*	-0.04*	0.06*	-0.41*	0.24*	-0.35*	0.02*	1							
HHI	-0.03*	-0.02*	-0.04*	-0.06*	0.03*	-0.01	0.02	-0.08*	-0.02	1						
IND_DIR	0.06*	0.09*	0.08*	0.05*	0.09*	-0.02*	0.00	0.05*	0.02*	-0.00	1					
CEO_AGE	0.02*	0.09*	0.07*	0.13*	0.18*	0.04*	-0.01	0.15*	-0.02*	0.00	0.06*	1				
CEO_GEN	0.05*	0.05*	0.06*	-0.00	0.03*	-0.02	0.01	-0.05*	-0.03*	0.00	-0.05*	0.00	1			
TENURE	0.03*	0.05*	0.05*	0.31*	0.01	0.11*	-0.09*	0.07*	0.09*	-0.02*	0.01	0.22*	-0.01	1		
SOE	0.01	-0.06*	-0.06*	-0.21*	0.21*	-0.10*	0.23*	0.01	-0.20*	0.05*	-0.07*	0.09*	0.07*	-0.14*	1	
DUAL	0.05*	0.05*	0.07*	0.19*	-0.09*	0.05*	-0.11*	-0.00	0.11*	-0.05*	0.10*	0.19*	0.00	0.15*	-0.26*	1

2.4.3 Mean Comparisons by Ownership Structure

Table 2-4 reports the mean comparison tests between non-state-owned enterprises and state-owned enterprises. These t-tests provide preliminary descriptive evidence on whether ownership structure is associated with systematic differences in innovation outcomes, CEO overconfidence, and firm characteristics before the multivariate regressions are introduced. Several notable patterns emerge. First, non-SOEs and SOEs differ significantly in terms of patent-based innovation outcomes. While the mean difference in CiteI is statistically insignificant, non-SOEs exhibit significantly higher values of CiteU and CiteIU than SOEs. This suggests that the ownership difference is more pronounced in utility model-related and aggregate citation outcomes than in invention citation outcomes alone. At the same time, OC is substantially higher in non-SOEs than in SOEs, indicating that overconfident CEOs are more frequently observed in non-state-owned firms. Second, the two groups differ considerably in firm fundamentals. Compared with SOEs, non-SOEs are smaller in size, have higher profitability, lower leverage, and higher Tobin's Q. They also operate in relatively less concentrated industries, as reflected by the lower HHI. These patterns suggest that

Table 2-4. Mean Comparisons between Non-SOEs and SOEs

This table reports mean comparisons for the main variables between non-state-owned enterprises (SOE = 0) and state-owned enterprises (SOE = 1). Mean-diff is calculated as Mean(0) minus Mean(1). t-statistics are based on two-sample t-tests of mean differences. To remain consistent with the regression specifications, AGE, CEO_AGE, and TENURE are reported in logarithmic form in this table. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

VarName	Obs(0)	Mean(0)	Obs(1)	Mean(1)	Mean-diff	t
CiteI	5640	1.465	7480	1.495	-0.030	-1.011
CiteU	5640	2.127	7480	1.886	0.241***	7.227
CiteIU	5640	2.574	7480	2.313	0.261***	7.446
OC	5640	0.258	7480	0.099	0.159***	24.696
TA	5640	21.862	7480	22.389	-0.527***	-24.493
ROA	5640	0.043	7480	0.032	0.011***	11.948
D/A	5640	0.421	7480	0.517	-0.096***	-27.618
AGE	5640	2.747	7480	2.751	-0.003	-0.580
Q	5640	2.200	7480	1.738	0.462***	23.773
HHI	5640	0.108	7480	0.121	-0.013***	-5.980
IND_DIR	5640	0.370	7480	0.363	0.008***	8.191
CEO_AGE	5640	3.886	7480	3.909	-0.023***	-10.041
CEO_GEN	5640	0.929	7480	0.963	-0.033***	-8.590
TENURE	5640	3.705	7480	3.443	0.262***	15.849
DUAL	5640	0.290	7480	0.093	0.198***	30.355

ownership type is associated not only with innovation outcomes, but also with markedly different financial conditions, market environments, and growth expectations. By contrast, the difference in firm age is statistically insignificant, indicating that the two groups do not differ materially in this dimension. Third, governance and CEO characteristics also vary systematically across ownership types. Non-SOEs exhibit a slightly higher proportion of independent directors, are more likely to have younger CEOs, and show a significantly longer CEO tenure. In addition, CEO duality is much more common in non-SOEs than in SOEs. Overall, these results suggest that ownership structure is associated with broad differences in innovation performance, managerial traits, and governance arrangements. This also indicates that the role of CEO overconfidence may differ across ownership types, which provides descriptive support for the subsequent heterogeneity analysis.

2.4.4 Mean Comparisons by CEO Duality

Table 2-5 presents the mean comparison tests between firms without CEO duality and firms where the CEO also serves as board chair. Similar to the ownership-based comparison, these t-tests are intended to reveal whether CEO power concentration is accompanied by systematic differences in innovation outcomes, CEO overconfidence, and firm characteristics. The results show that firms with CEO duality have significantly higher values of CiteI, CiteU, and CiteIU than firms without CEO duality. They also exhibit a substantially higher mean value of OC, indicating that CEO overconfidence is more prevalent when managerial authority is more concentrated. Descriptively, this suggests that CEO duality is associated with both stronger subsequent patent citation outcomes and a higher incidence of overconfident CEOs. In terms of firm characteristics, duality firms are smaller, more profitable, and less leveraged than non-duality firms. They also display higher Tobin’s Q and lower industry concentration, suggesting that firms with CEO duality tend to operate under somewhat different market and financial conditions. By contrast, there is no statistically significant difference in firm age, indicating that the two groups are broadly comparable in that respect. Differences are also visible in governance and CEO attributes. Firms with CEO duality have a slightly higher proportion of independent directors, are led by older CEOs on average, and exhibit longer CEO tenure. The gender composition of CEOs does not differ significantly across the two groups. In addition, duality firms are much less likely to be SOEs, suggesting that concentrated managerial authority is more common in non-state-owned settings. Overall, these descriptive results indicate that CEO duality is not randomly distributed across firms, but is instead associated with a distinct set of innovation, governance, and managerial characteristics. This provides a useful descriptive basis for the subsequent regression analysis of whether CEO duality moderates the overconfidence-innovation relationship.

Table 2-5. Mean Comparisons between Firms without CEO Duality and Firms with CEO Duality

This table reports mean comparisons for the main variables between firms without CEO duality (DUAL = 0) and firms with CEO duality (DUAL = 1). Mean-diff is calculated as Mean(0) minus Mean(1). t-statistics are based on two-sample t-tests of mean differences. To remain consistent with the regression specifications, AGE, CEO_AGE, and TENURE are reported in logarithmic form in this table. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

VarName	Obs(0)	Mean(0)	Obs(1)	Mean(1)	Mean-diff	t
CiteI	10791	1.442	2329	1.669	-0.227***	-5.900
CiteU	10791	1.944	2329	2.201	-0.257***	-5.966
CiteIU	10791	2.358	2329	2.733	-0.374***	-8.244
OC	10791	0.134	2329	0.320	-0.186***	-22.266
TA	10791	22.213	2329	21.928	0.285***	10.050
ROA	10791	0.036	2329	0.042	-0.007***	-5.434
D/A	10791	0.486	2329	0.429	0.057***	12.323
AGE	10791	2.750	2329	2.747	0.003	0.414
Q	10791	1.882	2329	2.192	-0.311***	-12.142
HHI	10791	0.118	2329	0.103	0.015***	5.336
IND_DIR	10791	0.364	2329	0.377	-0.013***	-11.034
CEO_AGE	10791	3.887	2329	3.954	-0.066***	-22.656
CEO_GEN	10791	0.948	2329	0.949	-0.001	-0.279
TENURE	10791	3.489	2329	3.863	-0.374***	-17.524
SOE	10791	0.629	2329	0.297	0.332***	30.355

2.5 Main Empirical Results

2.5.1 Baseline Regression Results

The dependent variable in this analysis is corporate innovation, measured by patent citation-based outcomes. In all specifications, industry and year fixed effects are included as sets of indicator variables. The industry effects absorb persistent sectoral heterogeneity in technological opportunities, appropriability conditions, and competitive structure, while the year effects absorb common macroeconomic, regulatory, and innovation-policy shocks. This specification is intended to remove confounding from between-industry and between-period differences, so that the coefficient on CEO overconfidence is identified from differences across firms within the same industry and year after conditioning on observed firm, governance, and CEO characteristics. Standard errors are clustered by industry and year to allow residual dependence along both dimensions (Petersen, 2009; Cameron et al., 2011; Thompson, 2011). To test the competing predictions in Hypotheses 1a and 1b, the baseline model is specified as follows:

$$Cite_{i,t+2} = \beta_0 + \beta_1 OC_{i,t} + \sum \beta_i \, Control_{i,t} + Industry + Year + \varepsilon_{i,t} \tag{2-9}$$

The control variables include total assets, return on assets, debt-to-asset ratio, firm age, Tobin's Q, HHI, the proportion of independent directors, and CEO age, gender, and tenure.

Table 2-6 shows the baseline regression results for the effect of CEO overconfidence on corporate innovation outcomes, with CiteI (invention patents), CiteU (utility model patents), and CiteIU (the sum of both) serving as the dependent variables. Focusing on the main independent variable, CEO overconfidence has a significantly positive influence in all models, and is statistically significant at the 1% level. Taking Model (2) as an example, the coefficient of OC on CiteI decreases from 0.286 in Model (1) to 0.152 after the inclusion of the control variables, but remains significantly positive. A similar pattern is observed for utility model patents (coefficient of 0.175 in Model (4)) and the combined measure (coefficient of 0.194 in Model (6)). These results suggest that CEO overconfidence is positively associated with subsequent patent citation outcomes across invention patents, utility model patents, and their combined total.

Turning to the control variables, TA is significantly positive in Models (2), (4), and (6), implying that larger firms possess more abundant resources to support innovation activities and therefore tend to achieve higher patent citation outcomes.

Table 2-6. Baseline Regression Results: CEO Overconfidence and Corporate Innovation

This table reports OLS regression results examining the relationship between CEO overconfidence (OC) and corporate innovation. The dependent variables are the natural logarithms of forward citations for invention patents (CiteI), utility model patents (CiteU), and their sum (CiteIU), each measured with a two-year lead (t+2). The key independent variable, OC, is a dummy equal to 1 if the CEO is classified as overconfident. Control variables are selected from three dimensions: firm-level characteristics (i.e., total assets, ROA, D/A, firm age, Tobin's Q, HHI), corporate governance factors (i.e., proportion of independent directors), and CEO demographics (i.e., CEO age, gender, tenure). All regressions include year and industry fixed effects. Standard errors are reported in parentheses. The sample includes 13,120 firm-year observations from Chinese A-share listed non-financial firms between 2005 and 2020. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	(1) CiteI	(2) CiteI	(3) CiteU	(4) CiteU	(5) CiteIU	(6) CiteIU
OC	0.286***	0.152***	0.274***	0.175***	0.328***	0.194***
	(0.037)	(0.035)	(0.039)	(0.037)	(0.041)	(0.038)
TA		0.664***		0.598***		0.710***
		(0.014)		(0.015)		(0.015)
ROA		1.538***		1.466***		2.175***
		(0.265)		(0.284)		(0.293)
D/A		-0.352***		0.083		-0.137
		(0.080)		(0.086)		(0.088)
AGE		-0.243***		-0.373***		-0.413***
		(0.043)		(0.046)		(0.048)
Q		0.137***		-0.003		0.059***
		(0.014)		(0.015)		(0.016)
HHI		-0.199*		0.628***		0.172
		(0.114)		(0.122)		(0.126)
IND_DIR		0.731***		0.615**		0.570**
		(0.233)		(0.250)		(0.258)
CEO_AGE		-0.120		-0.136		-0.199*
		(0.098)		(0.105)		(0.108)
CEO_GEN		0.154***		0.162***		0.191***
		(0.054)		(0.058)		(0.060)
TENURE		-0.003		-0.008		-0.004
		(0.014)		(0.015)		(0.015)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	13120	13120	13120	13120	13120	13120
R-squared	0.180	0.346	0.265	0.400	0.268	0.423

ROA is also significantly positive, which is consistent with the view that stronger profitability and internal financing capacity are conducive to innovative output. D/A exhibits a significantly negative effect on CiteI in Model (2), but is statistically insignificant in Models (4) and (6), suggesting that leverage may constrain invention-related citation outcomes more clearly than utility model or aggregate citation outcomes. AGE shows a significantly negative coefficient across all three measures, indicating that older firms may be more subject to path dependence or organisational inertia, which can weaken innovation dynamism. In addition, Q is significantly positive in Models (2) and (6), while HHI is significantly negative in Model (2) but significantly positive in Model (4), suggesting that market valuation and industry structure may affect different forms of patent outcomes in distinct ways. Among the governance and CEO characteristics, IND_DIR is significantly positive in all three specifications with controls, while CEO_GEN remains positively significant throughout. By contrast, CEO_AGE is only weakly negative in Model (6), and TENURE does not exhibit a statistically significant effect.

In terms of model fit, the inclusion of control variables in Models (2), (4), and (6) substantially raises the R-squared values. Whether focusing on invention patents or utility model patents, the positive effect of CEO overconfidence on patent citation outcomes remains robust across all specifications. Hence, these baseline regression results provide preliminary support for the central argument of this chapter: there is a significant positive correlation between CEO overconfidence and the quality of corporate patent output.

2.5.2 Moderating Effects of State Ownership

To test the potential moderating effect of ownership structure on the relationship between CEO overconfidence and corporate innovation, this study includes the dummy variable SOE (whether the firm is state-owned) and its interaction with CEO overconfidence in the model. Models (1), (3), and (5) add only the SOE dummy to the baseline specification, to examine the independent effect of being state-owned on innovation. Models (2), (4), and (6) further introduce the interaction term OC×SOE, capturing whether the state-owned context strengthens or weakens the effect of CEO overconfidence on innovation. The dependent variables remain CiteI, CiteU and CiteIU. Based on the second hypothesis, the following model is specified:

$$\begin{aligned} Cite_{i,t+2} = \beta_0 + \beta_1 OC_{i,t} + \beta_2 SOE_{i,t} + \beta_3 OC_{i,t} * SOE_{i,t} \\ + \sum \beta_i\, Control_{i,t} + Industry + Year + \varepsilon_{i,t} \end{aligned} \tag{2-10}$$

From the main results, OC continues to exhibit a significantly positive coefficient in Models (1), (3), and (5), indicating that CEO overconfidence is positively associated with subsequent patent citation outcomes, consistent with the baseline findings. After the interaction term is introduced, however, the coefficient on OC should be interpreted as the effect of CEO overconfidence among non-SOEs. In Model (2), the coefficient on OC is 0.092, while the coefficient on OC×SOE is 0.170, implying that the estimated effect of CEO overconfidence on CiteI is 0.262 for SOEs, compared with 0.092 for non-SOEs. A similar pattern appears even more clearly in the utility model regressions: in Model (4), the coefficient on OC for non-SOEs becomes small and statistically insignificant (0.023), whereas the significantly positive interaction term (0.368) implies a total effect of 0.391 for SOEs, indicating that the positive association between overconfidence and CiteU is concentrated mainly in state-owned enterprises. For the combined measure in Model (6), the coefficient on OC is 0.092, and the interaction term remains significantly positive at 0.232, implying a total effect of 0.324 for SOEs. Taken together, these results indicate that the positive association between CEO overconfidence and subsequent patent citation outcomes is materially stronger in state-owned enterprises than in non-SOEs.

The coefficient on SOE itself also provides additional insight. In the interaction specifications, SOE is statistically insignificant for CiteI, but significantly negative for CiteU and CiteIU. This suggests that, conditional on CEO overconfidence being zero, SOEs do not display a clear advantage in baseline citation outcomes and may even perform less favourably in utility model and aggregate citation measures than non-SOEs. Therefore, the moderating effect of state ownership is reflected less in a uniformly higher innovation level for SOEs per se, and more in the stronger way in which CEO overconfidence is translated into observable patent outcomes within the SOE context. This pattern is consistent with the view that state-owned firms provide a resource and institutional environment in which overconfident CEOs can more readily implement ambitious innovation strategies.

An additional feature of the interaction results is that the moderating effect of

Table 2-7. Interaction Effects of CEO Overconfidence and SOE

This table reports OLS regression results examining whether state ownership (SOE) moderates the relationship between CEO overconfidence (OC) and corporate innovation. The dependent variables are the natural logarithms of forward citations for invention patents (CiteI), utility model patents (CiteU), and their sum (CiteIU), each measured with a two-year lead (t+2). Columns (1), (3), and (5) include the SOE dummy as a control, while Columns (2), (4), and (6) further introduce the interaction term OC×SOE to test for moderation. In the interaction specifications, the coefficient on OC captures the effect of CEO overconfidence among non-SOEs, while the sum of the coefficients on OC and OC×SOE reflects the corresponding effect among SOEs. All models control for firm-level characteristics, corporate governance factors, and CEO demographic characteristics, and include year and industry fixed effects. Standard errors are reported in parentheses. The sample contains 13,120 firm-year observations from non-financial firms listed on the Shanghai and Shenzhen A-share markets during 2005–2020. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	(1) CiteI	(2) CiteI	(3) CiteU	(4) CiteU	(5) CiteIU	(6) CiteIU
OC	0.157***	0.092**	0.162***	0.023	0.179***	0.092*
	(0.035)	(0.044)	(0.038)	(0.047)	(0.039)	(0.048)
SOE	0.023	-0.004	-0.071**	-0.130***	-0.082***	-0.119***
	(0.028)	(0.030)	(0.030)	(0.032)	(0.031)	(0.033)
OC*SOE		0.170**		0.368***		0.232***
		(0.068)		(0.073)		(0.076)
TA	0.662***	0.661***	0.605***	0.602***	0.717***	0.716***
	(0.014)	(0.014)	(0.015)	(0.015)	(0.016)	(0.016)
ROA	1.555***	1.547***	1.413***	1.396***	2.114***	2.103***
	(0.266)	(0.266)	(0.285)	(0.284)	(0.294)	(0.294)
D/A	-0.353***	-0.355***	0.088	0.084	-0.132	-0.134
	(0.080)	(0.080)	(0.086)	(0.086)	(0.088)	(0.088)
AGE	-0.247***	-0.253***	-0.359***	-0.372***	-0.398***	-0.406***
	(0.044)	(0.044)	(0.047)	(0.047)	(0.048)	(0.048)
Q	0.137***	0.136***	-0.003	-0.006	0.058***	0.057***
	(0.014)	(0.014)	(0.015)	(0.015)	(0.016)	(0.016)
HHI	-0.195*	-0.204*	0.615***	0.596***	0.157	0.145
	(0.114)	(0.114)	(0.122)	(0.122)	(0.126)	(0.126)
IND_DIR	0.740***	0.752***	0.588**	0.614**	0.538**	0.555**
	(0.234)	(0.234)	(0.250)	(0.250)	(0.259)	(0.259)
CEO_AGE	-0.131	-0.136	-0.102	-0.113	-0.161	-0.168
	(0.099)	(0.099)	(0.106)	(0.106)	(0.109)	(0.109)
CEO_GEN	0.151***	0.156***	0.170***	0.182***	0.201***	0.209***
	(0.055)	(0.055)	(0.058)	(0.058)	(0.060)	(0.060)
TENURE	-0.002	-0.002	-0.011	-0.011	-0.007	-0.007
	(0.014)	(0.014)	(0.015)	(0.015)	(0.015)	(0.015)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	13120	13120	13120	13120	13120	13120
R-squared	0.346	0.346	0.400	0.402	0.423	0.424

state ownership is not uniform across patent types. Although the interaction term is significantly positive in all three specifications, its magnitude is largest in the CiteU regression. This suggests that the SOE context does not simply raise innovation outcomes across the board; rather, it appears to strengthen the extent to which CEO overconfidence is translated into particular forms of patent output. In the present sample, this amplification is especially pronounced for utility model citation outcomes, indicating that overconfident CEOs in SOEs may be particularly effective at converting confidence-driven strategic initiatives into more immediately implementable and observable patent results.

The control variables remain broadly consistent with the baseline results. Overall, the evidence suggests that state ownership operates less as a simple level effect and more as an institutional amplifier of the overconfidence-innovation relation. The amplification is present for invention patents, strongest for utility-model patents, and still economically large for the combined citation measure. On this basis, the evidence in Table 2-7 provides substantive support for Hypothesis 2.

2.5.3 Moderating Effects of CEO Duality

To further examine whether CEO power concentration influences the relationship between CEO overconfidence and corporate innovation, this study introduces the dummy variable DUAL (whether the CEO also serves as board chair) and its interaction with CEO overconfidence. Models (1), (3), and (5) first include DUAL as an additional explanatory variable, while Models (2), (4), and (6) further add the interaction term OC×DUAL in order to test whether CEO duality strengthens or weakens the effect of overconfidence on patent citation outcomes. The dependent variables remain CiteI, CiteU, and CiteIU.

$$\begin{aligned} Cite_{i,t+2} = \beta_0 + \beta_1 OC_{i,t} + \beta_2 DUAL_{i,t} + \beta_3 OC_{i,t} * DUAL_{i,t} \\ + \sum \beta_i \, Control_{i,t} + Industry + Year + \varepsilon_{i,t} \end{aligned} \tag{2-11}$$

First, OC continues to exhibit a consistently positive coefficient in all models, in line with the baseline findings. This suggests that, whether corporate innovation is measured using CiteI, CiteU, or CiteIU, overconfident CEOs remain positively associated with subsequent patent citation outcomes. In addition, DUAL itself is significantly positive in Models (1), (2), (5), and (6), and weakly positive in Model (3), indicating that firms in which the CEO also serves as board chair tend to show stronger invention-related and aggregate citation outcomes, while the direct association with utility model citations is less stable.

Once the interaction term OC×DUAL is added to Models (2), (4), and (6), a more differentiated pattern emerges. In Model (2), the coefficient on OC remains significantly positive (0.158), while the interaction term is negative but statistically insignificant (-0.099), implying a total effect of 0.059 for firms with CEO duality. This suggests that for invention patent citations, the positive association between CEO overconfidence and innovation remains present in both groups, but there is no strong statistical evidence that CEO duality significantly weakens this relationship. In Model (4), the coefficient on OC for firms without CEO duality is 0.126, while the interaction term OC×DUAL is positive and marginally significant (0.137), implying a total effect of 0.263 for firms with CEO duality. This indicates that the positive association between CEO overconfidence and utility model citation outcomes is stronger when the CEO also serves as board chair. By contrast, in Model (6), the interaction term for the combined citation measure is close to zero and statistically insignificant (-0.027), implying a total effect of 0.152 under CEO duality, which is broadly similar to the non-duality group.

These results do not provide consistent evidence that CEO duality generally dampens the positive effect of CEO overconfidence on corporate innovation. Instead, the moderating role of CEO duality appears to vary across patent types. The cross-equation pattern is economically informative: the interaction term is negative for CiteI, positive for CiteU, and close to zero for CiteIU, suggesting that CEO duality does not exert a uniform moderating effect on innovation but may alter the composition of innovation outcomes. Greater power concentration appears more conducive to translating overconfident CEO behaviour into utility model citations, which are often more implementation-oriented and shorter-horizon in nature, while offering little support for additional gains in invention-related citation outcomes. When the two patent types are aggregated, these offsetting forces largely cancel out, which helps explain why the interaction effect becomes statistically insignificant in the CiteIU specification.

Table 2-8. Interaction Effects of CEO Overconfidence and CEO Duality

This table reports OLS regression results examining whether CEO duality (DUAL) moderates the relationship between CEO overconfidence (OC) and corporate innovation. The dependent variables are the natural logarithms of forward citation counts for invention patents (CiteI), utility model patents (CiteU), and their sum (CiteIU), each measured with a two-year lead (t+2). Columns (1), (3), and (5) include the DUAL dummy as a control, while Columns (2), (4), and (6) introduce the interaction term OC×DUAL to test for moderation. In the interaction specifications, the coefficient on OC captures the effect of CEO overconfidence among firms without CEO duality, while the sum of the coefficients on OC and OC×DUAL reflects the corresponding effect among firms with CEO duality. All models control for variables selected from three dimensions: firm-level characteristics, corporate governance factors, and CEO demographics. All regressions include year and industry fixed effects. Standard errors are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	(1) CiteI	(2) CiteI	(3) CiteU	(4) CiteU	(5) CiteIU	(6) CiteIU
OC	0.128***	0.158***	0.166***	0.126***	0.171***	0.179***
	(0.035)	(0.041)	(0.037)	(0.044)	(0.039)	(0.045)
DUAL	0.181***	0.207***	0.065*	0.028	0.174***	0.181***
	(0.033)	(0.038)	(0.036)	(0.041)	(0.037)	(0.043)
OC*DUAL		-0.099		0.137*		-0.027
		(0.072)		(0.077)		(0.080)
TA	0.671***	0.671***	0.601***	0.601***	0.717***	0.717***
	(0.014)	(0.014)	(0.015)	(0.015)	(0.015)	(0.015)
ROA	1.498***	1.498***	1.452***	1.451***	2.137***	2.137***
	(0.265)	(0.265)	(0.284)	(0.284)	(0.293)	(0.293)
D/A	-0.357***	-0.358***	0.081	0.083	-0.142	-0.142
	(0.080)	(0.080)	(0.086)	(0.086)	(0.088)	(0.088)
AGE	-0.228***	-0.228***	-0.368***	-0.368***	-0.399***	-0.399***
	(0.043)	(0.043)	(0.047)	(0.047)	(0.048)	(0.048)
Q	0.136***	0.135***	-0.003	-0.002	0.058***	0.058***
	(0.014)	(0.014)	(0.015)	(0.015)	(0.016)	(0.016)
HHI	-0.197*	-0.199*	0.629***	0.631***	0.174	0.174
	(0.114)	(0.114)	(0.122)	(0.122)	(0.126)	(0.126)
IND_DIR	0.626***	0.629***	0.578**	0.573**	0.470*	0.471*
	(0.234)	(0.234)	(0.251)	(0.251)	(0.259)	(0.259)
CEO_AGE	-0.215**	-0.215**	-0.169	-0.169	-0.291***	-0.291***
	(0.099)	(0.099)	(0.106)	(0.106)	(0.110)	(0.110)
CEO_GEN	0.151***	0.152***	0.161***	0.159***	0.188***	0.189***
	(0.054)	(0.054)	(0.058)	(0.058)	(0.060)	(0.060)
TENURE	-0.007	-0.008	-0.010	-0.009	-0.008	-0.008
	(0.014)	(0.014)	(0.015)	(0.015)	(0.015)	(0.015)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	13120	13120	13120	13120	13120	13120
R-squared	0.347	0.347	0.400	0.401	0.424	0.424

Overall, the Table 2-8 results show that CEO duality is positively associated with several patent citation outcomes, but there is no robust evidence that it systematically weakens the innovation effect of CEO overconfidence. Therefore, the evidence does not support Hypothesis 3 in a general sense, although a positive moderating effect is observed for utility model patent citations.

2.6 Robustness Checks

2.6.1 Reverse Causality Tests

When examining the relationship between CEO overconfidence and corporate innovation, it is important to distinguish the possibility of reverse causality, namely whether CEO overconfidence drives subsequent innovation output, or whether stronger prior innovation performance instead increases CEO overconfidence. In the baseline regressions, patent citation outcomes are aligned two years ahead of the CEO and firm characteristics in order to reflect the lag between managerial decisions and observable innovation outcomes. In this reverse-causality test, however, CiteIU is considered on the original calendar scale, and innovation outcomes observed in years t and t−1 are introduced as explanatory variables, with CEO overconfidence (OC) as the dependent variable. This specification makes it possible to examine whether prior patent citation outcomes predict current CEO overconfidence. The specific estimation model is as follows:

$$OC_{i,t} = \beta_0 + \beta_1 Cite_{i,t/(t-1)} + \sum \beta_i\, Control_{i,t} + Industry + Year + \varepsilon_{i,t} \tag{2-12}$$

Table 2-9 reports the corresponding regression results. According to the main findings, neither CiteIU(t) nor CiteIU(t−1) is statistically significant. The coefficients are both negative and close to zero (-0.002), suggesting that neither contemporaneous nor lagged patent citation outcomes materially increase CEO overconfidence in the current period. In other words, the data do not support the view that stronger prior innovation output subsequently induces CEOs to become more overconfident. This result is consistent with the baseline specification and weakens the reverse-causality concern that the documented positive relationship is driven by innovation outcomes

Table 2-9. Testing for Reverse Causality: Effects of Lagged Innovation on CEO Overconfidence

This table examines the potential reverse causality between CEO overconfidence (OC) and corporate innovation by testing whether prior innovation output affects CEO overconfidence. The dependent variable is OC. The key explanatory variables are CiteIU(t) and CiteIU(t−1), representing patent citation outcomes observed in years t and t−1 on the original calendar scale, respectively. All regressions control for firm-level characteristics, corporate governance factors, and CEO demographics, and include year and industry fixed effects. Standard errors are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	(1) OC	(2) OC
CiteIU(t)	-0.002	
	(0.004)	
CiteIU(t-1)		-0.002
		(0.004)
TA	0.044***	0.031**
	(0.013)	(0.015)
ROA	-0.069	-0.110
	(0.095)	(0.105)
D/A	-0.024	-0.047
	(0.045)	(0.051)
AGE	-0.122	-0.146
	(0.095)	(0.124)
Q	0.002	0.003
	(0.006)	(0.007)
HHI	-0.075	-0.173***
	(0.057)	(0.067)
IND_DIR	0.109	0.058
	(0.107)	(0.120)
CEO_AGE	0.372***	0.422***
	(0.045)	(0.050)
CEO_GEN	0.013	0.026
	(0.027)	(0.030)
TENURE	0.093***	0.094***
	(0.004)	(0.005)
Industry FE	Yes	Yes
Year FE	Yes	Yes
Observations	7774	6359
R-squared	0.144	0.149

feeding back into CEO behaviour rather than the other way around.

Regarding the control variables, TA remains significantly positive in both models, indicating that larger firms are more likely to be associated with overconfident CEOs. CEO_AGE is also significantly positive across the two specifications, suggesting that older CEOs are more likely to exhibit overconfidence in the current sample. In addition, TENURE remains significantly positive at the 1% level, implying that CEOs with longer time in office are more likely to display confidence-related behavioural bias. Most of the remaining control variables are statistically insignificant and do not alter the core inference.

Overall, neither current nor lagged patent citation outcomes significantly affect CEO overconfidence. This suggests that the previously documented positive association between CEO overconfidence and subsequent patent citation outcomes is unlikely to be driven by prior innovation performance shaping CEO overconfidence. Therefore, the main findings are less likely to reflect reverse causality.

2.6.2 Self-Selection Bias: Propensity Score Matching (PSM)

Beyond potential reverse causality, another concern in the relationship between CEO overconfidence and corporate innovation is selection on observables. More specifically, firm-year observations led by overconfident CEOs may differ systematically from other firm-year observations in terms of firm fundamentals, governance arrangements, managerial characteristics, and operating environments, and these differences may themselves be related to subsequent patent citation outcomes. To mitigate this concern, this study employs Propensity Score Matching (PSM) as an additional robustness check. Following the Rosenbaum and Rubin (1983) framework, firm-year observations with OC equal to 1 are treated as the treatment group, while those with OC equal to 0 constitute the control group. Propensity scores are estimated using a logit model based on firm size, profitability, leverage, firm age, Tobin's Q, industry concentration, board independence, CEO age, CEO gender, CEO tenure, state ownership, as well as year and industry indicators. Based on the estimated scores, treatment and control observations are matched using 1:1 nearest-neighbour matching, with ties allowed and a common-support restriction imposed. The baseline regression is then re-estimated on the matched sample using the matching weights. This procedure preserves the original firm-year research design while placing observations associated with overconfident CEOs and those associated with non-overconfident CEOs into a more comparable empirical setting. The matched-sample estimates are therefore interpreted as evidence from treated and untreated firm-year observations that are comparable within the region of common support, rather than from the unrestricted full sample. Matching quality is evaluated through standardised bias diagnostics and propensity score distributions before and after matching. In this way, PSM is employed to improve comparability on observed characteristics and to provide a stricter robustness check for the baseline findings.

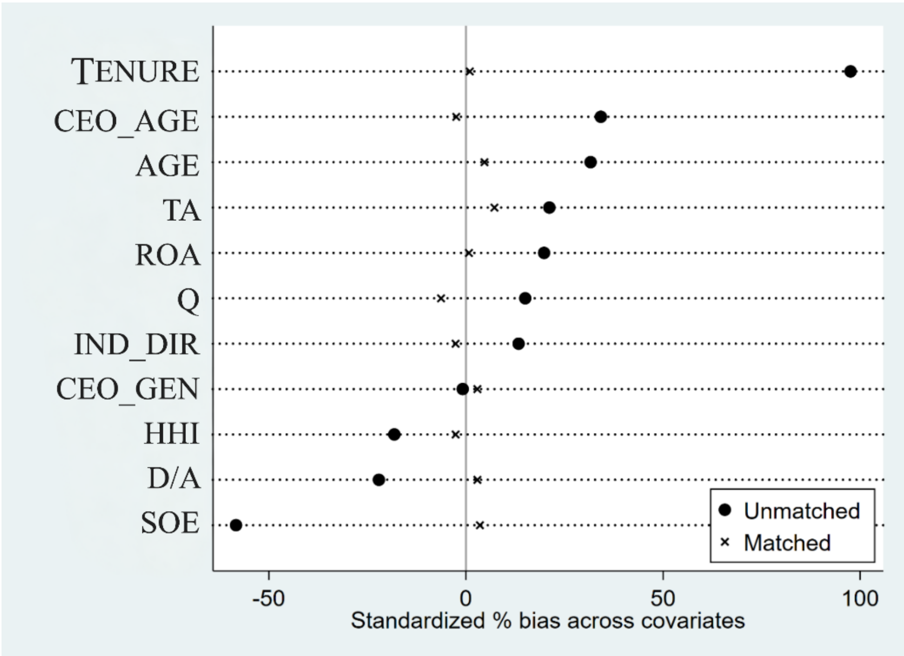
2.6.2.1 Balance Diagnostics

Before interpreting the matched-sample estimates, it is necessary to assess whether the matching procedure achieves adequate balance and common support. Figure 2-1 reports the standardised percentage bias of the core covariates before and after matching. Prior to matching, substantial imbalance is observed for several variables, particularly CEO tenure, CEO age, firm age, firm size, profitability, and state ownership, indicating that treated and untreated firm-year observations differ systematically along economically meaningful dimensions. After matching, however, the standardised biases of all reported core covariates are sharply reduced and cluster closely around zero. This pattern suggests a marked improvement in covariate balance and indicates that the matched control observations provide a much more comparable benchmark for the treated observations. For ease of presentation, Figure 2-1 focuses on the core economic and governance variables, while year and industry indicators are also included in the propensity score estimation.

Figures 2-2 and 2-3 further evaluate the overlap condition through the propensity score distributions before and after matching. Figure 2-2 shows that, prior to matching, treated and untreated firm-year observations differ substantially in their estimated propensity scores: treated observations are more concentrated in the middle and upper parts of the distribution, whereas untreated observations are heavily concentrated at low propensity scores. This pattern indicates limited comparability in the raw sample. After imposing the common-support restriction and applying 1:1 nearest-neighbour matching, Figure 2-3 shows that the propensity score distributions of treated observations and matched controls overlap much more closely across the support region. The post-matching density curves become highly aligned, indicating that the matching procedure removes a large portion of the observable imbalance present before matching.

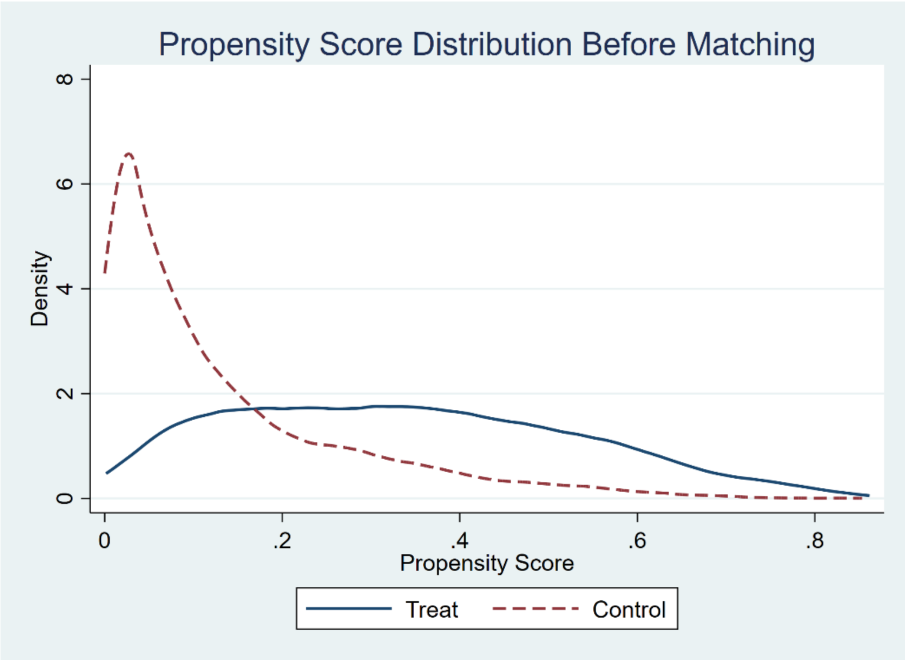
Taken together, the balance diagnostics and propensity score distributions indicate that the matching procedure substantially improves comparability between treated and control observations and yields satisfactory overlap within the common support region. The matched sample therefore provides a more appropriate basis for the subsequent regression analysis, as it allows firm-year observations associated with overconfident CEOs to be compared with observationally similar firm-year observations associated with non-overconfident CEOs. The matched-sample regressions reported below are thus used to examine whether the positive association identified in the baseline analysis remains after imposing a stricter comparison framework.

Figure 2-1. Standardised Bias Across Covariates Before and After PSM



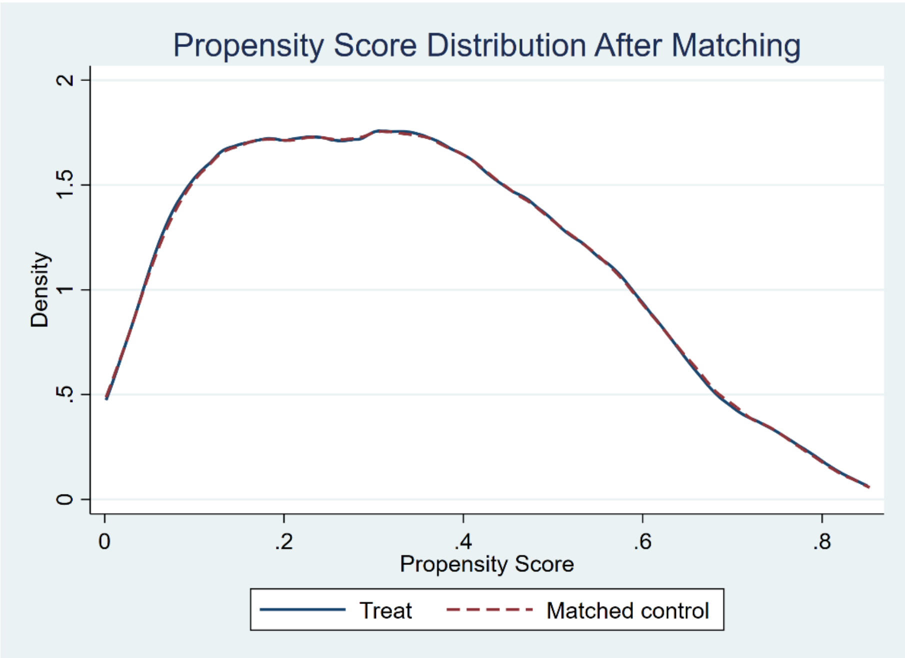
Notes: This figure presents the standardised percentage bias of core covariates before and after propensity score matching (PSM). The black dots represent the unmatched sample, and the crosses represent the matched sample.

Figure 2-2. Propensity Score Distribution Before Matching



Notes: This figure presents the propensity score distributions of treated and control firm-year observations before propensity score matching (PSM). The solid line represents the treatment group, and the dashed line represents the control group.

Figure 2-3. Propensity Score Distribution After Matching



Notes: This figure presents the propensity score distributions of treated firm-year observations and matched control firm-year observations after propensity score matching (PSM). The solid line represents the treatment group, and the dashed line represents the matched control group.

2.6.2.2 Matched-Sample Regression Results

Table 2-10 reports the regression results for the full sample and for the matched sample obtained from propensity score matching. Column (1) reproduces the baseline OLS result for CiteIU, while Column (2) reports the corresponding matched-sample regression estimated within the common support region using the matching weights. Comparing the two columns allows an assessment of whether the positive association between CEO overconfidence and subsequent patent citation outcomes remains after treated and untreated observations are made more comparable on observed characteristics.

The coefficient on OC remains significantly positive in the matched-sample regression. Specifically, the coefficient declines from 0.194 in the full-sample OLS regression to 0.157 in the PSM-OLS regression but remains statistically significant at the 1% level. This suggests that the positive association between CEO overconfidence and subsequent patent citation outcomes is not driven solely by observable differences between treated and untreated firm-year observations. In other words, after imposing a stricter comparison framework through propensity score matching, firm-year observations associated with overconfident CEOs still exhibit stronger patent citation outcomes than comparable observations associated with non-overconfident CEOs. Regarding the control variables, the signs of the main coefficients remain broadly similar across the two specifications. TA and ROA continue to be significantly positive, indicating that larger firms and more profitable firms tend to generate stronger patent citation outcomes. AGE remains significantly negative in both regressions, suggesting that older firms may face greater inertia in innovative activities. Some control variables, such as Q, IND_DIR, and CEO_GEN, become weaker in statistical significance in the matched sample, which is consistent with the reduced sample size and the improved comparability generated by the matching procedure.

Overall, the PSM-based evidence reinforces the baseline findings. The matched-sample regressions provide a stricter comparison framework in which treated and untreated firm-year observations are made more comparable on observed characteristics. The continued significance of OC in the matched sample therefore provides further support for a positive association between CEO overconfidence and subsequent patent citation outcomes.

Table 2-10. Robustness Check Using PSM

This table reports the regression results for the full sample and the matched sample obtained from propensity score matching (PSM). The dependent variable is CiteIU, measured as the natural logarithm of forward citations to invention and utility model patents with a two-year lead (t+2). The treatment group consists of firm-year observations with overconfident CEOs (OC = 1), while the control group consists of firm-year observations with non-overconfident CEOs (OC = 0). Propensity scores are estimated using a logit model based on firm characteristics, governance variables, CEO demographics, and year and industry indicators. The matched sample is constructed using 1:1 nearest-neighbour matching with ties allowed and a common-support restriction, and the matched-sample regression is estimated using the corresponding matching weights. Column (1) reports the baseline OLS result for the full sample, while Column (2) reports the PSM-OLS result for the matched sample. All regressions include year and industry fixed effects. Standard errors are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	(1) OLS CiteIU	(2) PSM-OLS CiteIU
OC	0.194***	0.157***
	(0.039)	(0.055)
TA	0.710***	0.781***
	(0.017)	(0.034)
ROA	2.175***	2.867***
	(0.295)	(0.623)
D/A	-0.137	0.187
	(0.089)	(0.206)
AGE	-0.413***	-0.381***
	(0.048)	(0.097)
Q	0.059***	0.024
	(0.016)	(0.031)
HHI	0.172	0.035
	(0.140)	(0.396)
IND_DIR	0.570**	0.552
	(0.270)	(0.551)
CEO_AGE	-0.199*	-0.265
	(0.108)	(0.226)
CEO_GEN	0.191***	0.203*
	(0.059)	(0.115)
TENURE	-0.004	-0.047
	(0.015)	(0.041)
Industry FE	Yes	Yes
Year FE	Yes	Yes
Observations	13120	3729
R-squared	0.423	0.413

2.6.3 Alternative Measures of Innovation and CEO Overconfidence

To further validate the robustness of the relationship between CEO overconfidence and corporate innovation, and to reduce potential bias arising from the measurement of the dependent and independent variables, this section re-estimates the model after substituting both the corporate innovation indicators and the CEO overconfidence variable. First, regarding the measurement of corporate innovation, in addition to the original patent citation measure (CiteIU), this study also adopts R&D intensity (RD_INT), measured as R&D expenditure divided by operating revenue, and PatIU, measured as the natural logarithm of the number of granted invention and utility model patents applied for and granted with a two-year lead (t+2), as alternative metrics, so as to more comprehensively capture firms' innovation inputs and patent outputs. RD_INT reflects the relative intensity of firms' innovation investment, while PatIU captures the quantity dimension of subsequent patent output. Compared with patent citations, which reflect the later influence of patent outcomes, this patent-count measure more directly reflects the scale and breadth of firms' technological activities.

Second, in terms of measuring CEO overconfidence, aside from the holdings-based revealed-beliefs proxy used in the main analysis, this section also employs a traditional approach based on earnings forecast bias in order to assess whether the conclusions are sensitive to the specific overconfidence measure adopted. Following the conventional approach, if the net profit forecast in the company's first annual earnings guidance (excluding subsequent revisions) significantly exceeds the actual result, the incumbent CEO is classified as exhibiting optimistic earnings bias, which is taken as an alternative indicator of CEO overconfidence (OC2). If this alternative overconfidence measure, combined with the alternative innovation indicators, still yields a positive effect on innovation, this would further demonstrate that the empirical findings are not driven by a particular measurement choice.

Table 2-11 reports the relevant regression results. Models (1) and (2) use RD_INT as the dependent variable, Models (3) and (4) adopt PatIU, and Models (5) and (6) revert to CiteIU while substituting the alternative overconfidence measure OC2. Across all models, the estimated effect of CEO overconfidence remains positive. In Models (1) and (2), the coefficients on OC are 0.400 and 0.297, respectively, and both remain statistically significant, suggesting that firms led by overconfident CEOs tend to exhibit higher R&D intensity. In Models (3) and (4), the coefficients on OC are 0.306 and 0.189, respectively, both significant at conventional levels, indicating that CEO overconfidence is also positively associated with the quantity dimension of patent output captured by PatIU. These results imply that overconfident CEOs are

Table 2-11. Robustness Check Using Alternative Measures

This table presents robustness checks using alternative measures of corporate innovation and CEO overconfidence. Models (1)-(2) use R&D intensity (RD_INT, measured as R&D expenditure divided by operating revenue) as the dependent variable, while Models (3)-(4) employ PatIU, defined as the natural logarithm of the number of invention and utility model patents applied for and granted, aligned with a two-year lead (t+2). Models (5)-(6) retain CiteIU as the dependent variable but replace the overconfidence indicator with an alternative proxy (OC2), defined based on earnings forecast bias. Control variables are selected based on three dimensions: firm-level characteristics, corporate governance factors, and CEO demographics. All regressions include year and industry fixed effects. Standard errors are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	(1) RD_INT	(2) RD_INT	(3) PatIU	(4) PatIU	(5) CiteIU	(6) CiteIU
OC	0.400***	0.297**	0.306***	0.189***		
	(0.128)	(0.132)	(0.038)	(0.035)		
OC2					0.205***	0.127**
					(0.068)	(0.061)
TA		0.030		0.652***		0.719***
		(0.064)		(0.014)		(0.022)
ROA		-12.073***		1.936***		1.788***
		(1.195)		(0.267)		(0.370)
D/A		-4.089***		-0.065		-0.483***
		(0.379)		(0.081)		(0.124)
AGE		-1.177***		-0.379***		-0.383***
		(0.186)		(0.044)		(0.074)
Q		0.649***		0.049***		0.075***
		(0.059)		(0.014)		(0.023)
HHI		-4.378***		0.214*		-0.357*
		(0.575)		(0.115)		(0.196)
IND_DIR		3.450***		0.551**		0.871**
		(0.988)		(0.235)		(0.381)
CEO_AGE		-0.360		-0.152		-0.359**
		(0.432)		(0.099)		(0.161)
CEO_GEN		0.346		0.194***		0.233**
		(0.242)		(0.055)		(0.092)
TENURE		0.124**		-0.010		0.046**
		(0.060)		(0.014)		(0.022)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6400	6400	13120	13120	6146	6146
R-squared	0.185	0.251	0.294	0.447	0.244	0.404

linked not only to stronger subsequent patent citation outcomes in the baseline regressions, but also to greater innovation input and a higher volume of patent output. Models (5) and (6) then use the earnings-forecast-based overconfidence proxy (OC2) to examine its association with CiteIU. The coefficients on OC2 are 0.205 and 0.127, respectively, and both remain significantly positive. Therefore, whether CEO overconfidence is measured through the holdings-based revealed-beliefs proxy used in the main analysis or through optimistic earnings forecasts, the empirical evidence continues to indicate a positive relationship between CEO overconfidence and subsequent patent citation outcomes.

In summary, even when CiteIU is replaced by RD_INT or PatIU, CEO overconfidence continues to exert a positive effect on firm innovation. Likewise, replacing the main overconfidence indicator with OC2 still yields a significantly positive coefficient. These findings further corroborate the robustness of the study's main conclusions and suggest that the positive association between CEO overconfidence and corporate innovation is not contingent on a single measurement approach.

2.7 Conclusion

This chapter focuses on the context of Chinese listed firms and, from the combined perspectives of behavioural finance and corporate governance, systematically examines how CEO overconfidence affects corporate innovation and whether this relationship is shaped by institutional and organisational conditions. Based on a large-sample empirical analysis of A-share listed companies, the chapter provides evidence on the innovation consequences of managerial psychological bias in an emerging-market setting and thereby extends the study of CEO overconfidence beyond the institutional environment in which the original literature was developed. To operationalise CEO overconfidence, this chapter does not mechanically replicate the option-based Holder 67 measure proposed by Malmendier and Tate (2005a). Instead, given the data structure of the Chinese market, it develops a holdings-based revealed-beliefs proxy that follows the same underlying identification logic. Specifically, the measure combines a normative portfolio-choice benchmark, a China-specific expected-return benchmark, and a repeated non-selling rule to capture persistent firm-specific over-optimism embedded in the CEO's stockholding behaviour. In this sense, the chapter not only adapts the original Holder 67 intuition to the local institutional setting, but also extends the applicability of the Malmendier–Tate framework to a market where detailed executive stock option exercise data are not readily available.

Using this measure, the empirical results show that CEO overconfidence is positively associated with subsequent patent citation outcomes. The baseline regressions indicate that overconfident CEOs are linked to higher invention patent citations, utility model patent citations, and aggregate patent citation outcomes. The heterogeneity analysis further suggests that this positive association is significantly stronger in state-owned enterprises, implying that the institutional and resource environment of SOEs may facilitate the translation of managerial overconfidence into observable innovation outcomes. By contrast, the moderating role of CEO duality is not uniform across patent types. Although CEO duality is itself positively associated with several innovation outcomes, there is no robust evidence that it systematically weakens the innovation effect of CEO overconfidence. Instead, its interaction with overconfidence is mainly concentrated in utility model patent citations, while the corresponding effects for invention patents and the aggregate citation measure are not statistically significant. A series of additional tests further supports the main findings. The reverse-causality analysis shows that prior patent citation outcomes do not significantly predict current CEO overconfidence, alleviating the concern that the documented relationship is driven by innovation performance feeding back into managerial beliefs. The propensity score matching results indicate that the positive association remains after treated and untreated firm-year observations are matched on observable characteristics. In addition, the results continue to hold when alternative measures of innovation and overconfidence are employed. Specifically, CEO overconfidence remains positively related to R&D intensity and the quantity of granted patents, and the main conclusion is preserved when overconfidence is alternatively proxied by earnings forecast bias.

Overall, the findings of this chapter are broadly consistent with the central insight of the behavioural finance literature, namely that managerial beliefs and psychological biases exert economically meaningful effects on major corporate decisions and outcomes. In the Chinese market, CEO overconfidence appears to be associated not only with stronger subsequent patent citation outcomes, but also with greater innovation input and patent output. At the same time, the results indicate that the consequences of overconfidence are conditioned by the governance and institutional environment in which managerial decisions are made. This chapter therefore contributes to the literature in two related respects. First, it provides large-sample evidence from China that supports the broader behavioural-finance view that managerial overconfidence can shape firms' innovative behaviour. Second, it shows that the identification spirit of Malmendier and Tate (2005a) can be meaningfully adapted to a local institutional setting through a holdings-based proxy, thereby offering a feasible way to study executive overconfidence when mature-market option data are unavailable.

The heterogeneity results further suggest that the innovation consequences of CEO overconfidence depend on the governance and institutional context in which managerial decisions are made. Future research could therefore examine more directly the channels through which governance arrangements shape the translation of managerial belief distortions into innovation outcomes. In particular, greater attention could be paid to board composition, ownership structure, external monitoring, and incentive design, as well as to whether these mechanisms operate differently across patent types, industries, and institutional settings. At the same time, this chapter is subject to several limitations. The main overconfidence variable is a holdings-based revealed-beliefs proxy rather than a direct replication of the original option-exercise measure in Malmendier and Tate (2005a), because detailed executive option grant, vesting, exercise, and moneyness data are not sufficiently complete or continuously observable for long-horizon analysis in the Chinese setting. Although the proxy is designed to preserve the same identification logic by combining a normative portfolio benchmark, a China-specific expected-return benchmark, and repeated non-selling behaviour, it still relies on maintained assumptions about risk aversion and outside wealth and may therefore be subject to calibration error. Moreover, persistent non-reduction of company stock may reflect not only optimistic beliefs, but also other motives or constraints, such as control considerations, trading restrictions, liquidity needs, or compensation design. The measure should therefore be interpreted as a revealed-beliefs proxy for persistent firm-specific over-optimism rather than as a direct observation of managerial psychology.

Chapter 3
Equity Incentives and Corporate Innovation: Evidence from China

3.1 Introduction

In modern corporate governance practice, equity incentives have attracted significant attention because of their potential to mitigate agency problems and encourage greater tolerance for risky long-term investments. Traditional compensation structures often place greater emphasis on short-term corporate performance and immediate managerial rewards. By linking the payoffs of managers or key technical personnel to a firm’s stock price or longer-term value (Jensen and Meckling, 1976), equity incentives may shift attention away from purely contemporaneous performance and towards projects whose returns are delayed, uncertain, and potentially substantial. This is particularly relevant for R&D and technological innovation, where early-stage investments are risky and difficult to evaluate using short-term performance measures (Manso, 2011). Existing studies on the relationship between equity incentives and corporate innovation, most of which focus on mature markets, generally report a positive association (Chang et al., 2015), although considerable debate remains. Some studies argue that equity incentives may induce management to overemphasise short-term stock prices (Bebchuk et al., 2002), thereby favouring incremental innovation at the expense of more substantive technological breakthroughs (Manso, 2011). Other research suggests that stronger innovation effects are more likely to arise when equity incentives are granted in high-technology industries or to core technical teams (Lerner and Wulf, 2007). Such variation may reflect not only differences in incentive instruments, such as stock options, restricted stock, and stock appreciation rights, but also broader differences in governance structures, market maturity, and institutional settings (Core and Guay, 1999; Conyon and He, 2011).

China, as a rapidly developing economy, provides a particularly informative setting in which to examine these issues. Following the introduction of the 2006 Administrative Measures for Equity Incentives of Listed Companies (Trial), equity incentive plans gradually became more common among Chinese A-share listed firms, while innovation was simultaneously elevated as a central corporate and policy objective. This institutional background makes China especially suitable for examining not only whether equity incentives are associated with innovation outcomes, but also how such effects vary across different incentive arrangements and firm contexts. Existing studies on Chinese listed firms have shown that equity incentives are related to firm performance, investment behaviour, and innovation; however, the evidence remains relatively fragmented with respect to the channels through which these plans affect innovation outcomes. In particular, less attention has been paid to differences in incentive recipients, variation across option-based and stock-based schemes, and the extent to which the innovation consequences of equity incentive adoption differ across ownership structures and industry settings. These issues are especially relevant in China, where state involvement, market development, and corporate governance arrangements vary substantially across firms. Since the adoption of equity incentive plans is not random, the empirical analysis further assesses the robustness of the main findings through complementary approaches that make use of pre-adoption comparability, adoption timing, and variation in incentive intensity.

Based on these considerations, this study uses Chinese A-share listed companies from 2007 to 2021 as the research sample and examines the relationship between equity incentives and corporate innovation over a relatively long policy window. This sample period captures the gradual diffusion of equity incentive plans after their formal introduction and allows the analysis to assess their innovation consequences under changing market and institutional conditions. Building on the existing literature, this study contributes in several respects. First, by employing a long-horizon sample of Chinese listed firms, it provides broader evidence than studies based on shorter post-reform windows. Second, it distinguishes between different equity incentive instruments and incentive recipients, thereby examining whether innovation effects vary across option-based and stock-based plans and between executives and non-executive core technical or operational personnel. Third, it further explores whether the innovation consequences of equity incentive adoption differ across ownership structures and industry contexts. To strengthen the empirical interpretation of the results, the analysis combines matched comparisons, timing-based robustness checks, and additional tests on incentive intensity. Collectively, these design choices allow the study to evaluate not only whether equity incentives are associated with corporate innovation, but also how and under what conditions that relationship is most pronounced.

The empirical results indicate that, whether measured by plan adoption or by incentive intensity, equity incentives are positively associated with corporate innovation across patent citations, patent grants, and R&D investment. For higher-value invention outcomes, option-based instruments linked to stock price appreciation, including stock options and stock appreciation rights, are more strongly associated with innovation performance than restricted stock. Restricted stock, by contrast, remains positively associated with utility-model and broader patent outcomes. The internal allocation of incentives also matters: equity incentives directed at core R&D and key operational personnel are more strongly associated with innovation outcomes than those directed solely at senior executives, with particularly pronounced patterns in non-SOEs and technology-intensive industries. Across matched comparisons, instrumental-variable estimates, and stacked PSM-DID analyses, the empirical pattern remains consistently positive, reinforcing the conclusion that equity incentives are closely related to subsequent corporate innovation in the Chinese market.

The remainder of this chapter is structured as follows. Section 3.2 reviews the relevant literature and proposes research hypotheses. Sections 3.3 and 3.4 introduce the data sources, research design, and descriptive statistics. Section 3.5 reports the baseline regressions together with a series of heterogeneity analyses. Section 3.6 conducts multiple tests to address endogeneity and robustness. Section 3.7 concludes the chapter and discusses managerial implications and directions for future research.

3.2 Literature Review and Hypothesis Development

Because the separation of ownership and control creates persistent conflicts of interest between principals and agents, compensation incentives have long occupied a central position in corporate governance research. Early organisational theorists such as Barnard (1968) and Simon (1957) emphasised that effective managerial control depends not only on formal authority, but also on appropriately designed systems of evaluation and reward. This insight was formalised by agency theory, which argues that managers may pursue private benefits when their wealth is insufficiently tied to firm value, thereby generating agency costs (Jensen and Meckling, 1976). Within this framework, equity-based compensation is of particular importance because it links a portion of managerial wealth to the residual value of the firm and therefore encourages managers to internalise the long-term consequences of their strategic decisions (Holmstrom, 1979). Equity incentives are thus not merely a payment arrangement; they are a governance mechanism through which firms attempt to align managerial effort, horizon choice, and risk-bearing with shareholders' long-run interests. Subsequent research has refined this alignment logic by showing that the effectiveness of compensation contracts depends not only on the level of pay, but also on the architecture of the incentive package and the form of the instrument. Accordingly, the literature has expanded from basic salary-based compensation to a wider set of equity-based arrangements, including stock options, restricted stock, and stock appreciation rights. Classical studies emphasised pay-performance sensitivity as the central channel through which compensation disciplines managerial behaviour (Murphy, 1985; Jensen and Murphy, 1990). More recent work, however, shows that incentive design also depends on the choice of performance measures, the benchmarking of pay against peer firms, the use of relative performance evaluation, the structure of pay components, and the vesting conditions attached to long-term awards (Edmans et al., 2017; Bettis et al., 2018; Bell et al., 2021; Grinstein et al., 2022; Kreilkamp et al., 2023). These design features matter because they affect how effectively compensation filters out common shocks, how closely rewards are mapped to managerial contribution, and how strongly executives are encouraged to undertake decisions whose payoffs materialise only over longer horizons. In this sense, the core question in the compensation literature is not simply whether incentives matter, but how different contractual designs shape managerial choices under uncertainty. This theoretical perspective provides the basis for the subsequent discussion of how incentive mechanisms influence broader firm outcomes and, eventually, corporate innovation.

Research on incentive mechanisms subsequently moved beyond the general agency problem to examine whether compensation contracts affect overall firm performance and major corporate policies. Early empirical studies focused on observable financial outcomes, showing that executive compensation design is associated with earnings (Murphy, 1985), stock-price performance (Jensen and Murphy, 1990), and financing choices, including capital-structure design (John and John, 1993). In parallel, evidence from mature capital markets suggests that stronger pay-performance sensitivity and greater managerial equity exposure align managerial wealth more closely with shareholder value and influence firms' investment and risk choices (Mehran, 1995; Hall and Liebman, 1998; Coles et al., 2006). This literature is important because it establishes that compensation contracts are not passive transfers of income; rather, they operate as decision-shaping devices that influence how managers respond to investment opportunities, market signals, and governance pressures. More recent studies continue to support this broader view by showing that executive incentives affect risk-taking (Chu et al., 2020), labour investment efficiency (Sualihu et al., 2021), and disclosure quality (Wruck and Wu, 2021), in addition to formal pay-performance alignment. As the literature matured, scholars increasingly shifted attention from aggregate firm performance to the specific corporate policies through which incentive contracts operate. Equity-based incentives have been linked to earnings management (Cheng and Warfield, 2005), financing decisions (Lewellen, 2006), risk-taking behaviour (Coles et al., 2006), R&D investment (Cheng, 2004), and accounting disclosure quality (Wruck and Wu, 2021). Taken together, these studies suggest that incentive design affects not only the level of firm performance, but also the composition, timing, and risk profile of managerial decisions. In particular, higher pay-performance sensitivity tends to strengthen managers' incentives to pursue value-enhancing investments, whereas greater equity holdings and longer-horizon compensation can shift managerial attention away from short-term accounting targets towards strategic decisions whose returns materialise over a longer period (Mehran, 1995; Hall and Liebman, 1998). At the same time, this literature also reveals a limitation of the broad firm-performance approach: aggregate performance measures combine heterogeneous channels, including profitability, financing, disclosure, and investment policy, and therefore do not by themselves identify why certain decisions are especially sensitive to incentive design. This limitation is particularly salient for corporate innovation, which is not simply another manifestation of firm performance, but a distinctive form of long-horizon, high-uncertainty investment.

Corporate innovation differs fundamentally from general corporate investment and overall firm performance because it is characterised by long gestation periods, substantial uncertainty, high failure rates, and outputs that are often intangible and difficult to evaluate ex ante. Unlike routine operating decisions, innovation projects typically require repeated experimentation, learning-by-doing, and the accumulation of firm-specific knowledge, while their economic returns are highly skewed and frequently realised only after a considerable delay. These features make innovation especially vulnerable to managerial myopia and underinvestment. From an agency perspective, when managerial effort, project quality, and the probability distribution of future payoffs cannot be fully observed or contracted upon, conventional performance measures become noisy proxies for actual contribution. As a result, innovative activities pose particularly acute incentive problems. This difficulty is further reinforced by the financing characteristics of R&D and innovation, since intangible investment is more difficult to collateralise and is more exposed to information asymmetry than ordinary capital expenditure. These characteristics imply that innovation should not be treated simply as another manifestation of overall firm performance. Standard compensation contracts tied closely to short-term accounting outcomes or contemporaneous stock-price performance may be effective for routine production or efficiency improvement, but they are less well suited to activities whose early stages are exploratory, failure-prone, and difficult to evaluate in real time. Innovation often requires managers and key employees to tolerate early setbacks, persist through ambiguous intermediate outcomes, and continue supporting projects that may depress current earnings before generating long-run value. Accordingly, the optimal incentive environment for innovation differs from that for ordinary performance enhancement: it must provide sufficient tolerance for early failure, meaningful reward for long-term success, and adequate discretion for experimentation. This insight is formalised by Manso (2011), who shows that innovation-motivating contracts differ systematically from standard pay-for-performance schemes, and is further supported by Ederer and Manso (2013), who demonstrate that conventional pay-for-performance can inhibit exploration relative to contracts that combine early-failure tolerance with long-term rewards. The same logic also helps explain why innovation outcomes depend not only on the presence of incentives, but also on their horizon, intensity, and contractual design. Because innovative effort is cumulative, team-based, and shaped by learning under uncertainty, incentive contracts that focus excessively on immediate and easily observable performance may bias decision-makers toward safer, more incremental projects while discouraging riskier exploratory innovation. Consistent with this view, Mao and Zhang (2018) show that reductions in managerial risk-taking incentives lead firms to scale back core-business and exploratory innovation. Related evidence from scientific and creative settings likewise suggests that greater latitude to experiment, longer evaluation horizons, and tolerance for early failure are conducive to more original and influential output. Therefore, the central theoretical issue is not merely whether incentives affect innovation, but why innovation is uniquely sensitive to the temporal structure and risk-bearing properties of incentive contracts. Building on the above discussion, a substantial body of literature argues that equity incentives can promote corporate innovation by aligning managerial and key employees' rewards with long-term firm value rather than current-period accounting outcomes. Because successful innovation typically involves substantial uncertainty, delayed payoffs, and highly skewed returns, equity-based compensation can encourage decision-makers to internalise the upside of future value creation and to tolerate the interim earnings volatility associated with R&D and experimentation. Manso (2011) formalises this logic by showing that innovation-motivating contracts should reward long-run success while tolerating early failure. Consistent with this prediction, Lerner and Wulf (2007) find that stronger long-term incentives are associated with more influential research output, Chang et al. (2015) document that equity-based incentives can enhance both the quantity and quality of patenting activity, and Mao and Zhang (2018) show that a reduction in managerial risk-taking incentives weakens firms' innovative activities. Francis et al. (2019) further report that compensation arrangements with stronger long-term features are more conducive to exploratory and high-impact innovation. Collectively, these studies suggest that equity incentives are particularly well suited to innovation projects whose value lies not in immediate accounting performance, but in uncertain and potentially substantial future gains.

However, the relationship between equity incentives and innovation is not mechanically positive. When equity-based pay is evaluated over short horizons or becomes excessively sensitive to near-term stock-price movements, managers may have incentives to favour actions that raise market valuation quickly rather than investments that maximise long-run innovative value. Under such circumstances, equity incentives may induce managerial myopia, a bias towards incremental rather than radical innovation, or even opportunistic behaviour designed to support short-run stock prices. This concern is central to Ederer and Manso (2013), who show experimentally that standard pay-for-performance contracts can discourage exploratory search relative to contracts that combine early-failure tolerance with long-term rewards. Related empirical work also warns that performance-based compensation may intensify incentives to misreport when contracts place excessive weight on contemporaneous equity-price gains (Burns and Kedia, 2006). Moreover, recent evidence is not entirely uniform. Biggerstaff et al. (2019), for example, question whether option-based compensation exerts as strong a causal effect on corporate innovation as some earlier studies suggest. Therefore, the literature does not imply that the mere adoption of equity incentives automatically stimulates innovation; rather, it indicates that the innovation consequences of equity pay depend crucially on the temporal structure and evaluation logic embedded in the contract. On balance, the literature suggests that equity incentives are neither universally beneficial nor inherently detrimental to innovation. Instead, innovation appears to respond most strongly to equity contracts whose payoff structure and evaluation horizon are aligned with the exploratory and failure-prone nature of innovative activity. This is also why recent studies increasingly emphasise contractual features such as deferred vesting, performance-vesting conditions, and other long-horizon design elements, which reduce pressure to maximise short-run stock prices and instead reward sustained value creation over time. When such design features are present, equity incentives are more likely to encourage managers and key personnel to persist with uncertain projects, absorb early setbacks, and pursue innovation strategies with larger long-run upside. Accordingly, although short-term distortions cannot be ruled out, the baseline theoretical expectation remains that equity incentives should, on balance, promote corporate innovation.

Whether equity incentives foster innovation depends not only on whether firms incentivise, but also on whom they incentivise. Innovation is rarely produced by senior executives alone. Rather, it is a cumulative and team-based process that depends heavily on engineers, scientists, designers, and key operational employees who possess tacit knowledge and participate directly in experimentation, problem solving, and implementation. As the strategic importance of human capital has increased, broad-based incentive programmes, including employee stock ownership plans and broad-based stock options, have become increasingly relevant in innovation-oriented firms. When equity rewards are extended beyond the top management team, they can strengthen employees' organisational identification, sense of ownership, and willingness to contribute to joint production and innovation-related activities (Klein, 1987; Jones and Kato, 1995; Kim and Ouimet, 2014). Theoretical work likewise suggests that firms have incentives to provide internal support for employee-generated ideas when innovation appropriability is high, because internal exploration and retention of employee innovators are essential for capturing the value of firm-relevant inventions (Krasteva et al., 2015). Existing empirical studies are broadly consistent with this view. Ittner et al. (2003) show that in new-economy firms equity grants are widely used below the executive level and that retention objectives are central to such plans, especially in critical technical positions. Core and Guay (2001) similarly argue that stock option plans for non-executive employees are used to sort, attract, and retain particular types of workers, while Oyer and Schaefer (2005) show that some firms deliberately grant options broadly rather than confining them to executives, motivated by talent retention, moral-hazard reduction, and the sharing of growth benefits. Hochberg and Lindsey (2010) further find that non-executive option incentives are positively related to subsequent operating performance, particularly when grants are broad-based and when growth opportunities are high. Consistent with the human-capital channel, Aldatmaz et al. (2018) show that large broad-based employee stock option grants reduce employee turnover, at least over the vesting horizon. These studies together indicate that broad-based equity incentives can function not only as effort incentives, but also as retention and coordination mechanisms in human-capital-intensive firms. These channels are especially important for innovation. Non-executive employees are often closer than senior executives to idea generation, technical experimentation, iterative design, and the conversion of knowledge into patentable outputs. Chang et al. (2015) provide direct evidence that non-executive employee stock options are positively associated with both the quantity and quality of corporate innovation, with stronger effects when employees are more important for innovation, when free-riding problems are weaker, and when option plans are broad-based and longer-dated. More recent quasi-experimental evidence reaches a similar conclusion: Jang et al. (2026) show that an exogenous shock weakening inventor-employees' intellectual property rights induce firms to increase non-executive option grants, and that these additional grants subsequently raise patenting and research productivity. At the same time, the effectiveness of employee equity incentives is not automatic; it depends on participation breadth, vesting horizon, complementary management arrangements, and employees' willingness to bear firm-specific stock-price risk (Faleye et al., 2006; Bergman and Jenter, 2007). Overall, this literature suggests that, although senior executives remain important because they allocate resources and define innovation strategy, equity incentives granted to non-executive core technical and key operational personnel may exert a more direct and stronger influence on corporate innovation.

Different equity instruments embed different incentive properties and therefore need not have identical effects on innovation. Option-based instruments, such as stock options and stock appreciation rights, reward recipients primarily when share values rise and thus provide a more convex payoff structure than restricted stock. For risk-averse managers and employees, this convexity can strengthen incentives to support projects with substantial upside potential, especially when compensation is more sensitive to stock-price volatility than to current-period accounting performance (Hall and Murphy, 2002; Armstrong and Vashishtha, 2012). This distinction is particularly relevant for innovation, whose outcomes are highly uncertain, long-horizon, and positively skewed (Holmstrom, 1989; Manso, 2011). Consistent with this view, executive stock-option incentives are positively associated with corporate innovative activities, especially when the embedded risk-taking incentives are stronger (Chen et al., 2014). Option-based incentives are therefore more likely to encourage exploratory and breakthrough innovation, for which success depends on bearing uncertainty in exchange for potentially large long-run gains (Manso, 2011; Chen et al., 2014). By contrast, restricted stock provides direct ownership but weaker convexity, which can temper excessive risk-taking while strengthening longer-horizon commitment, particularly when awards are subject to vesting conditions (Hall and Murphy, 2002; Bettis et al., 2018). The evidence is therefore not entirely one-sided. In research-intensive settings, Lerner and Wulf (2007) show that long-term incentives are associated with more heavily cited patents and that, once long-term compensation is separated into stock options and restricted stock, the restricted-stock component remains statistically significant. Related theoretical work also indicates that the optimal equity mix depends on the balance between encouraging the search for innovative ideas and preventing excessively risky implementation (Laux, 2015). Overall, the literature implies that instrument choice affects not only the strength but also the type of innovation induced. Given the stronger risk-taking incentives embedded in price-appreciation-based contracts, however, the baseline expectation is that option-based incentives will exert a stronger positive effect on corporate innovation than restricted stock.

Industry context is also likely to condition the innovation effect of equity incentives. In technology-driven industries, competitive advantage depends more directly on continuous R&D, knowledge accumulation, and the retention of highly skilled employees, while innovative investment is often harder to finance because its underlying assets are intangible, firm-specific, and subject to substantial information asymmetry (Hall and Lerner, 2010; Brown et al., 2009). Under these conditions, long-horizon equity incentives can be particularly valuable because they help firms retain critical human capital and sustain support for risky projects whose returns are realised only with delay (Tian and Wang, 2014; Chang et al., 2015). Consistent with this logic, Cheng et al. (2024) show that option incentives exert more pronounced effects on innovation in high-tech firms than in other firms. By contrast, in traditional industries, firm performance is more often driven by tangible assets, operational efficiency, and incremental adjustment, so innovation, while still relevant, may be less central to value creation than in technology-intensive sectors (Hall and Lerner, 2010). As a result, the marginal innovation benefit of equity incentives is likely to be weaker, especially for breakthrough innovation that requires sustained experimentation and tolerance for failure (Manso, 2011; Tian and Wang, 2014). The literature therefore suggests that industry characteristics shape the effectiveness of incentive contracts, and that equity incentives should have a stronger positive effect on corporate innovation in technology-intensive industries than in traditional industries.

China provides a distinctive institutional setting for examining the innovation effect of equity incentives. Following the CSRC's 2005–2006 regulatory change permitting listed firms to implement equity-based compensation, the use of stock incentives expanded within a corporate environment still characterised by concentrated ownership, substantial state control, and governance institutions that differ from those in mature market economies (Jiang et al., 2017; Conyon and He, 2011). In this setting, ownership type is especially important. Firth et al. (2006) show that firms with a state agency as the major shareholder make relatively limited use of performance-related CEO pay, while Conyon and He (2011) find that executive pay and CEO incentives are lower in state-controlled firms. Xin et al. (2019) further argue that managers in Chinese SOEs face multi-task objectives and are disciplined not only by monetary rewards but also by bureaucratic promotion incentives. Accordingly, in SOEs, equity incentives are only one component of a broader and more complex incentive system. By contrast, private firms and other non-SOEs generally operate under a more clearly defined ownership structure, and performance-based governance appears to function more directly in these firms. Using Chinese non-SOEs, Zhou et al. (2017) show that stronger monitoring by non-controlling directors is associated with higher pay-performance sensitivity, suggesting that incentive contracts are more effectively transmitted into managerial discipline when ownership and monitoring rights are clearer. This distinction matters for innovation because the same equity award is unlikely to have the same marginal motivational effect when managerial objectives are partly political or multi-task in nature. The argument, therefore, is not that SOEs are incapable of innovation, but that the behavioural transmission of equity incentives is likely to be weaker in SOEs than in private firms. In the Chinese context, ownership should thus be viewed as an institutional boundary condition, with equity incentives expected to exert a stronger innovation-promoting effect in private firms than in SOEs.

Synthesising the foregoing discussion, the relationship between equity incentives and corporate innovation can be understood as a special application of incentive theory to a distinctive class of corporate decisions. On the one hand, innovation is characterised by uncertainty, delayed payoffs, experimentation, and failure risk, making it especially vulnerable to short-termism and underinvestment when decision-makers are evaluated primarily on contemporaneous performance (Holmstrom, 1989; Manso, 2011; Ederer and Manso, 2013). On the other hand, equity-based incentives can mitigate these problems by linking managerial and key employees' rewards more closely to long-term firm value, thereby improving tolerance for uncertain projects and strengthening incentives to pursue innovative activities whose benefits materialise only over time (Jensen and Meckling, 1976; Lerner and Wulf, 2007; Chang et al., 2015; Mao and Zhang, 2018). Although the literature also points to possible short-term distortions when equity pay is excessively tied to near-term stock-price outcomes, the balance of theory suggests that, when appropriately designed, equity incentives should on average foster corporate innovation rather than inhibit it (Manso, 2011; Bettis et al., 2018; Francis et al., 2019).

The preceding review further suggests that this effect is unlikely to be homogeneous. Because innovation depends heavily on the efforts, retention, and coordination of core technical and business personnel, incentives directed at non-executive employees may influence innovative output more directly than incentives directed solely at senior executives (Ittner et al., 2003; Hochberg and Lindsey, 2010; Chang et al., 2015). Similarly, different equity instruments embed different payoff structures, implying different capacities to motivate risky and exploratory innovation: option-based instruments provide stronger upside incentives, whereas restricted stock places greater weight on ownership and retention (Hall and Murphy, 2002; Armstrong and Vashishtha, 2012; Chen et al., 2014). Finally, institutional and industrial contexts are also likely to shape incentive effectiveness. In China, ownership structure matters because the transmission of incentive contracts is weaker when firms face state control, multiple objectives, and less market-oriented governance (Firth et al., 2006; Conyon and He, 2011; Xin et al., 2019). Across industries, equity incentives should be especially valuable in technology-intensive sectors, where firm value depends more heavily on knowledge accumulation, R&D continuity, and the retention of highly skilled human capital (Hall and Lerner, 2010; Tian and Wang, 2014; Cheng et al., 2024). Based on these arguments, this study proposes the following hypotheses:

H1: Equity incentives positively promote corporate innovation.

H2: Equity incentives targeting core technical and operational employees (non-executives) are more effective in promoting corporate innovation than those targeting executives.

H3: Equity incentives based on stock options and stock appreciation rights exert a stronger positive effect on corporate innovation than those based on restricted stock.

H4: Equity incentives implemented in private enterprises exhibit a more pronounced innovation-promoting effect than those in state-owned enterprises.

H5: Equity incentives in technology-intensive industries have a stronger positive impact on corporate innovation than those in traditional industries.

3.3 Data, Variable Construction, and Methodology

3.3.1 Sample Selection and Data Sources

This study selects Chinese A-share listed companies on the Shanghai and Shenzhen Stock Exchanges from 2007 to 2021 as the research sample. The rationale behind this sample period is primarily based on the formal implementation of the Administrative Measures for Equity Incentives of Listed Companies (Trial) by the China Securities Regulatory Commission (CSRC) in January 2006, which marked the official introduction of equity incentives among Chinese listed companies. This provides the institutional background and ample empirical observations needed to analyse the effects of equity incentives on corporate innovation. After constructing the initial sample, companies designated as Special Treatment (ST or *ST) due to severe financial anomalies were first excluded to avoid interference from outliers stemming from significant financial distress. Subsequently, firms in the financial industry were also excluded owing to their distinctive characteristics in capital structure, regulatory environment, and accounting practices. Industry classifications adhere to the guidelines issued by the CSRC in 2012. Next, observations with missing values for key variables were removed, and corporate financial variables were winsorised at the 1st and 99th percentiles to mitigate the potential influence of outliers on the regression results. The primary data used in this research were sourced from the China Stock

Market & Accounting Research Database (CSMAR), covering patent grants and citations related to corporate innovation, detailed information regarding equity incentive schemes, as well as financial and corporate governance data of listed companies. After the screening and data-processing steps described above, the final dataset consists of 27,908 firm-year observations, covering 3,424 listed companies.

3.3.2 Measurement of Corporate Innovation

This study continues to measure corporate innovation from the perspective of innovation output, employing patent forward citations as the primary dependent variable. Specifically, for each firm, the cumulative number of citations is calculated for invention patents and utility model patents that were applied for and ultimately granted during the study period, with citations tracked up to the end of 2021. This study focuses exclusively on invention patents and utility model patents, which are more technically substantive and closely tied to R&D investment, while excluding design patents to reduce heterogeneity-induced noise in the sample. Additionally, to mitigate potential bias from uneven citation opportunities across different years, the empirical model incorporates year fixed effects. The patent citation variable is also logarithmically transformed in regression analyses to address issues of skewness and outliers. For robustness, this study also takes into account other innovation-related input and output indicators in subsequent tests, using R&D expenditure and the total number of granted patents as substitute variables to verify consistency. In light of the delayed nature of patent output, all dependent variable data are shifted forward by two years.

3.3.3 Measurement of Equity Incentives

This study constructs equity incentive variables using plan-level information on listed firms' equity incentive schemes obtained from CSMAR. For each plan, the starting year is defined as the first fiscal year in which the approved incentive scheme is actually granted and enters implementation. A plan is treated as active from that year until the earlier of: (i) the scheduled end of its lock-up, vesting, and/or exercise window, or (ii) any early termination, cancellation, repurchase, or full completion. Plans that were proposed but never implemented are excluded. Based on this coding rule, the dummy variable EI equals 1 for each firm-year in which at least one equity incentive plan is under active implementation, and 0 otherwise. To capture the scale of incentives, this study further constructs an intensity measure, EIR, defined as the proportion of equity incentives under active implementation in year t relative to the firm's total share capital. Accordingly, the firm-year coding follows an active-plan accumulation approach rather than a grant-year flow approach. Once an approved equity incentive grant enters implementation, the corresponding granted shares remain included in the firm-year measure throughout the active lock-up, vesting, and/or exercise period. If additional plans become effective during that period, their corresponding granted shares are cumulatively incorporated into the firm-year intensity measure. Where plan disclosures report allocations by recipient group, this intensity is further decomposed into EIR_EXEC and EIR_NEXEC, which measure the proportions allocated to executives and to non-executive core technical and operational employees, respectively. This decomposition allows the empirical analysis to distinguish the overall incentive effect from the heterogeneous effects associated with different recipient groups. The sample includes three main forms of equity-based compensation: stock options, stock appreciation rights, and restricted stock. Stock options and stock appreciation rights are grouped as option-based instruments because their gains are primarily realised through future share-price appreciation and do not immediately transfer ownership to recipients. Restricted stock, including both first- and second-category restricted stock, is grouped as a stock-based instrument because it is fundamentally ownership-based and typically remains subject to lock-up, service, and/or performance conditions. Because these instruments differ in payoff convexity, downside exposure, and retention properties, they may generate different innovation incentives. Accordingly, EI_OPT equals 1 if the active plan in year t contains stock options and/or stock appreciation rights, and EI_RS equals 1 if the active plan in year t contains restricted stock. If a plan contains both types of instruments, both dummies are coded as 1. These measures enable the study to examine not only whether firms adopt equity incentives, but also whether differences in incentive scale, recipient groups, and instrument design are associated with different innovation outcomes.

3.3.4 Grouping Variables: Ownership Structure and Technology-Driven Enterprises

Firms are classified as SOEs if their actual controlling entity is a state-owned enterprise, government agency, public institution, central authority, or local authority; all others are considered non-SOEs.

To identify technology-driven companies, this study integrates the high-technology industry classification standards of the Organisation for Economic Co-operation and Development (OECD) with China's recent policy orientations toward strategic emerging industries and "new quality productive forces" (OECD, 2016; State Council, 2010; National Bureau of Statistics, 2018). Based on these frameworks, this study selects the following industries from the CSRC industry codes as high-technology sectors: C25 (Petroleum Processing, Coking, and Nuclear Fuel Processing), C26 (Chemical Raw Materials and Chemical Products Manufacturing), C27 (Pharmaceutical Manufacturing), C28 (Chemical Fiber Manufacturing), C31 (Ferrous Metal Smelting and Rolling), C32 (Non-Ferrous Metal Smelting and Rolling), C34 (General Equipment Manufacturing), C35 (Specialised Equipment Manufacturing), C36 (Automobile Manufacturing), C37 (Railway, Shipbuilding, Aerospace, and Other Transportation Equipment Manufacturing), C38 (Electrical Machinery and Equipment Manufacturing), C39 (Computers, Communications, and Other Electronic Equipment Manufacturing), C40 (Instrumentation Manufacturing), I63 (Telecommunications, Radio, Television, and Satellite Transmission Services), I64 (Internet and Related Services), I65 (Software and Information Technology Services), M73 (Research and Experimental Development), and N77 (Ecological Protection and Environmental Governance). These industries are generally characterised by high R&D intensity and significant technological barriers, playing a prominent role in fostering innovation, cultivating new growth drivers, and achieving sustainable corporate development.

3.3.5 Control Variables

To accurately identify the impact of equity incentives on corporate innovation, this study incorporates control variables related to firm financial characteristics and corporate governance in the baseline regression model. In the financial dimension, the model includes firm size (total assets), profitability (return on total assets), leverage (debt-to-asset ratio), firm age, market valuation (Tobin's Q), industry concentration (HHI), and operating cash flow (OCF). Given that R&D typically entails high risk and uncertainty, a firm's internal cash flow is often critical to advancing innovation projects (Brown et al., 2009). Particularly in market environments characterised by significant external financing constraints or high information asymmetry, sufficient internal funds can alleviate funding gaps for innovation, enabling firms to better manage R&D risks and maintain continuity in research efforts. Thus, including operating cash flow in the model allows for a more comprehensive control of the financial constraints affecting innovation.

In terms of corporate governance, the model includes the proportion of independent directors, the shareholding ratio of the top five shareholders, and whether the CEO also serves as board chair. CEO duality is closely linked to governance efficiency and power structure, potentially influencing the management team's enthusiasm for innovation and the quality of decision-making (Finkelstein and D'Aveni, 1994). Meanwhile, the top five shareholders' shareholding ratio gauges ownership concentration. On one hand, greater ownership concentration can reinforce managerial oversight and reduce agency costs, nudging firms toward innovation that emphasises long-term value (Baysinger et al., 1991). On the other hand, if dominant shareholders favour short-term returns, they may weaken support for high-risk innovation initiatives (Bushee, 1998). Including this variable helps clarify the dual roles ownership structure can play in corporate innovation decisions and prevents confounding with the equity incentive variable.

Table 3-1. Variable definitions

Variable	Description
CiteI	Natural logarithm of forward citations of invention patents applied for and granted, aligned with a two-year lead (t+2).
CiteU	Natural logarithm of forward citations of utility model patents applied for and granted, aligned with a two-year lead (t+2).
CiteIU	Natural logarithm of forward citations of invention and utility model patents applied for and granted, aligned with a two-year lead (t+2).
EI	A dummy variable equal to 1 if the firm has at least one equity incentive plan under active implementation in a given year, and 0 otherwise.

EIR	Firm-year equity incentive intensity, measured as the proportion of granted shares associated with equity incentive plans under active implementation relative to the company's total shares.
EIR_EXEC	Firm-year executive equity incentive intensity, measured as the proportion of granted shares associated with equity incentive plans under active implementation that are allocated to executives, relative to the company's total shares.
EIR_NEXEC	Firm-year non-executive equity incentive intensity, measured as the proportion of granted shares associated with equity incentive plans under active implementation that are allocated to core technical and business personnel, relative to the company's total shares.
EI_OPT	A dummy variable equal to 1 if the equity incentive plan under implementation is based on stock options or stock appreciation rights, and 0 otherwise.
EI_RS	A dummy variable equal to 1 if the equity incentive plan under implementation is based on restricted stock, and 0 otherwise.
TA	Natural logarithm of total assets.
ROA	Return on assets.
D/A	Debt-to-asset ratio.
OCF	Operating cash flow to sales ratio, calculated as net cash flow from operating activities divided by operating revenue.
AGE	Natural logarithm of firm age.
Q	Tobin's Q, calculated as market value divided by total assets.
HHI	Herfindahl-Hirschman Index, calculated using firm revenue to determine market share within the industry.
IND_DIR	Proportion of independent directors on the board.
TOP5	The sum of the shareholding ratios of the top five shareholders.
DUAL	A dummy variable equal to 1 if the CEO also serves as board chair, and 0 otherwise.
SOE	A dummy variable equal to 1 if the firm is a State-owned enterprise, and 0 otherwise.
TDE	A dummy variable equal to 1 if the firm is classified as a technology-driven or high-tech enterprise, and 0 otherwise.
PatI	Natural logarithm of the number of invention patents applied for and granted, aligned with a two-year lead (t+2).
PatU	Natural logarithm of the number of utility model patents applied for and granted, aligned with a two-year lead (t+2).
PatIU	Natural logarithm of the number of invention and utility model patents applied for and granted, aligned with a two-year lead (t+2).
RD	Natural logarithm of R&D expenditure.
RD_INT	R&D intensity.

3.4 Descriptive Statistics and Preliminary Analysis

3.4.1 Descriptive Statistics

Table 3-2 presents the descriptive statistics for the main variables. Regarding innovation outcomes, the mean value of CiteU (2.035, log-transformed forward citations) is slightly higher than that of CiteI (1.265), while CiteIU averages 2.392, suggesting that utility model patents remain an important component of citation-based innovation output among Chinese listed firms. Turning to equity incentives, EI is constructed at the firm-year level and equals 1 when a firm has at least one equity incentive plan under active implementation in a given year; the mean of EI is 0.187, indicating that approximately 18.7% of firm-year observations are classified as incentive-active. The intensity measures (EIR, EIR_EXEC, and EIR_NEXEC) are reported as percentages of total share capital. The mean EIR is 0.564 (i.e., 0.564% of total shares) with a standard deviation of 1.540, and the median is zero, implying a highly skewed distribution in which many firm-years have no active equity incentives while a smaller subset implements relatively large-scale plans. Moreover, a clear distinction emerges between executive and non-executive incentive allocations: EIR_NEXEC has a substantially higher mean (0.445%) than EIR_EXEC (0.134%), suggesting that a non-trivial fraction of adopting firms place greater emphasis on incentivising core technical or operational personnel rather than executives. With respect to instrument types, EI_OPT and EI_RS have mean values of 0.086 and 0.132, respectively, indicating that restricted stock plans are observed more frequently than option-based plans, noting that these two dummies are not mutually exclusive when a plan contains multiple instruments. The control variables exhibit plausible ranges after winsorisation. Firm size (TA) averages 21.977. Profitability (ROA) has a mean of 0.040 with a standard deviation of 0.051, while leverage (D/A) averages 0.431. Operating cash flow to sales (OCF) averages 0.091 with a standard deviation of 0.149, reflecting heterogeneity in internal financing capacity. Tobin’s Q has a mean of 1.990 (median 1.630), indicating variation in market valuation and growth expectations across firms. In terms of corporate governance, the average shareholding ratio of the top five shareholders (TOP5) is 0.541, suggesting relatively concentrated ownership. SOEs account for about 41.4% of the sample, and 25.7% of firm-year observations feature CEO duality (DUAL). The proportion of independent directors (IND_DIR) averages 0.372, indicating a generally consistent level of board independence. Finally, technology-driven enterprises (TDE) comprise approximately 71.8% of the sample, consistent with the increasing weight of high-tech firms in China’s capital market over the sample period.

Table 3-2. Summary Statistics

This table reports summary statistics for the main variables based on 27,908 firm-year observations from a panel of 3,424 non-financial firms listed on the Shanghai and Shenzhen A-share markets during 2007–2021. CiteI, CiteU, and CiteIU represent the natural logarithm of forward citations for invention patents, utility model patents, and their combined total, respectively, all adjusted with a two-year lead. The key independent variable is EI, a firm-year dummy equal to 1 if the firm has at least one equity incentive plan under active implementation in that year (and 0 otherwise), and thus varies over time within firms. EIR, EIR_EXEC, and EIR_NEXEC measure equity incentive intensity for all employees, executives, and non-executives, respectively, and are reported in percentage terms of total share capital. EI_OPT and EI_RS are dummy variables indicating whether the incentive plan under implementation includes option-based instruments (stock options or stock appreciation rights) or restricted stock, respectively; these two dummies may both equal 1 in the same firm-year if a plan contains both types of instruments. Control variables are selected from two dimensions: firm-level characteristics and corporate governance factors, including firm size, return on assets, leverage, operating cash flow, firm age, Tobin's Q, industry concentration, board independence, ownership concentration, and CEO duality. Only corporate financial variables are winsorised at the 1st and 99th percentiles. All variable definitions are provided in Table 3-1.

VarName	Obs	Mean	SD	Min	Median	Max
CiteI	27908	1.265	1.551	0.000	0.693	9.868
CiteU	27908	2.035	1.779	0.000	2.079	9.368
CiteIU	27908	2.392	1.849	0.000	2.485	10.006
EI	27908	0.187	0.390	0.000	0.000	1.000
EIR	27908	0.564	1.540	0.000	0.000	19.242
EIR_EXEC	27908	0.134	0.488	0.000	0.000	10.159
EIR_NEXEC	27908	0.445	1.273	0.000	0.000	19.177
EI_OPT	27908	0.086	0.280	0.000	0.000	1.000
EI_RS	27908	0.132	0.339	0.000	0.000	1.000
TA	27908	21.977	1.203	19.436	21.821	24.975
ROA	27908	0.040	0.051	-0.222	0.039	0.167
D/A	27908	0.431	0.208	0.061	0.423	0.940
OCF	27908	0.091	0.149	-0.293	0.079	0.561
AGE	27908	2.801	0.371	0.000	2.833	4.190
Q	27908	1.990	1.088	0.899	1.630	8.321
HHI	27908	0.114	0.127	0.016	0.075	1.000
IND_DIR	27908	0.372	0.054	0.133	0.333	0.800
TOP5	27908	0.541	0.156	0.030	0.544	0.992
DUAL	27908	0.257	0.437	0.000	0.000	1.000
SOE	27908	0.414	0.492	0.000	0.000	1.000
TDE	27908	0.718	0.450	0.000	1.000	1.000

3.4.2 Correlation Matrix

Table 3-3 presents the correlation coefficients among the main variables and their significance levels. Overall, most correlation coefficients are below 0.3, suggesting a relatively low risk of multicollinearity. First, the innovation variables (CiteI, CiteU, CiteIU) exhibit relatively high pairwise correlation coefficients, which aligns with expectations. The citation performance of invention patents and utility model patents often simultaneously reflects a firm's R&D capabilities. These patent citation measures also show moderately positive correlations with technology-driven enterprises (TDE), indicating that patent citations tend to be more robust in high-tech industries, reinforcing the notion that high-tech sectors exhibit higher innovation intensity. Second, regarding the relationships between equity incentives (EI) and other variables, EI demonstrates a significant positive correlation with the innovation variables, particularly with CiteU, where the correlation coefficient is approximately 0.13. This suggests that, at a basic correlation level, firms implementing equity incentives tend to perform more strongly in terms of patent citations. However, it is noteworthy that EI exhibits a relatively strong negative correlation with ownership structure (SOE), potentially indicating that SOEs adopt equity incentive plans with greater caution or face stronger institutional constraints. Moreover, equity incentives (EI) show a significant positive correlation with CEO duality (DUAL), suggesting firms whose CEO also serves as the chairperson may be more inclined to adopt equity incentive plans. This association should be further explored within corporate governance contexts in subsequent empirical analyses. The positive correlation between equity incentives and technology-driven enterprises (TDE) also matches expectations, as high-tech companies typically rely heavily on human capital and knowledge assets, thus preferring equity incentives to attract and retain core talent. Among firm characteristic variables, leverage (D/A) has a positive correlation with state ownership (SOE), consistent with the reality in the Chinese context that SOEs have easier access to debt financing. Conversely, the negative correlation between TDE (high-tech enterprises) and SOE indicates that state ownership does not entirely overlap with technology-driven attributes, as high-tech enterprises are predominantly private-owned. This echoes the characteristic features of technology-oriented companies within China's diverse ownership structure.

Table 3-3. Correlation Matrix

This table presents Pearson correlation coefficients among the main variables based on 27,908 firm-year observations from a panel of 3,424 non-financial firms listed on the Shanghai and Shenzhen A-share markets during 2007-2021. CiteI, CiteU, and CiteIU are log-transformed measures of forward patent citations, adjusted by a two-year lead. EI is a dummy variable indicating whether the firm implements an equity incentive plan in a given year. Control variables include firm size, return on assets, leverage, operating cash flow, firm age, Tobin's Q, industry concentration, board independence, ownership concentration, and CEO duality. * indicates significance at the 5% level.

	CiteI	CiteU	CiteIU	EI	TA	ROA	D/A	OCF	AGE	Q	HHI	IND_DIR	TOP5	DUAL	SOE	TDE
CiteI	1															
CiteU	0.59*	1														
CiteIU	0.79*	0.93*	1													
EI	0.05*	0.13*	0.13*	1												
TA	0.26*	0.35*	0.33*	0.04*	1											
ROA	0.11*	0.07*	0.11*	0.06*	0.03*	1										
D/A	0.01*	0.03*	-0.00	-0.08*	0.28*	-0.36*	1									
OCF	0.01	0.02*	0.02*	0.02*	0.07*	0.19*	-0.13*	1								
AGE	-0.18*	-0.03*	-0.09*	0.05*	0.16*	-0.10*	0.13*	-0.02*	1							
Q	-0.05*	-0.14*	-0.12*	0.03*	-0.40*	0.01*	-0.02*	-0.03*	0.04*	1						
HHI	-0.02*	-0.04*	-0.05*	-0.07*	0.04*	-0.01*	0.01*	0.05*	-0.08*	0.01	1					
IND_DIR	0.02*	0.05*	0.04*	0.06*	0.03*	-0.02*	-0.01	-0.01*	-0.01	0.04*	0.01	1				
TOP5	0.06*	0.10*	0.10*	-0.04*	0.17*	0.19*	-0.11*	0.10*	-0.22*	-0.16*	0.05*	0.05*	1			
DUAL	-0.01	0.01	0.02*	0.12*	-0.17*	0.04*	-0.13*	-0.00	-0.05*	0.05*	-0.05*	0.10*	0.03*	1		
SOE	0.09*	0.00	0.01	-0.29*	0.34*	-0.07*	0.24*	0.03*	0.08*	-0.11*	0.07*	-0.07*	-0.01*	-0.31*	1	
TDE	0.23*	0.27*	0.32*	0.13*	-0.27*	0.04*	-0.20*	-0.02*	-0.11*	0.10*	-0.25*	0.01	-0.03*	0.15*	-0.28*	1

3.5 Main Empirical Results

3.5.1 Baseline Regression Results

3.5.1.1 Baseline Specification: Equity Incentive Adoption (With PSM)

Based on the preliminary results from the descriptive statistics and correlation matrix outlined above, this study first employs ordinary least squares (OLS) regression analysis using the sample data to investigate the impact of equity incentives on corporate innovation outputs. The following linear regression model is constructed:

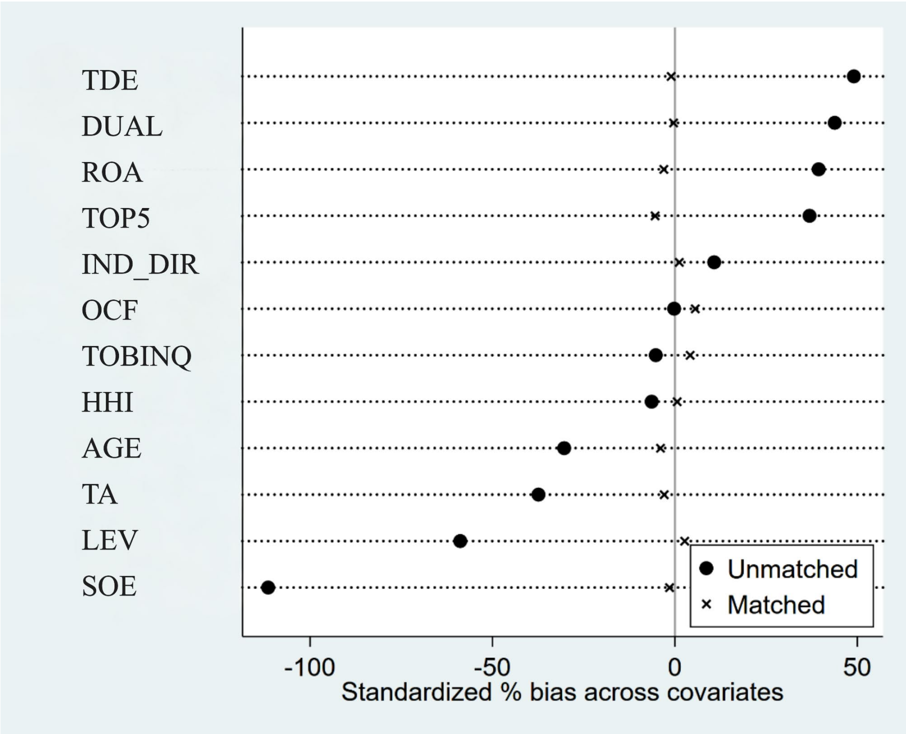
$$Cite_{i,t+2} = \beta_0 + \beta_1 EI_{i,t} + \beta_2 Control\_Variable_{i,t} + i.year + i.industry + \varepsilon_{it} \qquad (3\text{-}1)$$

Specifically, Cite denotes patent-based innovation output, measured by the natural logarithm of forward citations to invention patents, utility model patents, and their combined total, all aligned with a two-year lead. The key explanatory variable (EI) is a dummy variable indicating whether the firm has at least one equity incentive plan under active implementation in year t. The set of control variables includes the natural logarithm of total assets (TA), return on assets (ROA), debt-to-asset ratio (D/A), operating cash flow (OCF), the natural logarithm of firm age (AGE), Tobin's Q (Q), industry concentration (HHI), proportion of independent directors (IND_DIR), cumulative shareholding proportion of the top five shareholders (TOP5), and CEO duality (DUAL). Industry fixed effects are included to absorb persistent cross-industry differences in technological opportunity, competitive structure, and innovation intensity, while year fixed effects absorb macroeconomic, regulatory, and capital-market shocks common to all firms in a given year. Accordingly, the estimated coefficient on EI is identified after netting out broad sectoral heterogeneity and common time-series shocks that could otherwise confound the relation between equity incentives and innovation.

To enhance the robustness and persuasiveness of the results, this study further employs the Propensity Score Matching (PSM) approach to generate a matched sample, subsequently conducting a comparative analysis within the same regression framework. Firms are categorised into two groups based on whether they have adopted equity incentives during the sample period: the treatment group (Treat=1), which includes firms that have implemented equity incentive plans at some point, and the control group (Treat=0), consisting of firms that never adopted equity incentives throughout the entire sample period. Matching is performed based on firm characteristics in the year prior to the first equity incentive for the treatment group and the corresponding year for the control group. In the matching process, the following financial and structural covariates are controlled: total assets (TA), return on assets (ROA), leverage (D/A), operating cash flow (OCF), firm age (AGE), Tobin's Q (Q), industry concentration (HHI), proportion of independent directors (IND_DIR), cumulative shareholding of top five shareholders (TOP5), CEO duality (DUAL), state ownership (SOE), and whether the company is technology-driven (TDE). These variables capture the principal firm characteristics that may jointly influence both the adoption of equity incentives and subsequent innovation outcomes. A nearest-neighbour matching method based on logistic regression is adopted, where propensity scores are estimated for matching treated and control groups. To increase matching flexibility, ties are permitted, allowing multiple matches in situations where propensity scores are identical. A new matched sample is then extracted from the original dataset according to successful matching indicators, generating a new dataset for subsequent analyses.

Balance test is conducted to assess the post-matching differences in covariates between the treatment and control groups, with results visualized in a covariate balance plot (Figure 3-1). The plot shows that post-matching covariate biases are significantly reduced and approach zero for most variables, indicating improved covariate balance after matching. Additionally, Figures 3-2 and 3-3 illustrate kernel density plots of propensity scores before and after matching for the treatment and control groups. After PSM, the propensity score distributions of the two groups become more similar, with increased overlap between the curves, further suggesting improved comparability between treated and control firms. Overall, these diagnostics indicate materially improved covariate balance after matching, thereby enhancing the comparability of the treatment and control groups.

Figure 3-1. Standardised Bias Across Covariates Before and After PSM



Notes: This figure plots the standardised percentage bias for each covariate before and after propensity score matching (PSM). Black dots indicate the bias before matching, and crosses represent the bias after matching.

Figure 3-2. Propensity Score Distribution Before Matching

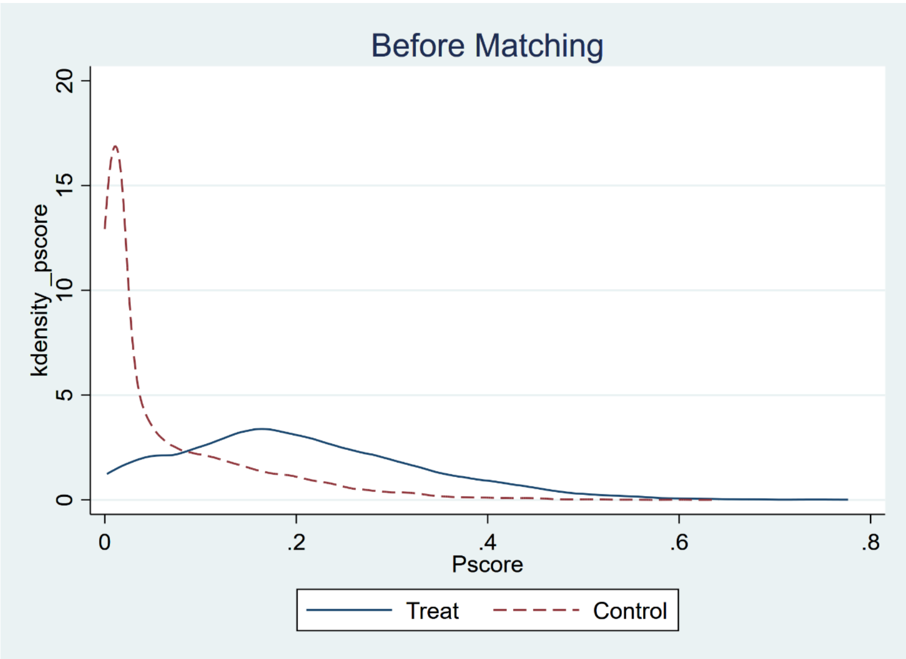
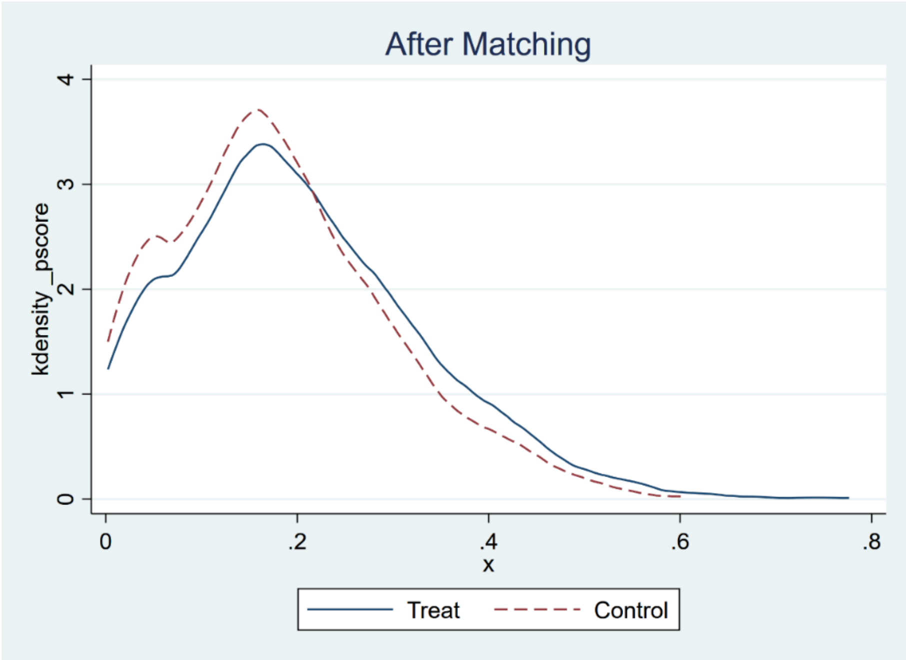


Figure 3-3. Propensity Score Distribution After Matching



Notes: These kernel density plots show the distribution of estimated propensity scores for the treatment and control groups before and after matching. Figure 3-2 displays the distribution before matching, showing significant imbalance. Figure 3-3 illustrates the overlap between groups after matching.

Table 3-4 presents the baseline regression results examining the effects of equity incentives (EI) on corporate innovation outputs, including the ordinary least squares (OLS) estimations without propensity score matching (columns (1)–(3)) and OLS estimations after propensity score matching (columns (4)–(6)). Overall, the core explanatory variable (EI) consistently exhibits significantly positive coefficients across all models, showing clear positive impacts on the three patent citation variables (CiteI, CiteU, CiteIU), and remains significant at the 1% level. These results provide robust empirical support for the central argument that " equity incentives positively promote corporate innovation." When comparing OLS results without matching (columns (1)–(3)) and those after PSM (columns (4)–(6)), the coefficients of EI in the matched samples are generally larger in magnitude and remain highly significant across invention patents, utility model patents, and their combined measure. Specifically, for CiteI, the change in coefficients before and after matching is modest. However, for CiteU and CiteIU, the regression coefficients of EI increase from 0.172 to 0.199 and from 0.209 to 0.233, respectively, following PSM. This indicates that the

Table 3-4. Baseline Regression Results: Equity Incentives and Corporate Innovation

This table reports OLS regression results examining the relationship between equity incentives (EI) and corporate innovation. The dependent variables are the natural logarithms of forward citations for invention patents (CiteI), utility model patents (CiteU), and their sum (CiteIU), each adjusted by a two-year lead. Columns (1)–(3) report results using the full sample, while columns (4)–(6) apply OLS estimation to a matched subsample obtained through propensity score matching (PSM). Matching covariates include total assets, return on assets, leverage, operating cash flow, firm age, Tobin's Q, industry concentration, board independence, ownership concentration, CEO duality, state ownership, and technology-oriented status. Control variables are selected based on two dimensions: firm-level characteristics and corporate governance factors. All regressions include year and industry fixed effects. Standard errors are reported in parentheses. The full sample includes 27,908 firm-year observations from Chinese A-share listed non-financial firms between 2007 and 2021. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	OLS			PSM-OLS		
	(1) CiteI	(2) CiteU	(3) CiteIU	(4) CiteI	(5) CiteU	(6) CiteIU
EI	0.163^{***}	0.172^{***}	0.209^{***}	0.163^{***}	0.199^{***}	0.233^{***}
	(0.020)	(0.021)	(0.022)	(0.022)	(0.023)	(0.024)
TA	0.569^{***}	0.602^{***}	0.679^{***}	0.577^{***}	0.611^{***}	0.687^{***}
	(0.007)	(0.008)	(0.008)	(0.008)	(0.008)	(0.009)
ROA	0.759^{***}	1.142^{***}	1.377^{***}	0.751^{***}	1.018^{***}	1.275^{***}
	(0.102)	(0.106)	(0.112)	(0.108)	(0.112)	(0.118)
D/A	-0.292^{***}	-0.040	-0.209^{***}	-0.319^{***}	-0.067^{*}	-0.243^{***}
	(0.033)	(0.034)	(0.036)	(0.035)	(0.037)	(0.039)
OCF	-0.036	-0.056^{*}	-0.035	-0.033	-0.046	-0.028
	(0.031)	(0.032)	(0.034)	(0.032)	(0.034)	(0.036)
AGE	-0.113^{***}	-0.241^{***}	-0.238^{***}	-0.146^{***}	-0.279^{***}	-0.284^{***}
	(0.024)	(0.025)	(0.026)	(0.025)	(0.027)	(0.028)
Q	0.082^{***}	0.040^{***}	0.052^{***}	0.086^{***}	0.042^{***}	0.055^{***}
	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
HHI	0.452^{***}	0.204	0.237^{*}	0.505^{***}	0.365^{***}	0.369^{**}
	(0.128)	(0.133)	(0.140)	(0.133)	(0.138)	(0.146)
IND_DIR	0.262^{*}	0.191	0.070	0.347^{**}	0.320^{**}	0.147
	(0.136)	(0.141)	(0.149)	(0.145)	(0.151)	(0.159)
TOP5	0.010	-0.035	-0.011	-0.057	-0.129^{**}	-0.111^{*}
	(0.051)	(0.054)	(0.056)	(0.055)	(0.057)	(0.060)
DUAL	0.069^{***}	-0.001	0.046^{**}	0.072^{***}	0.018	0.060^{***}
	(0.017)	(0.018)	(0.019)	(0.018)	(0.019)	(0.020)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	27908	27908	27908	24383	24383	24383
R-squared	0.408	0.512	0.498	0.412	0.520	0.506

motivating effect of equity incentives on patent output becomes more pronounced within the matched sample. Hence, after controlling observable characteristics between adopters and non-adopters, the genuine impact of equity incentives may indeed be stronger than initially estimated by the simple OLS regressions, reinforcing the robustness of the claim that equity incentives significantly enhance corporate innovation outputs.

Regarding control variables, most findings align consistently with those in the previous chapter. For example, firm size (TA) is significantly positive in all models, confirming that larger firms generally have more resources to allocate to R&D activities. Profitability (ROA) is similarly positive and significant at the 1% level, suggesting that more profitable firms have greater flexibility to invest in innovation projects. Leverage (D/A) tends to exhibit negative coefficients, consistent with the reasoning that firms under greater financial pressure find it challenging to sustain high-risk innovation projects. Additionally, industry and year fixed effects are controlled across all models to eliminate potential confounding influences from industry-specific factors and macroeconomic conditions.

Overall, Table 3-4 provides consistent evidence of a positive association between equity incentive adoption and corporate innovation. The matched-sample estimates further indicate that this positive relation remains present after improving comparability between treated and control firms on observable pre-adoption characteristics.

3.5.1.2 Alternative Specification: Incentive Intensity

To explore how the intensity of equity incentives influences corporate innovation, this section constructs a linear regression model using the proportion of equity incentives relative to total shares and patent-related innovation output measures:

$$Cite_{i,t+2} = \beta_0 + \beta_1 EIR_{i,t} + \beta_2 Control_{Variable_{i,t}} + i.year + i.industry + \varepsilon_{it} \tag{3-2}$$

Table 3-5 reports the regression results after replacing the dummy variable (EI) with equity incentive intensity (EIR). Compared to simply distinguishing whether a firm adopts equity incentives, EIR captures the variations in the scale of equity incentive arrangements more precisely. The results demonstrate that the coefficients of

Table 3-5. Baseline Regression Results: The Intensity of Equity Incentives and Corporate Innovation

This table reports OLS regression results examining the relationship between the intensity of equity incentives (EIR) and corporate innovation. The dependent variables are the natural logarithms of forward citations for invention patents (CiteI), utility model patents (CiteU), and their sum (CiteIU), each adjusted by a two-year lead. EIR is measured at the firm-year level as the proportion of granted shares associated with equity incentive plans under active implementation relative to total company shares. Control variables are selected based on two dimensions: firm-level characteristics and corporate governance factors. All regressions include year and industry fixed effects. Standard errors are reported in parentheses. The sample includes 27,908 firm-year observations from Chinese A-share listed non-financial firms between 2007 and 2021. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	(1) CiteI	(2) CiteU	(3) CiteIU
EIR	0.044***	0.039***	0.052***
	(0.005)	(0.005)	(0.005)
TA	0.570***	0.603***	0.680***
	(0.007)	(0.008)	(0.008)
ROA	0.761***	1.152***	1.384***
	(0.102)	(0.106)	(0.112)
D/A	-0.295***	-0.044	-0.213***
	(0.033)	(0.034)	(0.036)
OCF	-0.036	-0.056*	-0.035
	(0.031)	(0.032)	(0.034)
AGE	-0.113***	-0.243***	-0.238***
	(0.024)	(0.025)	(0.026)
Q	0.082***	0.040***	0.052***
	(0.005)	(0.006)	(0.006)
HHI	0.449***	0.202	0.235*
	(0.127)	(0.133)	(0.140)
IND_DIR	0.266**	0.196	0.075
	(0.135)	(0.141)	(0.149)
TOP5	0.032	-0.021	0.012
	(0.052)	(0.054)	(0.057)
DUAL	0.067***	-0.001	0.045**
	(0.017)	(0.018)	(0.019)
Industry FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	27908	27908	27908
R-squared	0.409	0.512	0.498

EIR are significantly positive at the 1% level in all three models (CiteI, CiteU, and CiteIU), indicating that firms with a higher proportion of equity incentives under active implementation tend to exhibit stronger patent-based innovation outcomes in both quality- and quantity-related dimensions. Economically, a one-percentage-point increase in EIR is associated with increases of approximately 4.4%, 3.9%, and 5.2%

in CiteI, CiteU, and CiteIU, respectively. The estimates for the control variables remain broadly consistent with the earlier findings.

Overall, the EIR regressions show that the positive relation between equity incentives and corporate innovation is present not only at the adoption margin, but also along the intensity margin. Integrating this finding with the earlier analysis based on the dummy variable (EI), it can be inferred that, on the one hand, firms' decisions regarding the adoption of equity incentives are associated with innovation outcomes; on the other hand, a higher firm-year level of equity incentives under active implementation is likewise associated with stronger innovation outcomes.

3.5.1.3 Analysis by Incentive Recipient (Executive vs. Non-Executive Incentives)

Table 3-6 further decomposes equity incentive intensity under active implementation into the portion allocated to executives (EIR_EXEC) and the portion allocated to core technical or operational employees (EIR_NEXEC), so as to investigate their differential impacts on corporate innovation outcomes. Regression results indicate that the incentive coefficients for executives (EIR_EXEC) do not show significant effects on any of the patent citation variables (CiteI, CiteU, and CiteIU). In contrast, the incentive intensity targeted at core technical and business personnel (EIR_NEXEC) consistently demonstrates significantly positive effects at the 1% level. This implies that offering a greater share of equity incentives to key R&D and operational personnel significantly enhances the quality of patent outputs. This observation may reflect that although executives hold substantial strategic and resource allocation authority within the firm, their risk-bearing willingness and technical engagement might not directly impact specific innovation outcomes. On the other hand, frontline technical personnel, actively involved in research and development, are likely to perceive equity incentives as mechanisms that align their personal benefits with corporate growth, thus dedicating more effort and creativity to innovative activities. This finding is consistent with prior literature emphasising the motivational effects of equity incentives on key technical employees and non-executive staff. Overall, Table 3-6 indicates that the internal allocation of equity incentives is closely related to the innovation response of the firm.

Table 3-6. Differential Effects of Executive and Non-Executive Equity Incentives

This table reports OLS regression results examining the differential effects of executive versus non-executive equity incentives on corporate innovation. The dependent variables are the natural logarithms of forward citations for invention patents (CiteI), utility model patents (CiteU), and their sum (CiteIU), each adjusted by a two-year lead. EIR_EXEC and EIR_NEXEC measure the proportions of granted shares associated with equity incentive plans under active implementation that are allocated to executives and non-executives, respectively, relative to total company shares. Control variables are selected from two dimensions: firm-level characteristics and corporate governance factors. All regressions include year and industry fixed effects. Standard errors are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	(1) CiteI	(2) CiteU	(3) CiteIU
EIR_EXEC	-0.000	0.024	0.025
	(0.018)	(0.018)	(0.019)
EIR_NEXEC	0.051***	0.039***	0.054***
	(0.007)	(0.007)	(0.008)
TA	0.570***	0.603***	0.681***
	(0.007)	(0.008)	(0.008)
ROA	0.762***	1.155***	1.388***
	(0.102)	(0.106)	(0.112)
D/A	-0.296***	-0.044	-0.213***
	(0.033)	(0.034)	(0.036)
OCF	-0.036	-0.056*	-0.035
	(0.031)	(0.032)	(0.034)
AGE	-0.113***	-0.243***	-0.239***
	(0.024)	(0.025)	(0.026)
Q	0.082***	0.040***	0.053***
	(0.005)	(0.006)	(0.006)
HHI	0.449***	0.202	0.235*
	(0.128)	(0.133)	(0.140)
IND_DIR	0.255*	0.192	0.068
	(0.136)	(0.141)	(0.149)
TOP5	0.027	-0.024	0.007
	(0.052)	(0.054)	(0.057)
DUAL	0.067***	-0.001	0.046**
	(0.017)	(0.018)	(0.019)
Industry FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	27908	27908	27908
R-squared	0.409	0.512	0.498

3.5.1.4 Analysis by Incentive Instrument (Option-Based vs. Stock-Based Incentives)

Table 3-7 further distinguishes between equity incentive schemes using “option-based tools” (EI_OPT), comprising stock options or stock appreciation rights, and “stock-based tools” (EI_RS), consisting of restricted stock, examining their differing impacts on corporate innovation. Regression results indicate that EI_OPT shows significant

Table 3-7. Differential Effects of Option-Based and Stock-Based Equity Incentives

This table reports OLS regression results examining the differential effects of option-based and stock-based equity incentive schemes on corporate innovation. The dependent variables are the natural logarithms of forward citations for invention patents (CiteI), utility model patents (CiteU), and their sum (CiteIU), each adjusted by a two-year lead. EI_OPT and EI_RS are dummy variables equal to 1 if the active equity incentive plan in a given firm-year includes option-based instruments (stock options and/or stock appreciation rights) or restricted stock, respectively; both indicators may equal 1 when a plan contains multiple instruments. Control variables are selected based on two dimensions: firm-level characteristics and corporate governance factors. All regressions include year and industry fixed effects. Standard errors are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	(1) CiteI	(2) CiteU	(3) CiteIU
EI_OPT	0.260***	0.212***	0.277***
	(0.027)	(0.028)	(0.030)
EI_RS	0.004	0.077***	0.067***
	(0.023)	(0.024)	(0.025)
TA	0.566***	0.600***	0.676***
	(0.007)	(0.008)	(0.008)
ROA	0.790***	1.161***	1.406***
	(0.102)	(0.106)	(0.112)
D/A	-0.289***	-0.038	-0.206***
	(0.033)	(0.034)	(0.036)
OCF	-0.035	-0.055*	-0.034
	(0.031)	(0.032)	(0.034)
AGE	-0.117***	-0.242***	-0.240***
	(0.024)	(0.025)	(0.026)
Q	0.080***	0.039***	0.050***
	(0.005)	(0.006)	(0.006)
HHI	0.449***	0.204	0.237*
	(0.127)	(0.133)	(0.140)
IND_DIR	0.267**	0.195	0.075
	(0.135)	(0.141)	(0.149)
TOP5	0.003	-0.038	-0.017
	(0.051)	(0.053)	(0.056)
DUAL	0.065***	-0.004	0.043**
	(0.017)	(0.018)	(0.019)
Industry FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	27908	27908	27908
R-squared	0.409	0.512	0.498

positive effects on all three patent citation variables (CiteI, CiteU, CiteIU). In contrast, EI_RS shows a significant positive relationship with utility model patents (CiteU) and the combined measure (CiteIU) but does not achieve statistical significance for invention patents (CiteI). This differentiation suggests that option-based incentives (stock options or stock appreciation rights) are more effective at encouraging firms to pursue breakthrough inventions or high-value patents. In contrast, stock-based incentives (restricted stock) appear to be more closely associated with utility-model and broader patent outcomes than with invention-patent citations. Options and appreciation rights typically require substantial stock price increases to yield returns, motivating recipients to engage in high-potential, high-risk R&D activities likely to drive stock price growth and deliver above-average returns. Conversely, restricted stocks, which gradually vest ownership rights, are more effective in promoting cumulative improvements or innovations with visible short-to-medium-term outcomes, maintaining stock price stability.

This finding aligns with the earlier discussion regarding the question of "whom to incentivise and how," underscoring that, in designing equity incentive schemes, firms must consider not only the scale and target of incentives but also the specific attributes of incentive instruments to align effectively with their innovation objectives and strategies. Overall, these conclusions provide empirical evidence for companies aiming to balance "long-term value" and "depth of incentives" when designing equity incentive plans, and also reinforce the earlier findings regarding incentive intensity and innovation outputs.

3.5.2 Heterogeneity Analysis

3.5.2.1 By Ownership Structure (SOEs vs. Non-SOEs)

SOEs and non-SOEs exhibit significant differences in ownership structures, business objectives, management mechanisms, and market responsiveness. To accurately capture the distinct impacts of equity incentives on innovation within these two types of enterprises, this section performs regression analyses separately for SOEs and non-SOEs based on ownership type.

Table 3-8 reports regression results for patent citations (CiteI, CiteU, and CiteIU) after splitting the sample into SOEs and non-SOEs. For SOEs (columns (1)–(3)), the coefficient on EIR is statistically insignificant for invention-patent citations (0.027) and remains positive only for utility-model and combined citation outcomes (0.049 and 0.048, respectively). By contrast, for non-SOEs (columns (4)–(6)), the

Table 3-8. Heterogeneous Effects of Equity Incentives: SOEs vs. Non-SOEs

This table reports OLS regression results examining the heterogeneous effects of equity incentive intensity (EIR) on corporate innovation, comparing state-owned enterprises (SOEs) and non-state-owned enterprises (Non-SOEs). The dependent variables are the natural logarithms of forward citations for invention patents (CiteI), utility model patents (CiteU), and their sum (CiteIU), each adjusted by a two-year lead. Columns (1)–(3) report results for SOEs, while columns (4)–(6) report results for Non-SOEs. All regressions control for firm-level characteristics and corporate governance factors, and include year and industry fixed effects. Standard errors are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	SOE			Non-SOE		
	(1)	(2)	(3)	(4)	(5)	(6)
	CiteI	CiteU	CiteIU	CiteI	CiteU	CiteIU
EIR	0.027	0.049***	0.048**	0.065***	0.052***	0.069***
	(0.018)	(0.018)	(0.019)	(0.005)	(0.005)	(0.006)
TA	0.612***	0.661***	0.730***	0.457***	0.514***	0.593***
	(0.012)	(0.012)	(0.013)	(0.010)	(0.011)	(0.012)
ROA	1.040***	0.580***	1.150***	0.760***	1.308***	1.420***
	(0.211)	(0.210)	(0.226)	(0.112)	(0.122)	(0.127)
D/A	-0.557***	-0.392***	-0.484***	-0.211***	0.060	-0.133***
	(0.066)	(0.066)	(0.071)	(0.037)	(0.040)	(0.041)
OCF	-0.117**	-0.136***	-0.152***	0.055	0.034	0.088**
	(0.051)	(0.051)	(0.055)	(0.037)	(0.040)	(0.042)
AGE	-0.245***	-0.294***	-0.293***	-0.048*	-0.210***	-0.209***
	(0.042)	(0.042)	(0.045)	(0.029)	(0.032)	(0.033)
Q	0.091***	0.061***	0.070***	0.053***	0.010	0.023***
	(0.011)	(0.011)	(0.011)	(0.006)	(0.007)	(0.007)
HHI	0.268	-0.358*	-0.253	0.231	0.239	0.125
	(0.201)	(0.201)	(0.216)	(0.167)	(0.182)	(0.189)
IND_DIR	0.524**	0.528**	0.324	-0.070	-0.206	-0.246
	(0.223)	(0.222)	(0.239)	(0.168)	(0.183)	(0.190)
TOP5	-0.002	-0.077	-0.073	-0.021	-0.124*	-0.058
	(0.087)	(0.087)	(0.094)	(0.064)	(0.070)	(0.073)
DUAL	0.167***	-0.026	0.063	0.097***	0.032	0.073***
	(0.040)	(0.040)	(0.043)	(0.019)	(0.021)	(0.021)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	11543	11543	11543	16365	16365	16365
R-squared	0.504	0.595	0.586	0.344	0.460	0.439

coefficient on EIR is positive and statistically significant across all three innovation measures, with estimated coefficients of 0.065, 0.052, and 0.069. In economic terms, a one-percentage-point increase in EIR is associated with approximately 6.7%, 5.3%, and 7.1% higher citation outcomes in non-SOEs, whereas in SOEs the corresponding associations are weaker, and the invention-patent estimate remains statistically indistinguishable from zero. This pattern indicates that equity incentives are more closely related to higher-value inventive output in non-SOEs than in SOEs. Further examining the control variables, SOEs generally have higher leverage (D/A), which exerts a more negative influence on innovation, suggesting stricter financial constraints faced by SOEs. Additionally, operating cash flow (OCF) is significantly negative for SOEs but not significant or positive for non-SOEs, underscoring fundamental differences between these two types of enterprises regarding internal fund utilisation efficiency and selection of innovation projects. Firm size (TA) and profitability (ROA) continue to demonstrate a positive influence on innovation across both groups, while firm age (AGE) consistently exhibits significant negative coefficients, indicating that younger companies possess greater innovative dynamism. Moreover, the significant coefficient of CEO duality (DUAL) in the non-SOE sample suggests that concentrated leadership may better leverage operational flexibility and rapid decision-making advantages within private enterprise.

Overall, these results indicate substantial differences in the impact of equity incentives on innovation outcomes across the two ownership contexts, consistent with Hypothesis 4. The limited effect of equity incentives on innovation in SOEs suggests that policy and institutional reforms are needed to improve internal incentive mechanisms and unlock their latent R&D potential. For non-SOEs, stronger equity incentives significantly boost innovation outputs, providing valuable empirical evidence in support of market-oriented approaches to innovation within the private sector.

3.5.2.2 By Technology-Driven Status (TDEs vs. Non-TDEs)

In exploring the relationship between equity incentives and corporate innovation, it is essential to acknowledge fundamental differences between technology-driven enterprises (TDE) and non-technology-driven enterprises (non-TDE) in strategic focus, core competencies, resource allocation, and innovation potential. Technology-driven firms typically rely heavily on technological innovation to sustain their market position and competitive advantage. Conversely, non-technology-driven firms may place greater emphasis on services, operational efficiency, or customer relationship management; although technological innovation remains relevant, it may not constitute their primary competitive advantage. Thus, examining these two groups separately helps prevent confounding effects in analysing the impact of equity incentives on innovation.

Table 3-9 splits the sample into technology-driven enterprises (TDEs) and non-technology-driven enterprises (Non-TDEs) based on industry characteristics, with the aim of assessing whether the relationship between equity incentive intensity (EIR) and innovation outputs varies with technological orientation. For TDEs (columns (1)–(3)), EIR is positively associated with all three citation-based innovation measures. The estimated coefficients are 0.054 for invention patent citations (CiteI), 0.041 for utility model citations (CiteU), and 0.058 for the combined measure (CiteIU), all significant at the 1% level. Given the log specification of the dependent variables, these estimates imply economically meaningful semi-elasticities: a one-percentage-point increase in EIR (as a share of total equity) is associated with approximately a 5.5% increase in CiteI, a 4.2% increase in CiteU, and a 6.0% increase in CiteIU, holding other factors constant. In contrast, for Non-TDEs (columns (4)–(6)), the coefficient on EIR for invention patent citations is economically small and statistically indistinguishable from zero (0.003), whereas EIR remains positively related to CiteU (0.033, significant at the 5% level) and CiteIU (0.037, significant at the 1% level). In economic terms, the latter two coefficients correspond to roughly 3.4% and 3.8% higher citation-weighted innovation outputs, respectively, per one-percentage-point increase in EIR. In summary, the split-sample evidence suggests that equity incentives are more closely aligned with higher-barrier inventive innovation in technology-intensive industries, while in less technology-driven sectors the association is concentrated in incremental innovations reflected by utility model patents. Control variables also display patterns consistent with this heterogeneity. Profitability (ROA) is strongly positive in the TDE regressions, indicating that financially stronger technology-driven firms are better positioned to translate resources into higher-impact patent outputs. In Non-TDEs, ROA is not statistically significant, while leverage tends to show a more uniformly negative association with innovation outcomes, suggesting that debt burdens and financial constraints may be more binding for sustaining innovation in traditional industries. Operating cash flow is largely insignificant for TDEs but appears negatively related to innovation in some Non-TDE specifications, potentially reflecting stronger

Table 3-9. Heterogeneous Effects of Equity Incentives: TDEs vs. Non-TDEs

This table reports OLS regression results examining the heterogeneous effects of equity incentive intensity (EIR) on corporate innovation, comparing technology-driven enterprises (TDEs) and non-technology-driven enterprises (Non-TDEs). The dependent variables are the natural logarithms of forward citations for invention patents (CiteI), utility model patents (CiteU), and their sum (CiteIU), each adjusted by a two-year lead. Columns (1)–(3) present results for TDEs, while columns (4)–(6) present results for Non-TDEs. All regressions control for firm-level characteristics and corporate governance factors, and include industry and year fixed effects. Standard errors are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	TDE			Non-TDE		
	(1) CiteI	(2) CiteU	(3) CiteIU	(4) CiteI	(5) CiteU	(6) CiteIU
EIR	0.054***	0.041***	0.058***	0.003	0.033**	0.037***
	(0.006)	(0.006)	(0.006)	(0.011)	(0.013)	(0.014)
TA	0.636***	0.626***	0.713***	0.432***	0.560***	0.621***
	(0.009)	(0.009)	(0.010)	(0.011)	(0.013)	(0.014)
ROA	1.083***	1.549***	1.808***	-0.278	-0.194	-0.022
	(0.121)	(0.122)	(0.127)	(0.177)	(0.216)	(0.232)
D/A	-0.252***	0.055	-0.142***	-0.374***	-0.245***	-0.332***
	(0.039)	(0.040)	(0.041)	(0.056)	(0.068)	(0.073)
OCF	0.015	0.025	0.075	-0.046	-0.072*	-0.073*
	(0.050)	(0.050)	(0.052)	(0.033)	(0.040)	(0.043)
AGE	-0.064**	-0.210***	-0.215***	-0.330***	-0.350***	-0.338***
	(0.029)	(0.030)	(0.031)	(0.037)	(0.045)	(0.049)
Q	0.070***	0.010	0.023***	0.112***	0.115***	0.128***
	(0.007)	(0.007)	(0.007)	(0.009)	(0.011)	(0.012)
HHI	0.281	0.560**	0.484**	0.697***	0.008	0.236
	(0.230)	(0.233)	(0.242)	(0.129)	(0.157)	(0.168)
IND_DIR	0.177	0.019	-0.028	0.733***	0.625**	0.408
	(0.167)	(0.169)	(0.176)	(0.209)	(0.255)	(0.273)
TOP5	0.130**	-0.001	0.074	0.021	0.087	-0.004
	(0.065)	(0.065)	(0.068)	(0.077)	(0.094)	(0.101)
DUAL	0.087***	-0.007	0.039*	-0.010	0.012	0.058
	(0.020)	(0.020)	(0.021)	(0.032)	(0.039)	(0.042)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	20050	20050	20050	7858	7858	7858
R-squared	0.392	0.466	0.432	0.414	0.517	0.503

short-term operating and liquidity pressures that can crowd out longer-horizon innovative investment in less technology-oriented sectors.

In summary, high-tech industries demonstrate greater effectiveness in employing equity incentives to enhance innovation, particularly for breakthrough invention patents. Conversely, traditional industries exhibit limited innovation momentum; even with greater incentive intensity, their innovation outputs predominantly manifest as incremental innovations such as utility models. Combined with earlier analyses on ownership structure and incentive targets, these findings emphasise the importance for enterprises to thoroughly consider their industrial context and technological intensity when designing and implementing equity incentive programmes. By aligning incentive mechanisms closely with their specific industry environment and resource allocation strategies, firms can optimise the effectiveness of equity incentives, thus maximising their positive impact on corporate innovation behaviour.

3.6 Robustness Checks

Following the baseline regressions and heterogeneity analyses, this section implements a set of additional tests to examine whether the positive relation between equity incentives and corporate innovation is robust to alternative identification strategies and outcome measures. The first test adopts an instrumental-variable framework to address the possibility that firms with stronger innovation prospects choose higher levels of incentive intensity. The second test applies a stacked PSM-DID design around the first observable adoption of equity incentive plans, thereby tracing post-adoption changes relative to matched never-treated firms. The final set of tests replaces the main citation-based innovation indicators with patent grant counts and R&D measures so as to assess whether the empirical pattern extends across alternative dimensions of innovation performance. Taken together, these exercises provide complementary evidence on reverse causality, selection, and measurement concerns.

3.6.1 Reverse Causality Test: Instrumental Variable Approach

Although the baseline regressions, heterogeneity analyses, and matching-based estimates consistently indicate a positive relation between equity incentives and corporate innovation, the estimated effect of incentive intensity may still be influenced by reverse causality. Firms with stronger innovation capabilities, richer innovation opportunities, or more favourable expectations about future innovation performance may be more willing to adopt larger equity incentive plans. To isolate variation in equity incentive intensity that is less directly tied to the focal firm's contemporaneous innovation conditions, this subsection employs a two-stage least squares (2SLS) design.

The instrumental variable, denoted as IV_Size, is constructed as the lagged average equity incentive intensity of other firms in the same size group and year, excluding the focal firm itself. Firms are sorted annually into three size groups according to total assets. This design reflects the fact that firms of comparable size are often subject to similar compensation benchmarking practices, governance constraints, and contracting environments when determining the scale of equity-based incentives. The leave-one-out construction removes the focal firm's own contribution to the peer average, while the lag structure reduces contemporaneous simultaneity. Relative to an industry-based peer measure, the size-based benchmark is also less directly exposed to common technology- or sector-specific innovation shocks. In this setting, the instrument is expected to be strongly correlated with firms' own equity incentive intensity (EIR), while being less directly connected to the focal firm's contemporaneous patent innovation outcomes (CiteIU). It therefore provides a plausible source of identifying variation for the effect of equity incentive intensity on patent-based innovation.

A falsification specification is further estimated using the pre-period innovation outcome, CiteIU(t−1), as the dependent variable. Because this placebo outcome predates the focal firm-year incentive intensity, it provides a direct empirical check on whether the size-based instrument is associated with pre-existing innovation performance. The placebo results reported below show no significant relation between IV_Size and pre-period innovation, which is consistent with the intended exclusion logic of the instrument.

Within the 2SLS framework, the first-stage regression is specified as follows:

$$EIR_{i,t} = \alpha_0 + \alpha_1 IV\_Size_{i,t-1} + \alpha_2 Control\_Variables_{i,t} + i.year + i.industry + \varepsilon_{it} \tag{3-3}$$

where $IV\_Size_{i,t-1}$ is the lagged size-based instrumental variable, $Control\_Variables$ includes the same set of firm-level and governance controls employed in the baseline models, and industry and year fixed effects are included.

In the second stage, the predicted values of equity incentive intensity, $\widehat{EIR}_{i,t}$, obtained from the first stage are used in place of the original $EIR_{i,t}$:

$$Cite_{i,t+2} = \beta_0 + \beta_1 \widehat{EIR_{i,t}} + \beta_2 Control\_Variables_{i,t} + i.year + i.industry + \varepsilon_{it} \quad (3\text{-}4)$$

By extracting the variation in equity incentive intensity that is induced by the incentive-setting behaviour of comparable firms, rather than by the focal firm's own current innovation conditions, the IV approach provides a cleaner basis for causal interpretation than conventional OLS. At the same time, the effectiveness of this strategy depends on the validity of the excluded instrument, because the exactly identified specification relies entirely on the size-based peer variation for identification. The leave-one-out construction, lag structure, and placebo test together are therefore essential components of the identification strategy.

Table 3-10 reports the revised IV results. Column (1) presents the placebo regression, where the dependent variable is the pre-period innovation measure CiteIU(t−1). The coefficient on IV_Size is positive but statistically insignificant (0.080, s.e. = 0.087), indicating that the instrument does not explain innovation outcomes that were realised prior to the focal firm's current incentive intensity. This lack of predictive power for pre-existing innovation performance further supports the exogeneity of the instrument, indicating that IV_Size does not directly capture prior innovation conditions that would otherwise contaminate the second-stage estimates. Column (2) reports the first-stage regression. The coefficient on IV_Size is 0.534 and significant at the 1% level, confirming a strong positive association between the size-based instrument and firms' own equity incentive intensity. The Cragg–Donald F-statistic is 39.257, well above the conventional threshold of 10, indicating that the instrument is not weak and has sufficient explanatory power to support the 2SLS estimation. Column (3) reports the second-stage regression. After instrumenting for equity

Table 3-10. Instrumental Variable Regression Results: Equity Incentives and Innovation

This table reports revised two-stage least squares (2SLS) regression results examining the causal effect of equity incentive intensity (EIR) on corporate innovation. The excluded instrument is IV_Size, defined as the lagged average equity incentive intensity of other firms in the same size group and year, excluding the focal firm. Size groups are formed annually based on total assets. Column (1) presents a placebo (falsification) regression, where the dependent variable is the pre-period innovation outcome CiteIU(t−1), measured as the natural logarithm of forward citations of invention and utility model patents already realised prior to the focal firm's current incentive intensity. Column (2) reports the first-stage regression using IV_Size to predict EIR. Column (3) presents the second-stage regression using the predicted value of EIR to explain CiteIU, the natural logarithm of forward citations of invention and utility model patents, adjusted by a two-year lead. All models control for firm-level characteristics and corporate governance factors, and include industry and year fixed effects. Because one excluded instrument is used for one endogenous regressor, the 2SLS specification is exactly identified. Standard errors are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. The Cragg–Donald F-statistic is reported as a weak-instrument diagnostic for the first stage.

	Placebo(1)	(2)	(3)
	CiteIU(t-1)	EIR	CiteIU
IV_Size	0.080	0.534***	
	(0.087)	(0.085)	
EIR			0.349**
			(0.152)
TA	0.786***	0.111***	0.778***
	(0.013)	(0.012)	(0.020)
ROA	1.088***	2.938***	3.979***
	(0.237)	(0.225)	(0.495)
D/A	-0.416***	0.087	-0.310***
	(0.068)	(0.065)	(0.063)
OCF	-0.265***	-0.140*	-0.353***
	(0.078)	(0.074)	(0.074)
AGE	-0.330***	-0.441***	-0.463***
	(0.039)	(0.034)	(0.075)
Q	0.070***	0.027**	0.066***
	(0.012)	(0.012)	(0.012)
HHI	0.681***	0.191	0.459***
	(0.218)	(0.184)	(0.178)
IND_DIR	0.082	0.257	0.263
	(0.190)	(0.184)	(0.179)
TOP5	-0.260***	-1.122***	-0.406**
	(0.075)	(0.071)	(0.189)
DUAL	0.044*	0.284***	0.136***
	(0.025)	(0.024)	(0.049)
Industry FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	17473	24484	24484
R-squared	0.513		0.391
F	0.849	39.257	200.389

incentive intensity, the coefficient on EIR remains significantly positive at the 5% level (0.349, s.e. = 0.152). This result indicates that, after accounting for endogeneity arising from potential reverse causality, equity incentive intensity continues to exert a positive effect on firms' patent innovation output. The magnitude of the 2SLS estimate is also economically meaningful, suggesting that the motivational role of equity incentives remains substantial even after isolating the exogenous component of incentive intensity.

Overall, the IV results provide additional support for the interpretation that higher equity incentive intensity is positively related to corporate innovation. The placebo specification indicates that the instrument does not predict pre-existing innovation outcomes, the first stage confirms strong relevance, and the second stage preserves the positive coefficient on EIR. Taken together, these findings reduce the concern that the observed relation is driven solely by the tendency of more innovative firms to adopt stronger equity incentive plans.

3.6.2 Self-Selection Bias: Stacked PSM-DID

The preceding robustness checks address two important but distinct sources of concern. First, the earlier PSM-OLS analysis improves comparability between firms that eventually adopt equity incentive plans and firms that never adopt them by matching them on observable characteristics measured in the year immediately prior to the first adoption event. This helps reduce bias arising from observable differences, but it remains essentially a matched comparison in levels and does not fully exploit the timing of adoption. As a result, a related concern still remains: even if adopters and non-adopters look similar on pre-adoption observables, firms that eventually adopt equity incentive plans may nevertheless move onto a different innovation path around the time of adoption. Second, the IV analysis is mainly designed to address endogeneity in the intensity of equity incentives, that is, whether firms with stronger innovation prospects choose higher levels of incentive intensity. That analysis is therefore more closely related to the intensive margin of equity incentives. By contrast, the question considered here concerns the extensive margin, namely whether the initial decision to enter the equity incentive regime is itself associated with a change in firms' subsequent innovation performance. To examine this issue, this subsection combines the matched sample from the preceding PSM procedure with a cohort-stacked difference-in-differences design around the first observable adoption of equity incentive plans.

The DID analysis is implemented on the matched sample constructed in the previous PSM procedure. As in the baseline matching design, each treated firm is matched to never-treated firms using covariates measured in the year immediately preceding its first observable adoption year. Building on these baseline matches, the matched observations are reorganised into a cohort-stacked panel. Each treated firm is assigned to a cohort defined by its first observable adoption year, and each matched control firm inherits the same cohort in which it was selected as a match. A post-adoption indicator is then defined from the first observable adoption year onward, and the DID term is constructed as the interaction between treatment status and the post-adoption period. Estimation further incorporates firm-by-cohort and cohort-by-year fixed effects, applies the matching weights generated at the PSM stage, and clusters standard errors at the firm level. In this way, this design preserves the pre-adoption comparability delivered by matching while tracing post-adoption changes in innovation outcomes relative to matched never-treated firms.

Table 3-11 reports the stacked PSM-DID results. The coefficient on Treat × Post (first adoption) is positive and statistically significant for all three innovation measures. The estimated coefficients are 0.430 for CiteI, 0.263 for CiteU, and 0.372 for CiteIU, significant at the 1%, 5%, and 1% levels, respectively. These estimates indicate that, after matching treated firms to observationally similar never-treated firms and then comparing post-adoption changes across the two groups, the first observable adoption of equity incentive plans is followed by a clear improvement in innovation outcomes. In economic terms, the estimates correspond to increases of approximately 53.7% for invention-patent citation outcomes, 30.1% for utility-model citation outcomes, and 45.1% for the combined citation measure. The largest effect appears in invention-patent citations, suggesting that the adoption of equity incentive plans is associated not only with broader innovative activity, but also with a marked improvement in higher-value inventive output.

Table 3-11. Stacked PSM-DID Estimates around the First Observable Adoption of Equity Incentive Plans

This table reports stacked propensity score matching difference-in-differences (PSM-DID) estimates for the effect of the first observable adoption of equity incentive plans on corporate innovation. Treated firms are defined as firms that adopt equity incentive plans at least once during the sample period, while control firms are firms that never adopt such plans. For each treated firm, matching is conducted in the year immediately preceding the first observable adoption year. Within each pre-adoption year, treated firms are matched to never-treated firms using one-to-one nearest-neighbour propensity score matching with a logit specification, common support restriction, and tied matches allowed. The matched baseline observations are then reorganised into a cohort-stacked panel. Treat × Post equals one for treated firms from the first observable adoption year onward and zero otherwise. All regressions include the same firm-level and governance controls as in the baseline model. Standard errors are clustered at the firm level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	(1) CiteI	(2) CiteU	(3) CiteIU
Treat × Post	0.430***	0.263**	0.372***
	(0.091)	(0.112)	(0.111)
TA	0.695***	0.623***	0.722***
	(0.095)	(0.100)	(0.104)
ROA	1.849	2.780**	3.103**
	(1.264)	(1.414)	(1.479)
D/A	-1.426***	-0.510	-1.081*
	(0.421)	(0.550)	(0.557)
OCF	-1.060***	-1.088***	-1.161***
	(0.336)	(0.382)	(0.415)
AGE	-0.644***	-0.689**	-0.795***
	(0.227)	(0.281)	(0.284)
Q	0.210***	0.031	0.099
	(0.048)	(0.067)	(0.065)
HHI	-0.957**	-0.099	-0.581
	(0.458)	(0.484)	(0.512)
IND_DIR	-0.237	1.151	0.656
	(1.084)	(1.311)	(1.308)
TOP5	-0.644	-0.650	-0.899
	(0.484)	(0.581)	(0.601)
DUAL	-0.104	0.026	0.011
	(0.096)	(0.118)	(0.113)
Firm × Cohort FE	Yes	Yes	Yes
Cohort × Year FE	Yes	Yes	Yes
Observations	17666	17666	17666
R-squared	0.320	0.224	0.236

The stacked PSM-DID evidence complements both the baseline PSM-OLS analysis and the IV results. Once treated firms are matched to observationally similar never-treated firms on pre-adoption characteristics, the subsequent adoption of equity incentive plans remains associated with a significant increase in innovation performance. The fact that the timing-based estimates preserve the same positive direction as the earlier cross-sectional and intensity-based results reinforces the conclusion that the main findings are not driven solely by pre-existing differences between adopters and non-adopters.

3.6.3 Alternative Measures of Innovation

To further corroborate this study's core conclusion that equity incentives effectively promote corporate innovation, and simultaneously to mitigate potential limitations from relying solely on patent citations as an innovation measure, this section substitutes alternative dependent variables into the baseline regression model. These variables encompass two main categories: patent grant counts (PatI, PatU, PatIU) and R&D investment indicators (RD, RD_INT), thereby enabling a comprehensive examination of firm performance across both innovation input and output dimensions. Specifically, PatI, PatU, and PatIU respectively measure the number of granted invention patents, granted utility model patents, and the combined total of these granted patent types. Meanwhile, RD and RD_INT gauge the absolute scale and relative intensity of corporate R&D expenditure, respectively. This approach not only facilitates testing the impact of equity incentives on the scale of patent output (as reflected by grants) but also captures their stimulative effects on R&D investment decisions.

Table 3-12 reports regression results using these alternative dependent variables. Columns (1)–(3) respectively use invention patent grants (PatI), utility model patent grants (PatU), and combined patent grants (PatIU) as dependent variables. Columns (4) and (5) measure corporate innovation input using absolute R&D expenditure (RD) and R&D intensity (RD_INT). The coefficient on EIR remains positive and statistically significant across all alternative measures. For patent grant outcomes, the coefficients are 0.040, 0.037, and 0.049 for PatI, PatU, and PatIU, respectively, indicating that greater equity incentive intensity is associated not only with more highly cited innovation outcomes, but also with a larger volume of realised patent output. The estimates for RD and RD_INT are likewise positive and significant, with coefficients of 0.059 and 0.104, suggesting that stronger equity incentives are also

Table 3-12. Robustness Check Using Alternative Innovation Measures

This table reports robustness checks using alternative measures of corporate innovation. The dependent variables in columns (1)-(3) are the natural logarithms of the number of granted invention patents (PatI), utility model patents (PatU), and their combined total (PatIU). Columns (4) and (5) use R&D expenditure (RD) and R&D intensity (RD_INT, measured as the ratio of R&D expenditure to operating revenue) as alternative innovation proxies. The key independent variable is EIR, which captures the intensity of equity incentives. All regressions control for firm-level characteristics and corporate governance factors, and include industry and year fixed effects. Standard errors are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)	(4)	(5)
	PatI	PatU	PatIU	RD	RD_INT
EIR	0.040***	0.037***	0.049***	0.059***	0.104***
	(0.004)	(0.005)	(0.005)	(0.004)	(0.025)
TA	0.505***	0.574***	0.634***	0.885***	0.199***
	(0.006)	(0.007)	(0.007)	(0.008)	(0.046)
ROA	0.666***	1.100***	1.299***	1.927***	-8.783***
	(0.085)	(0.101)	(0.102)	(0.106)	(0.654)
D/A	-0.192***	-0.009	-0.125***	-0.465***	-6.606***
	(0.027)	(0.032)	(0.033)	(0.044)	(0.276)
OCF	-0.029	-0.051*	-0.030	-0.215***	-2.529***
	(0.026)	(0.030)	(0.031)	(0.045)	(0.275)
AGE	-0.101***	-0.232***	-0.227***	-0.248***	-1.374***
	(0.020)	(0.024)	(0.024)	(0.024)	(0.141)
Q	0.074***	0.038***	0.048***	0.071***	0.472***
	(0.005)	(0.005)	(0.005)	(0.006)	(0.035)
HHI	0.360***	0.189	0.171	0.604***	0.245
	(0.107)	(0.126)	(0.128)	(0.146)	(0.903)
IND_DIR	0.318***	0.167	0.130	-0.218*	1.048
	(0.113)	(0.134)	(0.136)	(0.132)	(0.781)
TOP5	0.002	-0.034	-0.022	0.184***	-1.421***
	(0.043)	(0.051)	(0.052)	(0.051)	(0.306)
DUAL	0.037***	-0.014	0.016	0.086***	0.410***
	(0.014)	(0.017)	(0.017)	(0.016)	(0.094)
Industry FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	27908	27908	27908	24134	21688
R-squared	0.419	0.521	0.523	0.563	0.231

associated with greater innovation input. Overall, these results show that the positive relation documented in the baseline models is not confined to citation-based measures, but extends to patent grant output and R&D investment, thereby reinforcing the conclusion that stronger equity incentives are associated with both more intensive and more productive innovative activity.

3.7 Conclusion

This study focuses on the impact of equity incentives on corporate innovation, utilising data from Chinese A-share listed companies between 2007 and 2021 to systematically examine the effects of equity incentives on patent innovation and R&D investment across various contexts. To address potential endogeneity concerns, multiple robustness checks have been employed. Empirical findings consistently indicate a significant positive relationship between equity incentives and corporate innovation. The baseline regression results demonstrate that whether using a binary equity incentive variable (EI) or a more detailed incentive intensity measure (EIR), equity incentives are highly positively correlated with patent citation counts. When further distinguishing incentive tools into stock options/stock appreciation rights (option-based tools) and restricted stocks (stock-based tools), both types of incentives stimulate corporate innovation to varying degrees. However, options and stock appreciation rights demonstrate a more pronounced effect on high-value invention patents, highlighting the differential influence of incentive forms on the direction and depth of innovation. Second, the internal distribution of equity incentives plays a critical role. By categorizing incentive recipients into executives and core technical/operational personnel, results reveal that equity incentives targeted towards technical or operational personnel are more strongly associated with patent-based innovation outcomes than those directed at executives. This finding underscores the crucial role that frontline R&D or operational personnel play in corporate innovation, often surpassing the direct influence of executives. Hence, management should strategically prioritise incentives towards technical and R&D teams. Third, ownership type and industry context significantly moderate the effectiveness of equity incentives. Due to institutional constraints and multiple managerial objectives, SOEs exhibit relatively limited incentive effectiveness in fostering high-level innovation such as invention patents. In contrast, non-SOEs can better leverage equity incentives within more flexible governance frameworks, fully realising their potential to stimulate innovation. Similarly, technology-driven firms demonstrate significantly stronger innovation responses to equity incentives, particularly in relation to high-value invention-patent outcomes, compared with firms in traditional industries, which appear less responsive in achieving breakthrough innovation.

To examine whether these findings are sensitive to selection, adoption timing, and alternative measurement, this chapter combines baseline regressions with matched comparisons, an instrumental-variable design for incentive intensity and a cohort-stacked PSM-DID analysis around the first observable adoption of equity incentive plans. The resulting estimates remain positive across these complementary specifications. These complementary estimates yield a consistent empirical pattern regarding the positive relation between equity incentives and corporate innovation. Further robustness checks using alternative innovation measures based on patent grants and R&D expenditure also strengthen this conclusion. These findings align with prior literature (Lin et al., 2011), reaffirming the positive effect of incentive mechanisms on technological innovation within the Chinese market context. These findings are also broadly consistent with the agency and incentive-contracting literature, which emphasises that aligning managerial rewards with long-term firm value is conducive to innovation-related investment.

As highlighted in prior literature, incentive design and related agency issues have already been extensively analysed in the executive-compensation literature (Hall and Liebman, 1998; Hall and Murphy, 2003). Thus, proposing radically distinct theoretical breakthroughs based on existing theories remains inherently challenging. Rather than proposing a new theoretical framework, this study contributes by re-examining the innovation implications of equity incentives within a long post-reform sample of Chinese listed firms and by doing so through a design that combines matched comparisons, timing-based post-adoption analysis, intensity-based tests, and alternative innovation measures. Specifically, the equity incentive management regulations formally piloted in 2006 introduced a modern remuneration framework for Chinese listed companies. This study collects and compiles a comprehensive sample of Chinese listed firms from 2007 to 2021. On one hand, this period captures the full implementation process of the equity incentive policy since its introduction; on the other hand, it allows examination of the sustained impact of equity incentives on corporate innovation amidst multiple changes in policy and market environments. Moreover, this study further complements the matching analysis by examining post-adoption changes around the first observable adoption of equity incentive plans through a timing-based design, thereby allowing the empirical analysis to trace changes in innovation performance after adoption. Taken together, the evidence from pre-adoption matching, post-adoption comparisons, intensity-based tests, and alternative innovation measures provides a broader empirical basis for the conclusion that equity incentives are positively associated with corporate innovation in the Chinese market.

Nonetheless, this research still faces several limitations. The sample utilised is drawn exclusively from Chinese listed firms. As indicated in the descriptive statistics, the proportion of firms implementing equity incentives remains relatively low. More importantly, because the research sample primarily focuses on Chinese publicly listed companies, it cannot capture a substantial number of younger high-tech entrepreneurial firms that do not enter the capital market. Consequently, this study is unable to examine small and medium-sized private firms, for which equity-based incentives may play a more important role in attracting, retaining, and motivating innovative talent. It would significantly enhance the comprehensive understanding of China's overall equity incentive mechanisms if relevant data could be collected and integrated into future analyses. Overall, the primary contribution of this study lies in its long-term analytical window and rigorous identification methods to substantiating the widely accepted academic consensus "equity incentives effectively promote corporate innovation" from the perspective of the Chinese market. Furthermore, it provides valuable empirical evidence for managers regarding optimal targeting of incentive recipients, selection of incentive instruments, and considering ownership structures and industry contexts to align equity incentives more precisely with innovation objectives.

Chapter 4

Political Connections, Officials' Promotion Incentives, and Green Innovation: Evidence from Chinese Private Firms

4.1 Introduction

In the contemporary global context, environmental, social, and governance (ESG) principles, alongside the broader concept of corporate social responsibility (CSR), have transitioned from peripheral considerations to central elements in corporate strategy formulation, stakeholder engagement, and long-term firm value assessment (Eccles et al., 2014; Friede et al., 2015). Increasing pressure from investors, consumers, regulators, and other stakeholders has subjected firms to more stringent scrutiny regarding their commitments to sustainable practices. Within this comprehensive ESG framework, the environmental dimension has become particularly salient due to the intensifying global climate crisis and the depletion of natural resources. Green innovation, encompassing the development and implementation of new technologies, processes, products, and management systems aimed at enhancing resource efficiency, reducing pollution, and fostering environmental protection, represents a critical and tangible pathway for firms to address these environmental challenges, demonstrate responsible conduct, and contribute to the transition towards a greener economic model (Porter and Van der Linde, 1995). As the world's second-largest economy, China's promotion of green innovation is not only a response to global sustainability norms but also a strategic initiative to support its economic restructuring to fulfil international environmental commitments such as the 2060 carbon neutrality target and enhance global competitiveness. Consequently, incentivising green technological advancement has been explicitly identified as a national priority in recent years. Against this backdrop, corporations, as key agents in driving green innovation, play a crucial role through dedicated research and development (R&D) investments and the application of green technologies. However, the trajectory of green innovation among Chinese firms is shaped not only by market opportunities and the rising prominence of ESG awareness, but also by the distinctive institutional environment of China, characterized by complex interactions among government policy, regulatory pressure, and the political embeddedness of corporate leadership.

Political connections, defined as the ties between corporate executives and government officials or political institutions, can serve as a non-market asset for firms, particularly in environments characterized by intricate relational networks such as China (Xin and Pearce, 1996). These connections can facilitate access to critical resources, such as preferential financing, government subsidies, and valuable policy information, potentially reducing operational uncertainties and conferring competitive advantages (Faccio, 2006; Li et al., 2008). Given that green innovation typically requires substantial upfront investments, faces technological uncertainties, and relies on a supportive regulatory landscape, it seems plausible that CEO political connections could play a significant role in helping firms overcome these hurdles and pursue ambitious green agendas. However, the nature and extent of this influence, particularly concerning different types and intensities of green innovation output, warrant more in-depth investigation. Existing research offers mixed evidence, sometimes linking political connections to enhanced innovation or CSR (Lin et al., 2014; Lin et al., 2015), but also highlighting potential downsides such as rent seeking or efficiency inhibition under certain conditions (Boubakri et al., 2012; Maung et al., 2016).

This complexity is further compounded by the distinctive institutional features of China's local governance system, in which local officials compete for promotion based on performance metrics (Li and Zhou, 2005). Historically dominated by GDP growth targets, this system has undergone significant reform, increasingly incorporating environmental performance into cadre evaluation criteria, partly in response to mounting environmental pressures and the enactment of stringent legislation such as the 2015 Environmental Protection Law. These changes have altered the incentive structure for local officials, who must now weigh the trade-offs between economic growth and environmental protection. Consequently, promotion-related pressures, especially when mayors are closer to empirically salient promotion stages in their career trajectories, may exert significant influence on their regulatory and supportive roles in shaping corporate environmental behaviour, including green innovation (Ren et al., 2024; Wang and Lei, 2020). How these politically driven incentives of local officials interact with firm-level political connections to shape green innovation outcomes remains a critical yet underexplored nexus.

To elucidate these relationships, this study aims to investigate the impact of CEO political connections on corporate green innovation. Using data from Chinese A-share listed private enterprises, it examines whether and how CEO political connections affect firms' green innovation patent output. The study further explores the boundary conditions under which these connections are most effective, testing how this relationship is moderated by city administrative level, the stringency of local environmental regulatory regimes, and whether the firm operates in a heavily polluting industry. Critically, as a key contribution, this study incorporates a political economy perspective by introducing the moderating effect of local officials' promotion incentives. Drawing on a long-span dataset and employing multiple robustness tests to address potential endogeneity concerns, the findings reveal several key insights: higher levels of CEO political connections significantly promote green invention innovation, while their effect on green utility model innovation is comparatively weaker and less robust across specifications. Consistent with contingency theory, the positive impact of political connections is more pronounced in cities with lower administrative levels, in regions subject to stricter environmental regulation, and among firms operating in high-pollution industries. Moreover, this study provides evidence that stronger mayoral promotion-window intensity significantly strengthens the positive relationship between CEO political connections and green invention innovation in quasi-sub-provincial and ordinary prefecture-level cities. This supports the argument that political connections and local officials' career incentives jointly shape substantive green innovation.

This research makes a significant contribution by integrating local officials' promotion incentives into the analytical framework linking political connections and corporate green innovation, thereby offering important theoretical insights into the interaction among political embeddedness, institutional incentives, and firms' sustainable development strategies. The remainder of this study is structured as follows: Section 4.2 reviews the relevant literature and presents the research hypotheses; Section 4.3 describes the data sources and research design; Section 4.4 presents the summary statistics and descriptive analysis; Section 4.5 reports the baseline regression results together with the heterogeneity analyses; Section 4.6 conducts multiple tests addressing endogeneity and robustness; and Section 4.7 concludes the study.

4.2 Literature Review and Hypothesis Development

ESG factors have become critical benchmarks for assessing a firm's capacity for sustainable development and long-term value creation. Early empirical studies examined the impact of corporate sustainability practices. Eccles et al. (2014) found a positive relationship between the adoption of sustainability policies and the optimisation of organisational processes as well as long-term performance. Subsequent research has further confirmed that firms exhibiting strong ESG performance are not only more attractive in capital markets but also enjoy amplified positive effects, particularly in areas related to environmental issues and stakeholder relations such as customers and employees (Friede et al., 2015; Flammer, 2015). The mechanisms through which ESG drives firm value have been examined from multiple perspectives in management and finance. Moderate investments in CSR have been shown to improve financial performance by enhancing stakeholder management, although this relationship may follow an inverted U-shape (Barnett and Salomon, 2012). Concurrently, by obtaining sustainability certifications, firms can accumulate greater public attention and reputational capital, thereby establishing differentiated advantages in market competition (Hawn et al., 2018). Moreover, corporate endeavours in fulfilling social responsibilities and improving governance quality are increasingly recognized as significant factors influencing investor decisions and market valuations (Gillan et al., 2021). This is partly because such practices contribute to building trust, lowering transaction costs, and ultimately achieving competitive advantages (Du et al., 2011).

Among the three ESG dimensions, the environmental aspect has drawn special attention due to its direct relevance to firms' resource efficiency and emission control, as well as its potential to become a source of sustained competitive advantage (Hart, 1995; Delmas and Toffel, 2008). In their invited editorial, Hart and Dowell (2011) reviewed the Natural-Resource-Based View (NRBV) theory, noting that over the past fifteen years it has inspired extensive research on the relationship between corporate environmental strategy and competitive advantage. The theory's core argument that environment-related capabilities can serve as a source of enduring competitive advantage has received substantial empirical support. Firms' decisions to pursue green development paths are driven by a combination of external pressures and internal factors. As Bansal and Roth (2000) argue, ecological responsiveness can arise from institutional legitimacy concerns, competitive advantage considerations, and intrinsic ecological responsibility. At the same time, investors' environmental awareness is continually increasing, making environmental responsibility not merely an ethical issue but also a significant economic factor influencing corporate market value and investor decisions (Flammer, 2013). Practices of greenwashing, where firms over-invest in environmental communications while underperforming in actual environmental actions, may appear effective in the short term or under conditions of high information asymmetry. However, as transparency improves and stakeholder scrutiny intensifies, such behaviour is likely to be uncovered, ultimately damaging a firm's reputation and legitimacy (Berrone et al., 2017).

The Porter Hypothesis posits that well-designed environmental regulations can serve as catalysts for innovation, thereby simultaneously enhancing both competitiveness and environmental performance (Porter and Van der Linde, 1995). The core of this hypothesis is that environmental regulations are not merely cost burdens as traditionally perceived, but can incentivize firms to achieve sustainable development through technological and managerial innovation. Green innovation enables firms to build unique competitive advantages while enhancing their green image and core capabilities (Chen et al., 2006; Chen, 2008). From the perspectives of organizational capability and social reciprocity, the positive impact of green innovation on firm performance relies on the effective integration of internal resources and collaboration with external networks (Huang and Li, 2017). Applying the Resource-Based View (RBV), green innovation can be further regarded as a strategic corporate resource that not only meets environmental compliance requirements but also creates sustained competitive barriers in the value creation process (Khanra et al., 2022; Farza et al., 2021).

However, the effectiveness of green innovation is not guaranteed and is largely conditioned by both internal and external factors of the firm. Firms with more robust internal governance mechanisms are better equipped to mitigate agency problems and are more inclined to engage in green investment and innovation activities (Amore and Bennedsen, 2016). Concurrently, the external market environment and institutional context are also of critical importance (Delmas and Toffel, 2008). Recent systematic literature reviews highlight that Green Innovation Implementation (GII) is a complex, multi-stage process encompassing idea generation, project selection, resource allocation, organisational transformation, and market diffusion. Successful GII requires not only technological capability but also strong organisational support, effective management practices, and the ability to overcome various internal and external barriers (Qin et al., 2026). For instance, in the Chinese context, green innovation has been shown to be an important means of enhancing firm performance (Zhang et al., 2019). However, firms' green innovation investments and outputs may exhibit inconsistencies. These can arise from various factors, including policy incentives, market competition pressures (Wang et al., 2021), differences in regional economic development and industry characteristics, and varying modes of government intervention.

The discussion surrounding executives' political connections has primarily focused on identifying how such ties influence firms’ access to resources, likelihood of receiving regulatory favouritism, and market reactions (Faccio, 2006; Hillman et al., 1999). Resource dependence theory provides a foundation for this view, positing that firms actively seek to build ties with critical external actors including government bodies, because such relationships facilitate resource acquisition, reduce uncertainty, and allow influence over rule-making, thereby enhancing environmental adaptability and organisational performance (Pfeffer and Salancik, 1978). Empirical findings indicate that the market often reacts positively to politically connected firms, particularly when connected politicians gain power or influence, suggesting that investors perceive these connections as valuable (Faccio, 2006; Goldman et al., 2009). Claessens et al. (2008), studying the Brazilian context, found that political connections can indeed help firms secure preferential treatment, such as access to loans from state-owned banks. In economies with underdeveloped institutional environments or significant government intervention, political connections can serve as an informal substitute mechanism, helping firms compensate for the deficiencies of formal institutions and cope with uncertainty (Peng and Luo, 2000). Evidence from countries such as Indonesia and Malaysia suggests that political connections significantly enhance firm market valuation and help mitigate risks and improve performance during external shocks like financial crises (Fisman, 2001; Johnson and Mitton, 2003). Additionally, Zheng et al. (2015) found that political connections have a dual role, buffering and enabling, in terms of firm survival and sales growth: on one hand, they help firms maintain stability amidst external shocks; on the other, by providing resources and opportunities, they also promote sales growth. This finding deepens the understanding of the positive effects of political connections. Hillman (2005) further argues that political ties may help firms evade or mitigate regulatory burdens, thereby securing favourable positions in competitive markets.

However, political connections are not entirely beneficial, and their potential downsides related to rent-seeking have also received considerable attention. Such ties may incentivize firms to engage in non-productive rent-seeking activities, such as seeking short-term private benefits through bribery or exploiting relational networks, which can undermine long-term development and lead to inefficient resource allocation (Shleifer and Vishny, 1994). Over-reliance on official resources might disincentivize firms from focusing on internal governance and market competition, thereby negatively affecting long-term performance and innovation efficiency (Boubakri et al., 2012). Fisman (2001), when quantifying the value of politically connected firms during Indonesia's Suharto era, confirmed that the economic value derived from political connections (especially in countries with severe cronyism) declines significantly with the anticipated decay of political power. Further research indicates that political connections can directly affect the impartiality of regulatory practices. Lin et al. (2018) found that political connections are associated with weaker tax enforcement effectiveness, implying that politically connected firms may be more likely to receive favourable tax treatment or circumvent stringent tax scrutiny.

In the Chinese business environment, where market mechanisms are often weak or unreliable, firms tend to rely heavily on political relationship networks for resource acquisition and business development (Xin and Pearce, 1996). Li et al. (2008) found that private enterprises with political connections have easier access to bank loans, particularly in regions with relatively underdeveloped financial systems and greater government intervention. However, the study did not find significant positive effects of political connections on firm performance indicators such as sales growth or profitability. Empirical evidence has even shown that Chinese listed firms that appoint politically connected CEOs may experience poorer long-term performance after their IPOs, potentially due to governance issues and resource misallocation (Fan et al., 2007).

The impact of political connections on CSR is multifaceted and can be interpreted through various theoretical lenses, including resource dependence theory, legitimacy theory, and agency theory. Li and Zhang (2010) found that state-owned enterprises (SOEs) are more inclined to undertake government-assigned social responsibilities, though such behaviour may also reflect government interference, leading CSR activities to deviate from pure value maximization or stakeholder orientation. However, social responsibility like this can sometimes be merely symbolic, aimed at meeting external expectations and shaping a legitimate image to manage public perception rather than reflecting substantive commitment (Marquis and Qian, 2014). Lin et al. (2015) found that political connections significantly and positively influence strategic CSR behaviours such as corporate philanthropy. These activities are often used as tools to establish, maintain, or leverage political ties, with the expectation of reciprocal benefits such as government subsidies, tax breaks, financing facilitation, or regulatory forbearance. As such, CSR is often strategically motivated rather than purely driven by social responsibility concerns. In the U.S. context, Heitz et al. (2023) show that firms politically connected through campaign contributions do not exhibit lower emissions, but they face less environmental regulatory enforcement and lighter penalties, suggesting a form of regulatory favour. In China, however, Maung et al. (2016) discovered that politically connected firms, particularly SOEs, tend to generate higher levels of industrial pollution, especially when external constraints such as environmental taxes and fees are weak. This can lead to negative environmental externalities, undermine the effectiveness of environmental regulations, and highlight potential conflicts between economic development objectives and environmental protection goals. Following a similar line of inquiry, recent evidence from Wang et al. (2023) suggests that the impact of political connections on corporate pollution depends on the specific type of environmental regulation, indicating that under certain regulatory regimes, connections may lead to poorer environmental outcomes. From the perspective of agency theory, the political ideology of CEOs has a significant impact on corporate CSR and ESG performance. CEOs with liberal orientations tend to place greater emphasis on environmental responsibility and sustainable strategies, whereas conservative CEOs are relatively less inclined to invest in environmental protection (Chin et al., 2013). This phenomenon is sometimes captured by the phrase “Blue goes green,” emphasizing the tangible influence of executive political ideology on firm-level environmental outcomes (Kim, 2024).

Similar to corporate environmental responsibility, the impact of political connections on green initiatives is influenced, and sometimes biased by the lens of resource dependence theory. Lin et al. (2014) found that political capital can indeed serve as a positive driver of corporate green innovation. The underlying mechanisms may include firms' access to government subsidies for green innovation, greater ease in understanding and adapting to environmental policy directives, enhanced access to bank credit, or improved reputational standing through participation in government-led green projects (Peng and Luo, 2000; Jia, 2016). However, political connections alone are not sufficient to automatically translate into green innovation; a strong entrepreneurial strategy within the firm is also required (Zhang et al., 2022). While politically connected CEOs have been found to promote green innovation among listed industrial firms in China, their influence operates not directly but through the mediating role of the external governance environment (Huang et al., 2021). In regions with weaker governance systems, political connections may help firms obtain resources or circumvent regulatory constraints, either facilitating or hindering green innovation, though the positive effects often outweigh the potential drawbacks. In stronger governance environments, however, the influence of political connections tends to diminish. This contextual variation is also consistent with Liu et al. (2021), who find that political connections hinder firms’ green technology innovation and that the negative effect is more pronounced in less marketised environments. Focusing on specific green industries such as renewable energy further reveals the complexity of political connections. Li et al. (2019) found that political ties did not significantly improve, and may even reduce the operational efficiency of Chinese renewable energy firms, suggesting a possible disconnect between obtaining political support and achieving efficient green operations. Moreover, broader research on environmental performance indicates that while government involvement may enhance compliance, it does not always lead to meaningful environmental innovation, especially among heavily polluting firms (Chang et al., 2015). Thus, the relationship between political connections and green outcomes appears to hinge on institutional factors, regulatory intensity, and the firm's own strategic orientation, oscillating between facilitation and obstruction.

When discussing political connections and environmental responsibility, local government officials are an unavoidable part of the equation. China's unique political system is characterized by a "political tournament" in which local officials' career advancement largely depends on GDP growth (Li and Zhou, 2005). This system creates strong incentives to prioritise economic expansion, often at the expense of environmental protection. However, over the past decade, the central government has initiated reforms to incorporate environmental performance into officials' evaluation metrics. Research indicates that this shift is beginning to alter the priorities of local governments. Tang et al. (2021) found that in regions with stringent environmental assessments, the positive effect of economic growth on officials' promotion prospects significantly weakens when pollution levels exceed specific thresholds, indicating that environmental degradation can offset economic accomplishments. Further evidence shows that improvements in air quality have begun to positively influence the promotion probabilities of county-level party secretaries (Wu and Cao, 2021). This evolving incentive structure reflects a gradual transition towards dual goals of economic development and environmental protection (Du and Yi, 2022). Academic research has explored how these incentives shape local government behaviour, potentially leading to fluctuations in the stringency of environmental regulations (Wang and Lei, 2020), driving local policy innovations (Mei and Wang, 2017), influencing resource allocation in specific regions (such as resource-depleted cities) (Zhang et al., 2018), or intensifying environmental supervision particularly nearing performance evaluations or leadership transitions (Cao et al., 2019). This evolving structure of political incentives also significantly affects firm-level strategies and behaviour, especially within the context of China's state-business relations. Ren et al. (2024) provide direct evidence of how local officials' political incentives influence corporate green innovation. The broader principle that officials' career incentives significantly influence corporate decisions is also supported by research in other areas, such as the impact of incentives on corporate diversification strategies for officials nearing retirement (Wang and Luo, 2019). Overall, as the weight of environmental indicators in promotion assessments increases, local officials are increasingly motivated to encourage or pressure firms within their jurisdictions to adopt greener practices and invest in green innovation, thereby shaping corporate environmental agendas.

Existing literature offers multidimensional perspectives for understanding corporate environmental strategy, political connections (PC), and the institutional context in which firms operate. While prior studies acknowledge the growing importance of ESG factors, and particularly the potential of green innovation to confer competitive advantages, the pathways to realising these advantages remain complex and context dependent. A large body of research has examined the role of CEO political connections, primarily through the lens of resource dependence theory, suggesting that such ties help firms access resources, obtain preferential treatment, and reduce uncertainty, especially in environments with underdeveloped institutions. However, the literature also highlights potential drawbacks, including rent-seeking behaviour, agency problems, and adverse effects on certain performance dimensions. When applied specifically to corporate environmental behaviour and green innovation, the influence of political connections becomes even more nuanced. Moreover, the effectiveness of political connections may depend on internal firm characteristics and the quality of external governance. This ambiguity suggests that the relationship between political connections and green innovation is not uniform, but rather contingent on various moderating factors and may differ across types of green innovation outcomes. Critically, the literature has increasingly recognized the evolving role of local government officials' incentive mechanisms within China's political economy. The incorporation of environmental performance into official promotion evaluations suggests that career concerns can shape local environmental policy and its implementation, thereby influencing corporate environmental strategies. Nonetheless, direct empirical research on this "incentive-based moderating effect" remains limited. Early studies primarily investigated the influence of official incentives on environmental governance at the macro level and whether firms respond to environmental regulations. Few studies have directly examined the interaction between local officials' promotion incentives and firms' executive-level political connections.

Therefore, this study aims to fill these research gaps by systematically examining the impact of CEO political connections on corporate green innovation in the Chinese context. Drawing on resource dependence theory and acknowledging the mixed findings in prior literature, this study first proposes baseline hypotheses regarding the differentiated impact of political connections. Furthermore, drawing on a contingency theory perspective and insights into China's institutional heterogeneity, this study explores how this relationship is moderated by contextual factors: city administrative level, local environmental regulatory stringency, and the type of industry to which the firm belongs. Finally, and most distinctively, this study integrates the promotion incentive mechanism of local officials, hypothesizing that the pressure faced by officials during their promotion window periods interacts with CEO political connections to jointly shape corporate green innovation efforts. Based on this theoretical foundation and the identified research gaps, the hypotheses of this study are as follows:

H1: CEO political connections have a positive effect on corporate green innovation output, and this effect increases with the level of political connection.

H2: The positive relationship between CEO political connections and green innovation is stronger in cities with lower administrative levels than in cities with higher administrative levels.

H3: The positive relationship between CEO political connections and green innovation is more pronounced under stricter environmental regulation.

H4: The positive relationship between CEO political connections and green innovation is more significant for firms operating in heavily polluting industries than for those in non-heavily polluting industries.

H5: The positive relationship between CEO political connections and corporate green innovation is significantly stronger when the relevant local government officials are within their promotion window and face heightened incentive intensity.

4.3 Data, Variable Construction, and Methodology

4.3.1 Sample Selection and Data Sources

This study focuses on privately owned firms listed on China's A-share market between 2008 and 2021, specifically targeting enterprises within the secondary industry sector, while excluding ST and *ST firms. The sample window is determined by the joint availability and consistent measurement of the key constructs across data sources. The exclusive inclusion of private enterprises is motivated by the fact that they generally enjoy greater autonomy in managerial recruitment and CEO appointments under market-based mechanisms, making them more representative and distinctive for examining the impact of CEOs' political experience on corporate decision-making (Fan et al., 2007; Li et al., 2008). In contrast, in SOEs, the principle of the Party's leadership over cadre appointments is deeply embedded in all levels of SOEs governance. Regardless of the method of CEO selection, listed companies controlled by central or local state-owned assets supervision entities typically require final approval from Party organizations such as the Central Organization Department, local organization departments, or the State-owned Assets Supervision and Administration Commission (Leutert, 2018). Senior executives in these firms are often incorporated into the cadre management system governed by the Central Organization Department or local counterparts, carrying characteristics of political appointments, and are usually associated with administrative or Party ranks (Leutert, 2018). Although most of these individuals are technically classified as enterprise personnel rather than government officials, under the Criminal Law and the Supervision Law, they are still regarded as "public officials exercising public authority" or "state functionaries" when involved in the management of state-owned assets or public funds (Criminal Law of the People's Republic of China, 1997; Supervision Law of the People's Republic of China, 2018). Therefore, at the legal level, although their employment status differs from that of government officials, they are similarly regarded as public officials in matters concerning anti-corruption and the punishment of duty-related crimes. This implicit political ranking or political appointment characteristic significantly reduces the identifiability of a CEO's political background in the context of corporate green innovation decision-making. To avoid institutional differences and implicit political advantages associated with SOEs, this study focuses on private enterprises, aiming to more clearly identify the mechanism through which CEOs' political backgrounds affect corporate green innovation. Accordingly, firm ownership in this study is classified according to the nature of the actual controlling entity recorded in CSMAR. A firm-year is treated as state-owned if its actual controller is a state-owned enterprise, an administrative agency, a public institution, or a central or local government entity; all other firm-years are classified as private. This approach focuses on de facto control rather than the mere presence of state shareholding, and therefore helps exclude cases in which ongoing state control may directly shape CEO appointment and corporate decision-making. As a result, the measured political connection of the CEO is more likely to reflect the CEO's own political background rather than politically appointed executive status associated with state ownership.

Considering that the research focuses on green innovation and patent-related indicators, prior literature has shown that green invention patents are predominantly concentrated in industries such as energy and manufacturing (Johnstone et al., 2010; Popp, 2005). To mitigate potential biases introduced by sectors with low relevance to green patents or significantly different technological structures, such as agriculture, finance, and services, the sample is restricted to four industry categories based on the 2012 industry classification guidelines issued by the China Securities Regulatory Commission (CSRC): B (Mining), C (Manufacturing), D (Electricity, Heat, Gas and Water Production and Supply), and E (Construction). This restriction enhances the comparability of green innovation indicators and reduces the interference of industry structural heterogeneity in regression results. Additionally, ST and *ST companies, typically facing operational irregularities and delisting risks, are excluded, as such firms may exhibit abnormal innovation behaviour and distorted financial data. Data on green innovation related patent grants and citations, as well as CEOs' political backgrounds, are primarily sourced from the China Stock Market & Accounting Research (CSMAR) database. Information on local government officials, together with the inputs required to identify their promotion windows, is obtained from the CCER database of Chinese city leaders. The CCER database provides annual appointment and biographical records for prefecture-level mayors, including the city of office (city code) and its administrative rank, position titles, and demographic attributes (e.g., age and education). These records are merged with the firm-year panel using headquarters city code and year, which enables the construction and assignment of a city-year promotion-window indicator and the examination of its interaction with CEO political backgrounds in shaping corporate green innovation. Other firm-level financial data, corporate governance variables, and regional economic and environmental indicators are also sourced from the CSMAR database. Corporate financial variables are winsorized at the 1st and 99th percentiles to mitigate the influence of outliers on empirical results. After excluding observations with missing core variables, unidentified ownership types, or mismatched firm classifications, the final sample comprises 10,588 observations, covering 3,038 CEOs and 1,741 listed firms, as well as 696 mayors. Through this sampling strategy, the study constructs a relatively complete and targeted dataset that excludes potential implicit political ranking distortions among SOEs CEOs and ensures the consistency between the selected industries and green innovation variables, thereby providing a rigorous and reliable research setting to test the influence of CEO political connections on corporate green innovation.

4.3.2 Measurement of Corporate Green Innovation

This study defines corporate green innovation primarily as the quality of innovation output reflected in green patents that were applied for and successfully granted during the sample period. It is measured using the cumulative number of citations these patents have received. Specifically, the total citation counts for green invention patents and green utility model patents granted up to December 31, 2021, are used to assess the level of innovative achievement firms have attained in the field of green technologies. To ensure accurate identification of "green" attributes, the study adopts the International Patent Classification (IPC) Green Inventory developed by the World Intellectual Property Organization (WIPO) as the classification framework. The IPC Green Inventory comprises approximately 200 topics across seven major domains: alternative energy production, energy conservation, transportation, waste management, agriculture and forestry, administrative and regulatory matters, and nuclear energy technologies. The classification is based on technologies listed under the United Nations Framework Convention on Climate Change (UNFCCC), allowing for a systematic capture of innovation activities related to sustainable development and environmental protection (WIPO, 2010). In the regression analysis, the citation variable is log-transformed to reduce skewness in its distribution. Year fixed effects are included in the models to control for macroeconomic and systemic shocks. Given the common time lag between R&D investment and innovation output, this study leads the patent output data by two years to more accurately reflect the actual contribution of R&D activities to innovation performance. To test the robustness of the results, the number of green patent grants is also introduced as an alternative indicator, focusing on the quantity dimension of innovation output. This dual approach allows for a more comprehensive assessment of green innovation by considering both quality and quantity, thereby enhancing the consistency and reliability of the empirical results across different measurement specifications.

4.3.3 Measurement of CEO Political Connections

To measure the political connections of CEOs, this study focuses on the political background of the CEO (or general manager), including any past or current positions held within the government or the Chinese Communist Party (CCP) system. Given the variation in executive titles across Chinese firms, this study follows the title hierarchy defined in the CSMAR to identify the firm's top executive in a consistent manner across firms. The hierarchy is, in descending order of priority, Chief Executive Officer (CEO), President, General Manager, Executive General Manager, and Acting General Manager. CEO identity and executive-title information are obtained directly from CSMAR.

According to the Civil Servant Law of the People’s Republic of China (2005), civil service positions are classified into leadership and non-leadership positions. Leadership positions are ranked (from highest to lowest) as follows: National Level (principal), National Level (deputy), Provincial/Ministerial Level (principal), Provincial/Ministerial Level (deputy), Department/Bureau Level (principal), Department/Bureau Level (deputy), County/Division Level (principal), County/Division Level (deputy), Township/Section Level (principal), and Township/Section Level (deputy). Non-leadership positions are generally at the Department/Bureau Level or below and include Counsellor, Associate Counsellor, Consultant, Associate Consultant, Principal Staff Member, Deputy Principal Staff Member, Staff member, and Clerk. Although non-leadership roles are nominally without managerial responsibility, in practice they often carry administrative ranks and influence equivalent to those of leadership positions (Saich, 2015).

This study does not differentiate between leadership and non-leadership positions when they are associated with comparable administrative ranks; instead, it maps both types of titles into a unified administrative hierarchy based on rank. For example, a counsellor (a non-leadership position) is considered equivalent to a department/bureau level principal (a leadership position). The research focus lies in evaluating the level of political access held by the CEO, rather than the formal distinction between leadership and non-leadership roles. In operational terms, the highest administrative rank ever held by the CEO is used to construct a "political connection level" variable, scored on a scale from 10 to 1, corresponding respectively to the highest national level principal rank down to the lowest township/section deputy level. If a CEO has never held any position corresponding to the defined ranks, the political connection level is coded as 0, indicating no significant political connection. Consistent with this focus on meaningful political access, positions at the very bottom of the non-leadership ladder (i.e., staff member, clerk, and deputy principal staff member) are treated as no significant political connection and coded as zero. This classification reflects the reality that, within the civil service system, non-leadership roles, especially at the lower levels, are often filled by individuals who either lack the capacity to assume leadership roles or who require promotion compensation after long tenures in leadership (Chan and Li, 2007). As the lowest non-leadership rank, deputy principal staff members typically possess administrative resources and social networks very similar to those of staff members and thus are grouped with the non-politically connected.

Based on the above ranking system, a binary political connection indicator is also constructed. It is coded as 1 if the CEO has held a government/CCP position at township/section deputy level or above (including equivalent non-leadership titles mapped to these ranks), and 0 otherwise. This dual approach (continuous rank and binary indicator) allows for an examination of both the heterogeneity in political connection levels and the overall effect of having political ties on corporate green innovation. In practice, high-level political connections tend to confer broader resource networks, greater policy influence, and easier market access, while lower-level connections are more relevant to the implementation of local policies and access to regional resources. This setup enables a more comprehensive exploration of the potential mechanisms through which CEOs' political backgrounds influence green innovation decisions.

4.3.4 Measurement of Local Officials' Promotion Incentives

To capture the moderating effect of local government officials' dynamics on the relationship between CEO political connections and corporate green innovation, this study incorporates the concept of a promotion window for local officials into the analysis. China's local cadre promotion system is highly institutionalized and competitive, especially with regard to the appointment and promotion processes for municipal-level leaders. Officials experience significant performance pressure during key stages of their political careers. This pressure often leads them to pursue short-term achievements by relaxing environmental regulations or increasing policy support to stimulate economic growth and employment, thereby improving their promotion prospects (Li and Zhou, 2005). Such incentives may influence the interaction between CEO political connections and corporate green innovation.

In China's local administrative system, the municipal Party Secretary holds the top political authority in a city, with ultimate decision-making power over Party directives and local development strategy. However, the Mayor, as the head of the local government, is directly responsible for economic development and policy implementation (Landry, 2008). Particularly in the implementation and supervision of environmental policies (Zheng et al., 2014), the Mayor has a stronger influence on firms' daily operations and environmental compliance, as they directly manage government departments. Especially when major environmental incidents occur, mayors often bear direct responsibility (Ran, 2017), fostering closer ties with enterprises. Based on this rationale, this study selects Mayors, rather than Municipal Party Secretaries, as the primary subjects for examining the dynamics of local government officials.

This study focuses its investigation of the official promotion window period on prefecture-level cities, including ordinary prefecture-level cities and key cities whose Party secretaries also serve as members of the provincial standing committee. Municipalities directly under the central government, sub-provincial cities, sub-prefectural cities, and county-level cities are excluded. The rationale is that mayors of municipalities directly under the Central Government and sub-provincial cities generally already possess higher administrative ranks and greater political resources, making their promotion paths and timing more uncertain. China’s city classification includes four types: (1) municipalities (e.g., Beijing, Shanghai, Tianjin, Chongqing), which enjoy provincial-level administrative status; (2) 15 sub-provincial cities whose mayors and Party secretaries are sub-provincial level officials; (3) provincial capital cities, where Party secretaries are usually members of the provincial standing committee (sub-provincial rank), and mayors hold principal Department/Bureau Level rank; and (4) ordinary prefecture-level cities, where both mayors and Party secretaries typically hold principal Department/Bureau Level rank.

In China's official promotion system, the career progression of most officials often reaches a ceiling at the sub-provincial level. For mayors of municipalities directly under the Central Government and sub-provincial cities, who are officials at or above the sub-provincial level, promotion to principal provincial/ministerial or deputy national leadership positions depends not only on their performance during the tenure but is also closely tied to factors such as political loyalty and support from national political factions (Shih et al., 2012). The Chinese cadre hierarchy resembles a pyramid, with diminishing opportunities for promotion at higher levels; only a few can break through. In practice, officials at the sub-provincial level and above are considered senior officials. During anti-corruption campaigns, corrupt officials at the sub-provincial level and above are referred to as 'tigers,' while those at the prefecture level and below are termed 'flies.' Therefore, for prefecture-level officials, the prospect of promotion to the sub-provincial level, especially to an important position, is highly attractive. If department/bureau level officials can be promoted to the sub-provincial level, it often signifies entry into the ranks of senior officials (Shih et al., 2012). Studies show that, in provinces like Zhejiang, age limits alone prevent many mayors from advancing beyond this level or cause them to encounter a "promotion ceiling" beforehand (Gao, 2017). The promotion paths for local Chinese officials are relatively standardized, and the routes for department/bureau level mayors are particularly well-defined. The primary promotion pathway for most mayors is to become the Municipal Party Secretary in their own city or in another city within the same province. Accordingly, this study defines the promotion window based on the city's administrative level and the mayor's age.

In provincial capital cities that are not formally designated as sub-provincial cities, the mayor holds the principal Department/Bureau rank, whereas the municipal Party secretary typically already occupies a sub-provincial position by serving on the Provincial Party Standing Committee. This institutional arrangement implies that the mayor's relevant next-step promotion target is not merely an ordinary transfer within the prefectural hierarchy. Rather, the politically meaningful upward move is entry into powerful vice-provincial positions, such as vice governor, member of the Provincial Party Standing Committee, or municipal Party secretary of the provincial capital. In this sense, compared with mayors in ordinary prefecture-level cities, mayors of these provincial capitals are effectively "half a rank higher," and their promotion logic is closer to that of prefectural Party secretaries competing for advancement to powerful vice-provincial positions. Following the age-distribution evidence documented by Yi (2025), the promotion window for this group is therefore defined as an age-specific intensity measure that increases with the empirical concentration of promotions at each age and is normalized by the peak frequency within this promotion route. For mayors in ordinary prefecture-level cities, the promotion sequence is different. Their immediate upward move is typically to become the municipal Party secretary either in the same city or in another prefecture-level city within the same province. However, the key issue is not only whether they can become Party secretary, but whether they can do so early enough to preserve the possibility of further promotion to a powerful vice-provincial position. As shown by Yi (2025), officials who ultimately reach such positions generally need to enter the Party secretary track at a relatively early stage. Accordingly, for mayors in ordinary prefecture-level cities, the promotion window is defined using the age distribution of the mayor-to-Party-secretary transition among those who ultimately advance to powerful vice-provincial positions. The resulting measure captures the relative intensity of promotion pressure at each age and is likewise normalized by the peak frequency within this promotion route.

Based on the preceding analysis, this study measures the promotion window using the mayor's age and the administrative level of the city. Specifically, the promotion window variable (PPW) is constructed as a route-specific age-intensity index ranging from 0 to 1. For mayors in provincial capital cities that are not sub-provincial cities, PPW is based on the age profile associated with promotion to powerful vice-provincial positions. For mayors in ordinary prefecture-level cities, PPW is based on the age profile associated with the transition from mayor to Party secretary among those who ultimately obtain powerful vice-provincial promotion. In both cases, higher values indicate that the mayor's current age is closer to the empirically most salient promotion stage for that route, whereas ages outside the observed support of the relevant age distribution are coded as zero.

4.3.5 Grouping Variables

4.3.5.1 City Administrative Level

This study first distinguishes the administrative level of the city in which a firm's headquarters is located by defining it as a multi-categorical variable. This classification aims to better capture the heterogeneity of the institutional environment that may influence corporate decision-making. Specifically, city administrative levels are categorized into four groups: Level 1 refers to provincial-level municipalities directly under the central government; Level 2 refers to sub-provincial cities (including cities with independent planning status); Level 3 refers to quasi-sub-provincial cities, typically provincial capitals where the municipal Party secretary concurrently serves as a member of the provincial standing committee; and Level 4 includes ordinary prefecture-level cities. This classification follows the practical logic of China's administrative hierarchy and reflects the importance of city-level status in the implementation of economic and environmental policies, as discussed in prior literature. In this hierarchy, higher-ranking city governments possess greater administrative authority and resource access, which translates into stronger capacity to influence corporate operations, particularly in the areas of environmental regulation and innovation (Landry, 2008). Distinguishing between administrative levels thus allows for better control of variations in the local political-business environment and provides a robust foundation for examining the influence of local government structures on the relationship between CEO political connections and green innovation.

4.3.5.2 Key Environmental Protection Cities

In China's environmental planning and regulatory system, key environmental protection cities are subject to stricter environmental supervision and receive additional financial support. According to the 'National Environmental Protection Eleventh Five-Year Plan', a total of 113 cities were designated as key environmental protection cities (State Council, 2007). In this study, if a firm's headquarters is located in one of these cities, the corresponding dummy variable is coded as 1; otherwise, it is coded as 0. Including this variable allows the analysis to control more effectively for cross-regional variation in environmental regulatory stringency and to assess more precisely the marginal impact of CEO political connections on corporate green innovation.

4.3.5.3 Heavily Polluting Enterprises

To account for the institutional pressure and regulatory intensity faced by firms operating in high-pollution, high-energy-consuming industries, this study identifies heavily polluting industries based on the Environmental Inspection Categorization Guidelines for Listed Companies issued by the former Ministry of Environmental Protection in 2008, combined with the 2012 industry classification standard by the CSRC. Accordingly, heavily polluting industries are defined by the following CSRC codes: B06, B07, B08, B09, B11, B12; C17, C19, C22, C25, C26, C27, C28, C29, C30, C31, C32; and D44, D45 (MEP, 2008). Among them, B06 to B12 correspond to mining sectors, such as coal mining and processing, oil and gas extraction, ferrous and non-ferrous metal ore mining, and non-metallic mineral mining. Codes C17 to C32 include paper and paper product manufacturing, petroleum processing and coking, chemical raw material and product manufacturing, rubber and plastic product manufacturing, non-metallic mineral product manufacturing, ferrous and non-ferrous metal smelting and rolling, general and specialized equipment manufacturing, and automobile manufacturing. D44 and D45 include electricity and heat production and supply, as well as gas production and supply. These industries are typically characterized by high energy consumption and emissions and are therefore subject to stricter environmental regulations and more intensive government supervision (Zhong and Peng, 2022). Identifying heavily polluting industries allows the analysis to more precisely capture the environmental compliance pressures faced by firms, enabling the study to uncover industry-level heterogeneity in the relationship between CEO political connections and corporate green innovation.

4.3.6 Control Variables

To comprehensively examine the impact of CEO political connections on corporate green innovation, this study incorporates a set of control variables covering corporate financial characteristics, corporate governance structures, and regional economic conditions. These variables help isolate other potential factors that may influence the level of green innovation within firms.

In terms of financial characteristics, this study controls for firm size (total assets), profitability (return on assets), financial leverage (debt-to-asset ratio), firm age, market valuation (Tobin's Q), and industry concentration (Herfindahl-Hirschman Index), following standard practices in previous literature. Larger firms tend to have more resources, while more profitable firms are more willing and able to invest in R&D and environmental upgrades (Horbach, 2008). However, higher debt ratios may constrain long-term environmental R&D investment (Clarkson et al., 2011). Firm age reflects a trade-off between accumulated experience and innovation inertia; older firms benefit from experience but may lack motivation for innovation. Tobin's Q captures the firm's market valuation; firms with higher valuations tend to have stronger incentives to invest in green technologies (Calza et al., 2020). A higher HHI indicates greater industry concentration, and in such environments, leading firms may outperform in green technology adoption due to first-mover advantages and greater environmental responsibility.

This study also includes corporate governance variables: the proportion of independent directors, CEO gender, and CEO-chair duality. These variables serve to assess the level of external oversight and board diversity. A higher proportion of independent directors is typically associated with more effective internal controls and more prudent strategic decisions (de Villiers et al., 2011). Given that executive characteristics can significantly shape corporate decision-making styles, CEO gender is included to examine whether female CEOs exhibit greater caution and social responsibility in environmental investment and green innovation (Ben-Amar et al., 2017). Additionally, whether the CEO simultaneously serves as the board chair may affect corporate governance and decision-making efficiency. Over-centralization in top management could weaken board oversight and influence the scale of investment in R&D and environmental initiatives (Walls et al., 2012).

At the regional level, the study controls for two macroeconomic variables: provincial GDP per capita and EPR, measured as the ratio of provincial environmental protection expenditure to general public budget expenditure. The former reflects the region's level of economic development. Du et al. (2021) show that the effect of environmental regulation on green technology innovation and industrial structure upgrading is heterogeneous across cities with different levels of economic development. In more economically developed cities, environmental regulation is more likely to promote green technology innovation and industrial upgrading. The latter variable captures local governments' fiscal emphasis on environmental protection. A higher value indicates that a larger share of general public budget expenditure is devoted to environmental protection, which may be associated with stronger policy support and more rigorous compliance requirements for firms. Therefore, the inclusion of these two regional macroeconomic control variables helps mitigate potential confounding effects stemming from regional disparities in economic development and environmental governance.

Table 4-1. Variable definitions

Variable	Description
GCiteI	Natural logarithm of forward citations of green invention patents applied for and granted, aligned with a two-year lead (t+2).
GCiteU	Natural logarithm of forward citations of green utility model patents applied for and granted, aligned with a two-year lead (t+2).
GCiteIU	Natural logarithm of forward citations of green invention and utility model patents applied for and granted, aligned with a two-year lead (t+2).
PC	A dummy variable equal to 1 if the CEO has political connections, and 0 otherwise.
PCL	An index ranging from 0 to 10 that captures the CEO's civil service level during political tenure, where 0 indicates no political experience.
PPW	A route-specific age-intensity measure of the mayor's promotion window, ranging from 0 to 1.
CAL	The administrative level of the city.
TA	Natural logarithm of total assets.
ROA	Return on assets.
D/A	Debt-to-asset ratio.
AGE	Natural logarithm of firm age.
Q	Tobin's Q, calculated as market value divided by total assets.
HHI	Herfindahl-Hirschman Index, calculated using firm revenue to determine market share within the industry.
IND_DIR	Proportion of independent directors on the board.
CEO_GEN	Gender of the CEO.
DUAL	A dummy variable equal to 1 if the CEO also serves as board chair, and 0 otherwise.
PGDP	Natural logarithm of provincial GDP per capita.
EPR	Ratio of provincial environmental protection expenditure to general public budget expenditure.
KEPC	A dummy variable equal to 1 if the firm's city is designated as a key environmental protection city, and 0 otherwise.
HPI	A dummy variable equal to 1 if the firm operates in a heavily polluting industry, and 0 otherwise.
GPatI	Natural logarithm of the number of green invention patents applied for and granted, aligned with a two-year lead (t+2).
GPatU	Natural logarithm of the number of green utility model patents applied for and granted, aligned with a two-year lead (t+2).
GPatIU	Natural logarithm of the number of green invention and utility model patents applied for and granted, aligned with a two-year lead (t+2).
DIST_BJ	Natural logarithm of geographic distance between the firm's registered headquarters and Beijing.

4.4 Descriptive Statistics and Preliminary Analysis

4.4.1 Descriptive Statistics

Table 4-2 reports the descriptive statistics for all major variables. Beginning with the dependent variables, both the citation-based measures of green invention patents

(GCiteI, log-transformed) and green utility model patents (GCiteU, log-transformed) exhibit medians equal to zero. This indicates that a large number of private listed firms in the sample did not produce any cited green patents during the observation period, and the quality of green innovation displays a highly right-skewed distribution. Similarly, the combined citation metric (GCiteIU, log-transformed) has a mean of only 0.879, while its maximum reaches 7.393, further reflecting substantial dispersion in green innovation output and a concentration of green patent activity among a relatively small number of leading firms. Regarding the key explanatory variables, approximately 18.2% of CEOs have political experience (mean of PC = 0.182), while the average political connection level (PCL) is 1.167 and the median is 0, indicating that most CEOs in the sample have no political background and that politically connected CEOs are concentrated in the lower and middle parts of the administrative hierarchy. The promotion window variable for mayors (PPW) has 5,836 observations, fewer than the full sample, since this variable is defined only for mayors at the Department/Bureau Level. Its mean and median are 0.549 and 0.550, respectively, indicating a moderate average level of promotion-window intensity and meaningful variation across the relevant subsample.

The control variables show reasonable distributions after winsorization at the 1st and 99th percentiles. The logarithm of total assets (TA) has a mean of 21.608 and a standard deviation of 0.987, indicating considerable variation in firm size. Return on Assets (ROA) averages 4.7%, with a minimum of -22.2%, suggesting that some firms still experienced substantial losses during the sample period, but the influence of extreme observations is materially reduced after trimming. The mean leverage ratio (D/A) is 0.358, indicating moderate financial leverage overall, while the maximum value of 0.916 suggests that balance-sheet outliers have likewise been effectively contained. Market valuation (Q) has a mean of 2.087, still well above the theoretical benchmark of 1, indicating the generally high valuation premium of China's growth-oriented private listed firms. Industry concentration (HHI) averages just 0.093, suggesting that most sample firms operate in highly competitive sectors.

In terms of corporate governance characteristics, the average proportion of independent directors (IND_DIR) is 37.5%, roughly aligned with the one-third threshold mandated by the CSRC. Male CEOs (CEO_GEN) make up 92.8% of the

Table 4-2. Summary Statistics

This table reports summary statistics for the main variables based on 10,588 firm-year observations from a panel of 1,741 privately owned firms listed on China's A-share market during 2008-2021. The sample is restricted to enterprises in the secondary industry sector, including mining, manufacturing, utilities, and construction. GCiteI, GCiteU, and GCiteIU represent the natural logarithms of forward citations for green invention patents, green utility model patents, and their combined total, each adjusted with a two-year lead. The key independent variable, PC, is a dummy equal to 1 if the CEO has political connections, while PCL captures the ranked level of political experience. PPW is a route-specific age-intensity measure of local officials' promotion window and ranges from 0 to 1, with higher values indicating stronger promotion incentives. Control variables are selected from three dimensions: firm-level characteristics, corporate governance factors, and regional context, including total assets, return on assets, leverage, firm age, Tobin's Q, industry concentration, board independence, CEO gender and duality, local GDP per capita, and environmental protection spending. Continuous corporate financial variables are winsorized at the 1st and 99th percentiles. All variable definitions are provided in Table 4-1.

VarName	Obs	Mean	SD	Min	Median	Max
GCiteI	10588	0.334	0.787	0.000	0.000	6.555
GCiteU	10588	0.738	1.058	0.000	0.000	6.828
GCiteIU	10588	0.879	1.172	0.000	0.000	7.393
PC	10588	0.182	0.386	0.000	0.000	1.000
PCL	10588	1.167	2.612	0.000	0.000	10.000
PPW	5836	0.549	0.310	0.000	0.550	1.000
TA	10588	21.608	0.987	19.436	21.481	24.975
ROA	10588	0.047	0.053	-0.222	0.048	0.163
D/A	10588	0.358	0.188	0.061	0.338	0.916
AGE	10588	2.741	0.382	0.693	2.773	4.127
Q	10588	2.087	1.099	0.899	1.718	8.321
HHI	10588	0.093	0.089	0.016	0.073	1.000
IND_DIR	10588	0.375	0.054	0.133	0.333	0.750
CEO_GEN	10588	0.928	0.259	0.000	1.000	1.000
DUAL	10588	0.385	0.487	0.000	0.000	1.000
PGDP	10588	11.071	0.466	9.085	11.127	12.009
EPR	10588	0.049	0.031	0.011	0.039	0.414
CAL	10588	2.794	1.101	1.000	3.000	4.000
KEPC	10588	0.609	0.488	0.000	1.000	1.000
HPI	10588	0.365	0.481	0.000	0.000	1.000

sample, reflecting the ongoing rarity of female executives. CEO-chair duality (DUAL) is present in 38.5% of firms, consistent with prior literature describing the centralization of power in Chinese listed companies.

At the regional level, the mean logarithm of provincial GDP per capita for the sample firms is 11.071, corresponding to an actual level of approximately 65,000 RMB. The average value of EPR, defined as the ratio of provincial environmental protection expenditure to general public budget expenditure, is 4.9%. Finally, 60.9% of firms are located in key environmental protection cities designated by the State Council (KEPC), and 36.5% belong to heavily polluting industries (HPI). The mean value of City Administrative Level (CAL) is 2.794, with a median of 3.000, indicating that a substantial share of the sample is located in quasi-sub-provincial and ordinary prefecture-level cities. Overall, the means, standard deviations, and ranges of the variables are generally consistent with expectations.

4.4.2 Correlation Matrix

Table 4-3 presents the Pearson correlation coefficients for the main variables. Notably, the three citation-based measures of green patents (GCiteI, GCiteU, GCiteIU) are all positively and significantly correlated with one another, indicating a strong complementarity between green invention patents and utility model patents in terms of technological accumulation and external impact. Some firms exhibit a “multi-pronged” approach to green innovation. The strong correlation between GCiteIU and GCiteU, along with the gap in their means, suggests that green innovation quality among private firms is primarily driven by utility model patents, while invention patents, which require higher technological capabilities and longer development cycles, remain relatively scarce. This aligns with the tendency of Chinese private enterprises to engage in incremental rather than breakthrough innovation due to resource constraints.

Beyond these three variables, most pairwise correlations are moderate, with no coefficients exceeding 0.5, suggesting that multicollinearity is unlikely to be a significant concern for the analysis. Regarding the key independent variable, CEO political connections (PC), its correlation with the green innovation measures are 0.05 with GCiteI, -0.00 with GCiteU, and 0.02 with GCiteIU. These coefficients indicate a generally weak, and mixed, relationship between CEO political background and green patent citations, with only the correlation with GCiteI showing statistical significance at the 5% level, though the overall strength of these associations is not substantial. PC is also weakly correlated with most firm characteristics, except for CEO-chair duality (DUAL), where the correlation is more pronounced (0.22), implying that politically connected CEOs are more likely to hold consolidated power within the firm. Firm size (TA) and leverage (D/A) are positively correlated (0.12), consistent with findings in

Table 4-3. Correlation Matrix

This table presents Pearson correlation coefficients among the main variables based on 10,588 firm-year observations from a panel of 1,741 privately owned firms listed on China's A-share market during 2008-2021. GCiteI, GCiteU, and GCiteIU are log-transformed measures of forward green patent citations, adjusted by a two-year lead. PC is a dummy variable indicating whether the CEO has political connections. Control variables include firm size, return on assets, leverage, firm age, Tobin's Q, industry concentration, board independence, and CEO characteristics such as gender and duality, as well as regional indicators such as provincial GDP per capita and environmental protection spending. * indicates significance at the 5% level.

	GCiteI	GCiteU	GCiteIU	PC	TA	ROA	D/A	AGE	Q	HHI	IND_DIR	CEO_GEN	DUAL	PGDP	EPR	KEPC	HPI
GCiteI	1																
GCiteU	0.53*	1															
GCiteIU	0.74*	0.94*	1														
PC	0.05*	-0.00	0.02	1													
TA	0.23*	0.35*	0.35*	-0.01	1												
ROA	0.05*	0.04*	0.06*	0.02*	0.08*	1											
D/A	0.05*	0.10*	0.09*	-0.04*	0.12*	-0.40*	1										
AGE	-0.09*	-0.01	-0.05*	-0.05*	0.16*	-0.08*	0.10*	1									
Q	-0.04*	-0.09*	-0.09*	-0.05*	-0.35*	-0.06*	0.21*	0.10*	1								
HHI	0.00	0.01	-0.00	-0.00	0.02*	-0.04*	0.06*	-0.06*	-0.05*	1							
IND_DIR	0.00	-0.00	-0.00	0.04*	-0.05*	-0.01	-0.01	0.02*	0.03*	-0.03*	1						
CEO_GEN	0.03*	0.02*	0.03*	-0.01	0.03*	-0.01	0.03*	-0.01	-0.00	-0.01	-0.05*	1					
DUAL	-0.00	-0.02	-0.01	0.22*	-0.11*	0.01	-0.06*	-0.04*	-0.00	-0.06*	0.12*	0.07*	1				
PGDP	-0.09*	0.05*	0.01	-0.08*	0.13*	0.02*	-0.09*	0.22*	-0.05*	-0.11*	0.08*	0.02	0.10*	1			
EPR	-0.06*	-0.06*	-0.07*	-0.02	0.04*	-0.04*	0.05*	0.09*	0.05*	0.00	-0.05*	-0.04*	-0.07*	-0.40*	1		
KEPC	0.02*	0.10*	0.09*	-0.07*	0.03*	0.01	-0.03*	0.12*	0.08*	-0.01	0.02*	-0.01	0.02*	0.22*	-0.01	1	
HPI	-0.09*	-0.21*	-0.18*	0.03*	0.03*	0.04*	-0.00	0.04*	0.03*	-0.19*	-0.06*	0.02	-0.05*	-0.13*	0.12*	-0.08*	1

existing literature that larger private firms often rely more heavily on debt financing. CEO gender (CEO_GEN) is weakly correlated with most variables, consistent with the descriptive statistics showing that over 90% of CEOs are male. At the external environment level, some regional and industry-level indicators are associated with green innovation. For instance, KEPC shows stronger correlations with GCiteU and GCiteIU but less so with GCiteI, suggesting that utility model patents may be more responsive to local environmental regulatory pressure. Conversely, firms in heavily polluting industries (HPI) generally show negative correlations with all three citation measures, indicating that firms in traditionally high-polluting sectors are still relatively slow in adopting green innovation.

In sum, the correlation matrix reveals no excessive associations among key independent variables, alleviating concerns over multicollinearity. Additionally, control variables behave in economically consistent ways, lending further credibility to the empirical framework.

4.5 Main Empirical Results

4.5.1 Baseline Regression Results

4.5.1.1 Baseline Specification: Political-Connection Dummy

The following analysis employs Ordinary Least Squares (OLS) regression to examine the impact of CEO political connections on corporate green innovation. The dependent variable, Green Innovation, is measured using indicators of green patent quality: citations of invention patents (GCiteI), citations of utility model patents (GCiteU), and the sum of both (GCiteIU). All patent citation counts are measured with a two-year lead from the grant date to align with the typical maturation period of R&D investments leading to such outputs. These citation counts are then logarithmically transformed to mitigate the right-skewness of their distribution.

The core independent variables include CEO political connections (PC, a binary variable where 1 indicates political experience and 0 otherwise) and the political connection level (PCL, ranging from 0 to 10, capturing the CEO's highest administrative rank). Control variables include firm size (TA), profitability (ROA), leverage (D/A), firm age (AGE), market valuation (Q), industry concentration (HHI), proportion of independent directors (IND_DIR), CEO gender (CEO_GEN), CEO duality (DUAL), as well as regional characteristics such as provincial GDP per capita (PGDP) and the proportion of provincial fiscal expenditure on environmental protection (EPR). Industry fixed effects are included to absorb persistent cross-sector differences in technological opportunity, regulatory exposure, and baseline patenting intensity, while year fixed effects absorb economy-wide shocks and nationwide policy changes that affect all firms simultaneously. Conditional on these fixed effects and the set of firm-level, governance, and regional controls, the baseline specification reduces omitted-variable bias from sectoral heterogeneity and common time shocks. The regression model is specified as follows:

$$\begin{aligned} Green\ Innovation\left(GCite_{i,t+2}\right) \\ &= \beta_0 + \beta_1 Political\ Connections(PC_{i,t}, PCL_{i,t}) \\ &+ \beta_2 Control\_Variable_{i,t} + i.year + i.industry \\ &+ \varepsilon_{it} \end{aligned} \tag{4-1}$$

Table 4-4 presents the regression results for the effect of CEO political connections (PC) on green innovation, with green invention patent citations (GCiteI), green utility model patent citations (GCiteU), and their combined total (GCiteIU) serving as the dependent variables in respective columns. The results show that politically connected CEOs have a significantly positive impact on green invention patent citations (Column 1), and a positive and statistically significant effect at the 5% level on total green citations (Column 3). In contrast, the impact on utility model patent citations is not statistically significant (Column 2). This disparity suggests that political resources are more effective in promoting high-tech, long-cycle green invention activities, while their marginal contribution to lower-threshold utility model patents is limited. This aligns with the view that political connections facilitate access to high-end R&D subsidies, regulatory leniency, and knowledge networks.

Among the control variables, firm size (TA) shows a consistently strong and significant positive effect across all three models, confirming that larger firms possess greater resource advantages in environmental R&D and innovation. Profitability

Table 4-4. Baseline Regression Results: CEO Political Connections and Green Innovation

This table reports OLS regression results examining the relationship between CEO political connections (PC) and corporate green innovation. The dependent variables are the natural logarithms of forward citations for green invention patents (GCiteI), green utility model patents (GCiteU), and their sum (GCiteIU), each adjusted by a two-year lead. The key independent variable, PC, is a dummy variable equal to 1 if the CEO has political connections. Control variables are selected based on three dimensions: firm-level characteristics (i.e., total assets, ROA, D/A, firm age, and Tobin's Q, HHI), corporate governance factors (i.e., proportion of independent directors, CEO gender, and CEO duality), and regional context (provincial GDP per capita and environmental protection expenditure). All regressions include year and industry fixed effects. Standard errors are reported in parentheses. The full sample includes 10,588 firm-year observations from privately owned A-share listed firms in China's secondary industry sector between 2008 and 2021. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	(1) GCiteI	(2) GCiteU	(3) GCiteIU
PC	0.054***	0.030	0.056**
	(0.019)	(0.023)	(0.026)
TA	0.253***	0.393***	0.464***
	(0.008)	(0.010)	(0.011)
ROA	0.309***	0.733***	0.809***
	(0.088)	(0.109)	(0.121)
D/A	0.046*	0.234***	0.205***
	(0.027)	(0.034)	(0.038)
AGE	-0.031	-0.128***	-0.146***
	(0.021)	(0.026)	(0.029)
Q	0.029***	0.022***	0.032***
	(0.005)	(0.006)	(0.007)
HHI	0.086	-0.016	-0.165
	(0.187)	(0.233)	(0.259)
IND_DIR	0.386***	0.064	0.179
	(0.131)	(0.163)	(0.181)
CEO_GEN	0.038	-0.025	-0.006
	(0.027)	(0.034)	(0.037)
DUAL	0.029*	0.023	0.030
	(0.015)	(0.019)	(0.021)
PGDP	0.001	-0.121***	-0.082**
	(0.024)	(0.030)	(0.033)
EPR	-0.165	-0.862**	-0.866**
	(0.286)	(0.356)	(0.395)
Industry FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	10588	10588	10588
R-squared	0.196	0.312	0.309

(ROA) also positively contributes to green innovation, indicating that higher internal earnings and operational performance provide stronger financial support for environmental technology development. Leverage (D/A) likewise has a positive effect, suggesting that moderate debt levels may enhance access to external capital through financial leverage, thereby promoting green patent output. However, firm age (AGE) is negatively associated with green innovation in the utility model and combined patent models, indicating that older firms may suffer from organisational inertia or path dependence, making it harder for them to pivot towards emerging green technologies. The significant positive coefficient for Tobin's Q indicates that optimistic market expectations about a firm's future prospects may incentivize greater investment in green innovation. At the regional level, both provincial GDP per capita (PGDP) and the proportion of provincial environmental expenditure (EPR) exhibit a negative relationship with citations for utility model and combined green patent outputs. This suggests that in more economically developed regions or those with greater public environmental spending, corporate investment in 'low threshold' green patents might be partially rendered less necessary by stricter regulations or enhanced public governance. In contrast, no such negative relationship is observed with green invention patents (Column 1), underscoring the irreplaceable value of high-quality green innovation for firms in the face of institutional and regulatory constraints.

Overall, the results in Table 4-4 provide initial and compelling empirical evidence that political connections promote high-quality green innovation. These findings lay the groundwork for subsequent analyses involving the political connection level, local officials' promotion windows, and multiple robustness checks.

4.5.1.2 Alternative Specification: Political-Connection Level

Table 4-5 replaces the binary political connection indicator (PC) used in the baseline model with the CEO's political connection level (PCL) to examine whether higher past administrative ranks of the CEO exert a gradient effect on green innovation. The results show that PCL has a significantly positive effect on both green invention patent citations (Column 1) and the combined citation measure (Column 3), with coefficients of 0.010 in both models, significant at the 1% level. In contrast, the impact on utility model patent citations (Column 2) remains statistically insignificant. These findings are consistent with those in Table 4-4, which focused on the presence or absence of political ties, and further highlight the hierarchical nature of political resources: each

Table 4-5. Baseline Regression Results: CEO's Political Connection Level and Green Innovation

This table reports OLS regression results examining the relationship between the CEO's political connection level (PCL) and corporate green innovation. The dependent variables are the natural logarithms of forward citations for green invention patents (GCiteI), green utility model patents (GCiteU), and their sum (GCiteIU), each adjusted by a two-year lead. The key independent variable, PCL, is an index ranging from 0 to 10 that reflects the CEO's civil service rank during political tenure, with higher values indicating stronger political background. Control variables are selected based on three dimensions: firm-level characteristics, corporate governance factors, and regional context. All regressions include year and industry fixed effects. Standard errors are reported in parentheses. The full sample includes 10,588 firm-year observations from privately owned A-share listed firms in China's secondary industry sector between 2008 and 2021. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	(1) GCiteI	(2) GCiteU	(3) GCiteIU
PCL	0.010***	0.006	0.010***
	(0.003)	(0.003)	(0.004)
TA	0.252***	0.392***	0.463***
	(0.008)	(0.010)	(0.011)
ROA	0.308***	0.732***	0.808***
	(0.088)	(0.109)	(0.121)
D/A	0.047*	0.234***	0.205***
	(0.027)	(0.034)	(0.038)
AGE	-0.032	-0.129***	-0.146***
	(0.021)	(0.026)	(0.029)
Q	0.029***	0.022***	0.032***
	(0.005)	(0.006)	(0.007)
HHI	0.089	-0.014	-0.162
	(0.187)	(0.233)	(0.259)
IND_DIR	0.384***	0.062	0.176
	(0.131)	(0.163)	(0.181)
CEO_GEN	0.039	-0.024	-0.006
	(0.027)	(0.034)	(0.037)
DUAL	0.024	0.020	0.025
	(0.015)	(0.019)	(0.021)
PGDP	0.002	-0.120***	-0.080**
	(0.024)	(0.030)	(0.033)
EPR	-0.172	-0.866**	-0.873**
	(0.286)	(0.356)	(0.395)
Industry FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	10588	10588	10588
R-squared	0.196	0.312	0.310

incremental increase in the CEO's political rank is associated with a significant improvement in high-barrier green invention patent outputs, whereas the influence on more accessible utility model patents remains limited. The introduction of the PCL variable does not lead to a notable change in the model's overall R-squared. However, the observed gradient effect suggests that CEOs with higher-level political experience prior to their corporate roles enjoy stronger advantages in securing government subsidies, obtaining external research support, and communicating with regulatory bodies. These advantages more effectively drive long-term R&D investment and high-quality green patent strategies within the firm. The direction and significance of other control variables remain largely consistent with those in Table 4-4. The negative impacts of PGDP and EPR are observed only in the models for utility model patents and combined citations, which have relatively lower technological barriers. This implies that high-quality green inventions may be less susceptible to the 'crowding-out' effects of local public expenditure and economic structure. In summary, the findings in Table 4-5 further elaborate the linkage between political connections and green innovation: not only is the mere presence of a political background important, but also the higher the rank of these political resources, the more pronounced the firm’s innovation output in green R&D characterized by high technological barriers. This offers more compelling empirical evidence for the crucial role of the gradient effect of political connections in fostering green technological advancement.

4.5.2 Moderating Effects of Local Officials’ Promotion Incentives

4.5.2.1 Subsample Analysis by City Administrative Level

Before formally incorporating the interaction term between the officials' promotion window (PPW) and CEO political connections, the following analysis first classifies firms based on the administrative level of their headquarter city (CAL) and then estimates the impact of CEO political connections (particularly political connection level) on corporate green innovation through subsample regressions. This approach is motivated by two key considerations. First, significant disparities exist in the administrative hierarchy of Chinese cities. The ability of municipal governments to intervene in corporate behaviour and allocate public resources increases with administrative level (Landry, 2008). Second, the promotion window variable in this study applies exclusively to mayors at the Department/Bureau Level, which corresponds to quasi-sub-provincial and ordinary prefecture-level cities (i.e., CAL = 3 or 4). It is therefore necessary to distinguish city types prior to introducing the promotion window variable in order to avoid confounding effects arising from institutional heterogeneity across administrative levels.

Table 4-6 presents subgroup regression results based on CAL values (1 = provincial-level municipalities, 2 = sub-provincial cities, 3 or 4 = quasi-sub-provincial or ordinary prefecture-level cities), evaluating the effect of CEO political connection level (PCL) on green innovation. The regression specification remains consistent with previous models, with green invention patent citations (GCiteI) and green utility model patent citations (GCiteU) used as dependent variables. The results show that in higher-tier cities (CAL = 1 and 2, Columns 1–4), PCL has either a non-significant effect on both GCiteI and GCiteU. This suggests that in provincial-level municipalities or sub-provincial cities, where access to public resources and policy support is more institutionalized, CEOs' prior political experience may not offer substantial marginal benefits. However, in cities classified as CAL = 3 or 4 (Columns 5–6), PCL exhibits significantly positive coefficients for both GCiteI and GCiteU (significant at the 1% level). This implies that when firms are situated in quasi-sub-provincial or ordinary prefecture-level cities, CEOs with higher levels of political connections can more effectively leverage these ties to garner favourable treatment from local governments in areas such as environmental reviews, financial support, and resource allocation, thereby providing a stronger external impetus for green innovation.

This differentiation suggests that in provincial-level municipalities or sub-provincial cities, where higher-level governments exert more systematic control over corporate activities and where market and regulatory frameworks are more developed, firms' dependence on CEO political connections may be somewhat offset by these overarching institutional strengths. In contrast, within quasi-sub-provincial or ordinary prefecture-level cities, characterized by relatively lower administrative status, the administrative resources and policy networks previously cultivated by CEOs can yield more significant marginal advantages for corporate environmental innovation. This aligns with the real-world logic that 'the lower the administrative tier, the less developed the market and institutional frameworks, and thus the greater the corporate reliance on executives' political backgrounds. The control variables show broadly consistent patterns with previous analyses: firm size (TA) and profitability (ROA)

Table 4-6. Heterogeneous Effects of CEO's Political Connection Level by City Administrative Level

This table reports OLS regression results examining the heterogeneous effects of CEO political connection level (PCL) on corporate green innovation across cities with different administrative rankings. The dependent variables are the natural logarithms of forward citations for green invention patents (GCiteI) and green utility model patents (GCiteU), each adjusted by a two-year lead. The key independent variable, PCL, is an index ranging from 0 to 10 reflecting the CEO's civil service rank during political tenure. Columns (1)–(2) present results for firms headquartered in provincial-level municipalities (CAL = 1), columns (3)–(4) for sub-provincial cities (CAL = 2), and columns (5)–(6) for quasi-sub-provincial and ordinary prefecture-level cities (CAL = 3/4). All regressions control for firm-level characteristics, corporate governance factors, and regional context, and include year and industry fixed effects. Standard errors are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	CAL=1		CAL=2		CAL=3,4	
	(1) GCiteI	(2) GCiteU	(3) GCiteI	(4) GCiteU	(5) GCiteI	(6) GCiteU
PCL	0.008	0.010	0.003	-0.002	0.016***	0.013***
	(0.009)	(0.010)	(0.006)	(0.007)	(0.003)	(0.004)
TA	0.210***	0.300***	0.300***	0.468***	0.221***	0.356***
	(0.023)	(0.027)	(0.016)	(0.019)	(0.011)	(0.014)
ROA	0.415	1.208***	0.123	0.431**	0.449***	0.842***
	(0.265)	(0.308)	(0.165)	(0.199)	(0.115)	(0.148)
D/A	0.040	0.438***	-0.012	0.133***	0.127**	0.354***
	(0.114)	(0.132)	(0.040)	(0.049)	(0.053)	(0.069)
AGE	0.072	-0.202***	-0.085**	-0.183***	0.031	-0.067*
	(0.059)	(0.068)	(0.043)	(0.051)	(0.027)	(0.035)
Q	0.002	-0.022	0.040***	0.046***	0.031***	0.018**
	(0.012)	(0.014)	(0.009)	(0.010)	(0.007)	(0.009)
HHI	-0.096	0.330	0.119	-0.097	-0.032	-0.144
	(0.543)	(0.630)	(0.390)	(0.471)	(0.233)	(0.300)
IND_DIR	0.427	-0.363	0.847***	0.089	0.309*	0.332
	(0.345)	(0.400)	(0.263)	(0.318)	(0.166)	(0.214)
CEO_GEN	0.087	-0.019	0.055	-0.176**	0.020	0.036
	(0.067)	(0.077)	(0.057)	(0.069)	(0.034)	(0.044)
DUAL	-0.061	-0.009	0.096***	0.069*	-0.010	-0.022
	(0.039)	(0.045)	(0.030)	(0.036)	(0.020)	(0.026)
PGDP	0.030	-0.055	-0.084	-0.179*	-0.024	-0.104***
	(0.093)	(0.108)	(0.089)	(0.108)	(0.031)	(0.040)
EPR	3.140***	2.361*	-2.483**	-3.211**	-0.254	-0.568
	(1.079)	(1.251)	(1.230)	(1.486)	(0.311)	(0.400)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1493	1493	3259	3259	5836	5836
R-squared	0.292	0.422	0.250	0.354	0.185	0.295

generally have significantly positive effects on green patent output; leverage (D/A) is also positively associated in some specifications; firm age (AGE) shows negative effects in certain models, while Tobin's Q remains mostly positive. Other corporate governance and regional variables also behave as expected across different subgroups.

Overall, these results suggest the presence of significant interaction or stratification effects between executive political connections and city administrative level in shaping green innovation outcomes. This provides a strong rationale for further investigating the moderating role of local officials' promotion pressure as a dynamic institutional factor.

4.5.2.2 Interaction Effects of PCL and PPW

In the analysis presented in Table 4-7, the study sample is restricted to firms located in quasi-sub-provincial and ordinary prefecture-level cities (CAL=3 or 4), which are characterized by relatively lower administrative ranks. The regression models include the CEO's political connection level (PCL), the mayor's promotion window (PPW), and their interaction term (PCL × PPW) to investigate how local officials' promotion incentives interact with executive political resources to jointly influence firms' green innovation behaviour. Comparing Columns (1) and (2) with Columns (3) and (4) allows for a clearer understanding of how the interaction term functions across different types of green patents. The regression model is specified as follows:

$$\begin{aligned} Green\ Innovation\left(GCite_{i,t+2}\right) &= \beta_0 + \beta_1 PCL_{i,t} + \beta_2 PPW_{i,t} + \beta_3 PCL_{i,t} * PPW_{i,t} \\ &+ \beta_4 Control\_Variable_{i,t} + i.year + i.industry \\ &+ \varepsilon_{it} \end{aligned} \tag{4-2}$$

In the models without the interaction term (Columns 1 and 2), PCL continues to exhibit a significantly positive effect on both green invention patent citations (GCiteI) and green utility model patent citations (GCiteU), consistent with the findings in Table 4-6. Moreover, PPW has a weakly significant positive effect in the GCiteI regression, indicating that when mayors have stronger incentives to secure promotion, they may place greater weight on environmental and innovation-related performance in high-tech patent areas, thereby giving firms more policy support or stronger regulatory incentives. However, in the utility model regression (GCiteU), although the coefficient on PPW is positive, it does not reach conventional levels of statistical significance. This suggests that, on average and before taking CEO political connections into account, stronger promotion incentives for mayors do not on their own lead to a statistically significant increase in these lower-threshold green patents.

When the interaction term (PCL × PPW) is included (Columns 3 and 4), the coefficients and significance levels undergo notable changes. For green invention patents (Column 3), the coefficient on PCL changes from 0.015 (significant at 1%) to 0.003 (significant at 10%). In this specification, that coefficient captures the effect of PCL when the mayor is outside the promotion window (PPW = 0), that is, when the mayor is outside the key age range in which promotion is most likely for that career path. Similarly, PPW's coefficient decreases from 0.051 (significant at 10%) to 0.022 and becomes insignificant. Crucially, this coefficient for PPW in Column 3 now reflects its impact only when the CEO has no political connections (PCL = 0). For firms without CEO political connections, stronger incentives for the mayor to seek promotion do not, by themselves, significantly increase high-quality green innovation. However, the interaction term PCL × PPW is 0.022 and significant at the 5% level. This implies that the positive effect of CEO political connections on green invention patent citations becomes stronger when mayors have stronger incentives to secure promotion. Put differently, there is a complementary relationship between mayoral promotion incentives and CEO political background in driving high-quality green invention innovation. At the sample mean of PPW, the marginal effect of PCL on GCiteI is approximately $0.003 + 0.022 \times 0.549 \approx 0.015$, which is close to the estimate reported in Column 1.

In contrast, for green utility model patents (Column 4), PCL remains significantly positive at the 5% level (0.019), now representing its effect when PPW = 0. The coefficient on PPW is positive (0.055) but statistically insignificant, implying that for firms whose CEOs have no political connections (PCL = 0), stronger incentives for the mayor to seek promotion do not by themselves significantly increase green utility model patent citations. More importantly, the interaction term itself is negative (-0.014) but statistically insignificant. This indicates that, while CEO political background continues to enhance green utility model innovation, there is no evidence

Table 4-7. The Moderating Effect of Political Promotion Incentives

This table reports OLS regression results examining whether local officials' promotion-window intensity (PPW) moderates the relationship between CEO political connection level (PCL) and corporate green innovation. The dependent variables are the natural logarithms of forward citations for green invention patents (GCiteI) and green utility model patents (GCiteU), each adjusted by a two-year lead. PPW is a continuous route-specific age-intensity measure ranging from 0 to 1, with higher values indicating that the mayor's age is closer to the empirically most salient promotion stage for the relevant promotion route. Columns (1) and (2) include PCL and PPW as independent variables, while Columns (3) and (4) introduce the interaction term PCL × PPW to test for moderation. The analysis is restricted to firms located in quasi-sub-provincial and ordinary prefecture-level cities (CAL = 3, 4). All regressions control for firm-level characteristics, corporate governance factors, and regional context, and include year and industry fixed effects. Standard errors are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	CAL=3,4			
	(1)	(2)	(3)	(4)
	GCiteI	GCiteU	GCiteI	GCiteU
PCL	0.015***	0.012***	0.003*	0.019**
	(0.003)	(0.004)	(0.002)	(0.008)
PPW	0.051*	0.036	0.022	0.055
	(0.029)	(0.037)	(0.032)	(0.041)
PCL*PPW			0.022**	-0.014
			(0.010)	(0.013)
TA	0.226***	0.358***	0.226***	0.358***
	(0.012)	(0.015)	(0.012)	(0.015)
ROA	1.091***	1.709***	1.098***	1.704***
	(0.187)	(0.241)	(0.187)	(0.241)
D/A	0.137**	0.389***	0.136**	0.389***
	(0.061)	(0.079)	(0.061)	(0.079)
AGE	0.036	-0.060*	0.033	-0.058*
	(0.027)	(0.035)	(0.027)	(0.035)
Q	0.046***	0.019	0.046***	0.019
	(0.010)	(0.013)	(0.010)	(0.013)
HHI	-0.017	-0.121	-0.014	-0.123
	(0.232)	(0.300)	(0.232)	(0.300)
IND_DIR	0.312*	0.346	0.327**	0.337
	(0.166)	(0.214)	(0.166)	(0.214)
CEO_GEN	0.025	0.042	0.025	0.042
	(0.034)	(0.044)	(0.034)	(0.044)
DUAL	-0.009	-0.020	-0.010	-0.020
	(0.020)	(0.026)	(0.020)	(0.026)
PGDP	-0.024	-0.103**	-0.026	-0.102**
	(0.031)	(0.040)	(0.031)	(0.040)
EPR	-0.198	-0.451	-0.203	-0.448
	(0.310)	(0.400)	(0.310)	(0.400)
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	5836	5836	5836	5836
R-squared	0.188	0.295	0.188	0.295

that mayors' incentives to secure promotion systematically strengthen or weaken this effect. The lack of a significant interaction may imply that these lower-threshold or shorter-cycle green innovations are less dependent on the joint alignment of executive political capital and local political incentives.

Taken together, the models incorporating the interaction term reveal a clear distinction. For high-tech, long-cycle green invention patents (GCiteI), CEO political background and local officials' promotion incentives exhibit a positive and complementary relationship. In contrast, for lower-threshold green utility model patents (GCiteU), CEO political connection level remains positively associated with innovation output, but this relationship does not become significantly stronger or weaker when mayors have stronger incentives to secure promotion. This finding further suggests that the interplay between executive political capital and local political incentives is particularly important for more sophisticated forms of green innovation in lower-level administrative regions (CAL = 3, 4).

4.5.3 Heterogeneity Analysis

4.5.3.1 Key Environmental Protection Cities

When discussing regional heterogeneity in corporate green innovation, whether a firm is located in a nationally designated Key Environmental Protection City (KEPC) is a critical factor that cannot be overlooked. These cities typically feature stronger environmental regulation, greater fiscal support, and heightened public attention, which collectively impose more stringent compliance and innovation pressures on firms. At the same time, they may also provide more policy incentives for green technology projects, thus encouraging corporate investment in environmental R&D. To examine how CEO political connections perform under varying environmental regulatory conditions, this study divides the sample into KEPC=1 (Key Environmental Protection Cities) and KEPC=0 (Non-Key Environmental Protection Cities) and conducts regression estimations, with the results presented in Table 4-8.

According to Table 4-8, in key environmental protection cities (Columns 1 and 2), CEO political connection level (PCL) has a significantly positive effect on green invention patent citations (GCiteI), but no significant effect on green utility model citations (GCiteU). This finding is consistent with previous results emphasizing that political connections primarily manifest in the promotion of high-barrier, long-cycle green inventions. It suggests that in cities with stricter environmental regulation, CEOs with higher political ranks are more capable of mobilizing support for investments in technically sophisticated, long-term green inventions and translating them into substantive innovation. However, such political capital appears less effective in promoting “lightweight” innovations like utility model patents. In contrast, in non-key environmental cities (Columns 3 and 4), PCL does not have a statistically significant impact on invention patents but shows a positive effect on utility model patents at the 10% significance level. This finding implies that under more conventional environmental regulatory regimes, firms might be more inclined to choose green utility model technologies that are easier to implement, utilising the external resources derived from CEO political connections for their optimisation and application. For high-barrier invention patents, however, there may be an insufficient level of policy stringency and societal focus to adequately energize investment initiatives.

The role of CEO political connections in driving high-quality green innovation, particularly invention patents, remains a central finding; this effect is simply more pronounced in key environmental cities. In non-key cities, political connections may struggle to fully unleash firms' potential for advanced environmental R&D, possibly due to comparatively weaker regulatory pressure and less public attention. In summary, the subgroup regression results in Table 4-8 show that key environmental protection cities, due to their stricter policy mandates and higher public expectations, allow politically connected CEOs to obtain greater external support or preferential treatment in the environmental governance domain. This enhances their ability to drive green invention innovation. Conversely, in cities with relatively lenient regulatory environments, political connections are more likely to generate short-term returns through lightweight green patent activities. These findings further echo the differences in local government environmental management intensity and resource allocation, offering additional empirical evidence for the context-specific nature of the political connection-green innovation mechanism across regions.

Table 4-8. Heterogeneous Effects of CEO Political Connection: Key Environmental Protection Cities vs. Others

This table reports OLS regression results examining the heterogeneous effects of CEO political connection level (PCL) on corporate green innovation, comparing firms located in key environmental protection cities (KEPC = 1) versus those in other cities (KEPC = 0). The dependent variables are the natural logarithms of forward citations for green invention patents (GCiteI) and green utility model patents (GCiteU), each adjusted by a two-year lead. Columns (1) and (2) present results for key environmental protection cities, while columns (3) and (4) report results for non-key cities. All regressions control for firm-level characteristics, corporate governance factors, and regional context, and include year and industry fixed effects. Standard errors are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	KEPC=1		KEPC=0	
	(1)	(2)	(3)	(4)
	GCiteI	GCiteU	GCiteI	GCiteU
PCL	0.013***	0.005	0.006	0.009*
	(0.004)	(0.005)	(0.004)	(0.005)
TA	0.264***	0.420***	0.230***	0.347***
	(0.010)	(0.013)	(0.013)	(0.016)
ROA	0.426***	0.992***	0.229*	0.473***
	(0.122)	(0.157)	(0.129)	(0.152)
D/A	0.072*	0.425***	0.020	0.073
	(0.039)	(0.050)	(0.041)	(0.048)
AGE	-0.025	-0.141***	-0.007	-0.090**
	(0.029)	(0.037)	(0.032)	(0.037)
Q	0.027***	0.015**	0.039***	0.040***
	(0.006)	(0.008)	(0.009)	(0.011)
HHI	-0.047	-0.409	0.122	0.142
	(0.260)	(0.334)	(0.287)	(0.336)
IND_DIR	0.535***	-0.030	0.362*	0.298
	(0.168)	(0.215)	(0.210)	(0.247)
CEO_GEN	0.044	-0.090**	0.022	0.017
	(0.033)	(0.043)	(0.046)	(0.054)
DUAL	0.000	0.015	0.065**	0.039
	(0.019)	(0.024)	(0.026)	(0.030)
PGDP	-0.015	-0.139***	-0.003	-0.147**
	(0.028)	(0.036)	(0.050)	(0.059)
EPR	-0.245	-1.029**	-0.098	-1.132
	(0.323)	(0.415)	(0.633)	(0.743)
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	6447	6447	4141	4141
R-squared	0.224	0.350	0.190	0.269

4.5.3.2 Heavily Polluting Industries

To examine whether the stricter environmental regulations and heightened public scrutiny faced by heavily polluting industries amplify or weaken the effect of CEO political connections on corporate green innovation, this study further divides the sample based on industry characteristics into heavily polluting industries (HPI = 1) and non-heavily polluting industries (HPI = 0). Regression analyses are then conducted on these subsamples, with the findings reported in Table 4-9. Enterprises in heavily polluting industries typically encounter more rigorous emission standards and heightened supervisory pressures, rendering their need for environmental compliance and green technological advancements more pressing. In such contexts, CEOs with political connections might be better positioned to leverage advantages in resource coordination, navigating approval procedures, and securing government subsidies.

The regression results indicate that in heavily polluting industries (Columns 1 and 2), CEO political connection level (PCL) has a significantly positive effect (at the 5% level) on both green invention patent citations (GCiteI) and green utility model patent citations (GCiteU). In contrast, for firms in non-heavily polluting industries (Columns 3 and 4), PCL is positively and significantly associated with GCiteI (also at the 5% level), but has no statistically significant effect on GCiteU. This distinction suggests that in industries subject to higher regulatory and societal oversight, CEOs' prior political experience may broadly support corporate environmental technology strategies, enhancing both complex green invention activities and more application-oriented utility model innovations. By comparison, in sectors with relatively lighter environmental burdens, political connections still contribute positively to long-cycle, high-barrier green invention, but have a diminished impact on more accessible, short-term utility patents. In other words, when the industry itself is under intense environmental scrutiny, firms become more sensitive to external support derived from political connections, making them more likely to benefit from such resources across multiple layers of green innovation.

In addition, the control variables also exhibit differentiated patterns between the two industry groups. Notably, CEO-chair duality (DUAL) is significantly negatively associated with both GCiteI and GCiteU in heavily polluting industries, while showing a positive association in non-polluting industries. This could suggest that when confronted with stringent environmental mandates, CEO-Chairperson duality might undermine external oversight and specialized decision-making processes within heavily polluting firms, thereby somewhat impeding the internal drive for environmental technological advancement. In contrast, in less regulated sectors,

Table 4-9. Heterogeneous Effects of CEO Political Connection: Heavily Polluting vs. Non-Polluting Industries

This table reports OLS regression results examining the heterogeneous effects of CEO political connection level (PCL) on corporate green innovation across industry pollution intensity. The dependent variables are the natural logarithms of forward citations for green invention patents (GCiteI) and green utility model patents (GCiteU), each adjusted by a two-year lead. Columns (1) and (2) present results for firms operating in heavily polluting industries (HPI = 1), while columns (3) and (4) report results for firms in non-polluting industries (HPI = 0). All regressions control for firm-level characteristics, corporate governance factors, and regional context, and include year and industry fixed effects. Standard errors are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	HPI=1		HPI=0	
	(1)	(2)	(3)	(4)
	GCiteI	GCiteU	GCiteI	GCiteU
PCL	0.009**	0.009**	0.010**	0.003
	(0.004)	(0.004)	(0.004)	(0.005)
TA	0.144***	0.221***	0.315***	0.495***
	(0.011)	(0.013)	(0.011)	(0.014)
ROA	0.260**	0.479***	0.283**	0.741***
	(0.123)	(0.147)	(0.118)	(0.148)
D/A	0.072*	0.194***	0.016	0.194***
	(0.038)	(0.045)	(0.038)	(0.047)
AGE	-0.081***	-0.038	-0.001	-0.165***
	(0.029)	(0.035)	(0.028)	(0.036)
Q	0.013*	0.010	0.039***	0.026***
	(0.007)	(0.008)	(0.007)	(0.009)
HHI	-0.140	-0.021	0.030	-0.226
	(0.282)	(0.337)	(0.245)	(0.307)
IND_DIR	0.042	-0.140	0.607***	0.187
	(0.181)	(0.216)	(0.176)	(0.221)
CEO_GEN	0.032	0.071	0.036	-0.085*
	(0.038)	(0.046)	(0.036)	(0.045)
DUAL	-0.041*	-0.083***	0.057***	0.065**
	(0.021)	(0.026)	(0.020)	(0.025)
PGDP	0.052*	-0.130***	-0.040	-0.135***
	(0.030)	(0.036)	(0.034)	(0.043)
EPR	-0.425	-0.437	0.002	-1.797***
	(0.326)	(0.389)	(0.455)	(0.571)
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	3865	3865	6723	6723
R-squared	0.121	0.213	0.226	0.321

CEO-chair duality may enhance decision-making efficiency or facilitate resource integration, thus promoting environmental R&D. At the regional level, PGDP maintains a negative relationship in both industry groups, particularly in the utility model regressions. This reinforces previous findings that more developed regions may "crowd out" or substitute low-end green patents through public investments or higher regulatory thresholds.

Overall, this heterogeneity analysis indicates that the "green engine" effect of CEO political connections is more comprehensive in heavily polluting industries. Political ties not only accelerate the development of invention-type green technologies but also promote 'lightweight' innovation, helping firms cope with strict emission limits and high compliance costs to gain a competitive edge. This conclusion aligns with the main earlier finding that political resources predominantly bolster green innovations characterized by high technological barriers. Simultaneously, it underscores that industries exhibit significant differences in their degree of reliance on, and the specific focus of their need for, political connections when confronting environmental pressures.

4.6 Robustness Checks

Although the preceding regression analyses have incorporated a range of control variables and fixed effects, it remains difficult to fully rule out potential endogeneity concerns. To enhance the credibility of the findings, this section conducts multiple robustness checks. Specifically, it adopts an instrumental variable (IV) approach to address potential reverse causality, employs a two-step treatment effect model to account for firms' non-random appointment of politically connected CEOs, and replaces the original green patent citation metrics with the number of green patent grants to assess the consistency of results across different indicators. These complementary robustness checks provide a more comprehensive validation of the strength and direction of the effect of CEO political connections on corporate green innovation.

4.6.1 Reverse Causality Test: Instrumental Variable Approach

The baseline regression results presented earlier reveal a significantly positive relationship between CEO political connections and certain dimensions of green innovation. However, OLS regressions alone are insufficient to eliminate endogeneity concerns, particularly reverse causality. While it is possible that politically connected CEOs drive green innovation, it is also plausible that firms with a strategic emphasis on environmental innovation may be more inclined to hire CEOs with political connections, thereby introducing endogeneity bias. To more rigorously identify the causal effect of CEO political connections on corporate green innovation, this section employs the IV method to address this endogeneity issue.

This study uses a lagged size-based instrumental variable, IV_Size. Firms are grouped by total assets into small, medium, and large categories. Within each size group, the average CEO political connection level of all other firms, excluding the focal firm itself, is calculated and then lagged by one period. This instrument captures common appointment tendencies among firms of similar size, while remaining unlikely to directly affect any single firm's green innovation decisions. As such, it is expected to satisfy the relevance requirement and to provide plausibly exogenous variation in CEO political connection level. To further assess the plausibility of this identification assumption, a placebo test is also conducted using pre-period green innovation outcomes, namely GCiteI(t−1) and GCiteU(t−1), as dependent variables. If IV_Size directly reflected firms' underlying green innovation conditions or pre-existing innovation propensity, it would be expected to significantly predict these earlier outcomes as well.

Methodologically, the empirical strategy therefore combines placebo regressions with two-stage least squares (2SLS) estimation. The first-stage regression isolates the exogenous variation in the endogenous explanatory variable (CEO political connection level) that is attributable to the instrumental variable. The second-stage regression then uses this predicted component of CEO political connection level to estimate its effect on green innovation. Specifically:

First Stage:

$$\begin{aligned} PCL_{i,t} = \alpha_0 + \alpha_1 IV\_Size_{i,t-1} + \alpha_2 Control\_Variable_{i,t} + i.year \\ + i.industry + \varepsilon_{it} \end{aligned} \tag{4-3}$$

Where IV_Size is the lagged average political connection level of other firms in the same size group (small, medium, large), excluding the focal firm;

Control_Variables are the same as used previously; and industry and year fixed effects are included.

Second Stage:

$$GCite_{i,t+2} = \beta_0 + \beta_1 \widehat{PCL_{i,t}} + \beta_2 Control_{Variable_{i,t}} + i.year + i.industry + \varepsilon_{it} \tag{4-4}$$

Where $\widehat{PCL_{i,t}}$ is the fitted value from the first stage, and the dependent variable refers to either green invention patent citations (GCiteI) or green utility model citations (GCiteU).

Table 4-10 reports the estimation results obtained using this instrumental variable. Columns (1) and (2) first present the placebo regressions, where the dependent variables are pre-period green invention patent citations, GCiteI(t−1), and pre-period green utility model patent citations, GCiteU(t−1), respectively. The coefficients on IV_Size are statistically insignificant in both columns, indicating that the instrument does not significantly predict earlier green innovation outcomes. This placebo evidence reduces the concern that IV_Size merely captures firms' pre-existing green innovation conditions or an underlying innovation propensity, and therefore provides additional support for the plausibility of the exclusion restriction.

Column (3) reports the first-stage regression, in which CEO political connection level (PCL) is regressed on IV_Size and the full set of controls. The coefficient on IV_Size is -1.500 and statistically significant at the 1% level, indicating strong first-stage relevance. The Cragg–Donald Wald F-statistic is 22.469, providing further support for the relevance of the instrument. Columns (4) and (5) report the second-stage regressions, where GCiteI and GCiteU are the dependent variables, respectively. In Column (4), PCL retains a positive and statistically significant effect on GCiteI, with a coefficient of 0.278 at the 1% level. This result is consistent with the baseline findings and supports the interpretation that CEO political connections exert a causal effect on high-barrier, long-cycle green invention innovation. In Column (5), by contrast, the coefficient on PCL is negative but statistically insignificant (-0.062), again aligning with the earlier conclusion that the effect of political connections on green utility model innovation remains limited. Overall, after accounting for potential reverse causality and endogeneity, the positive effect of CEO political connections on

Table 4-10. Instrumental Variable Regression Results: CEO Political Connection and Green Innovation

This table reports the placebo and two-stage least squares (2SLS) regression results, using an instrumental variable (IV) strategy, to examine the causal effect of CEO political connection level (PCL) on corporate green innovation. The excluded instrument is IV_Size, defined as the lagged average political connection level of other firms in the same size group, excluding the focal firm. Columns (1) and (2) present placebo (falsification) regressions, where the dependent variables are the pre-period green invention patent citation measure GCiteI(t−1) and the pre-period green utility model patent citation measure GCiteU(t−1), respectively. Column (3) presents the first-stage regression using IV_Size to predict PCL. Columns (4) and (5) report the second-stage regressions using the predicted value of PCL to explain the natural logarithms of forward citations for green invention patents (GCiteI) and green utility model patents (GCiteU), each adjusted by a two-year lead. All regressions control for firm-level characteristics, corporate governance factors, and regional context, and include industry and year fixed effects. In Column (3), the reported F-statistic is the Cragg–Donald Wald F-statistic. Standard errors are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. The Cragg–Donald F-statistic is reported as a weak-instrument diagnostic for the first stage.

	Placebo(1) GCiteI(t-1)	Placebo(2) GCiteU(t-1)	(3) PCL	(4) GCiteI	(5) GCiteU
IV_Size	-0.126	0.193	-1.500***		
	(0.147)	(0.127)	(0.252)		
PCL				0.278***	-0.062
				(0.066)	(0.061)
TA	0.528***	0.395***	0.261***	0.211***	0.404***
	(0.023)	(0.020)	(0.040)	(0.017)	(0.016)
ROA	-0.262	0.707***	0.169	0.844***	1.950***
	(0.309)	(0.267)	(0.563)	(0.221)	(0.207)
D/A	0.029	0.548***	-0.343*	0.187**	0.458***
	(0.103)	(0.089)	(0.179)	(0.073)	(0.068)
AGE	-0.069	-0.183***	-0.058	-0.022	-0.141***
	(0.052)	(0.045)	(0.085)	(0.033)	(0.031)
Q	0.071***	0.036**	-0.110***	0.067***	0.014
	(0.017)	(0.014)	(0.030)	(0.014)	(0.013)
HHI	-0.731	-0.347	-2.129**	0.672*	-0.111
	(0.597)	(0.516)	(0.846)	(0.353)	(0.331)
IND_DIR	0.605**	-0.089	1.357***	0.033	0.115
	(0.280)	(0.242)	(0.498)	(0.215)	(0.201)
CEO_GEN	0.012	-0.090*	-0.248**	0.111**	-0.045
	(0.059)	(0.051)	(0.103)	(0.044)	(0.041)
DUAL	0.088***	0.006	1.511***	-0.378***	0.132
	(0.032)	(0.028)	(0.056)	(0.102)	(0.095)
PGDP	0.049	-0.096**	-0.575***	0.170***	-0.157***
	(0.051)	(0.044)	(0.091)	(0.052)	(0.048)
EPR	-0.038	-0.645	-0.294	0.152	-0.628
	(0.656)	(0.567)	(1.094)	(0.428)	(0.400)
Industry FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	5586	5586	8838	8838	8838
R-squared	0.220	0.319		0.121	0.306
F	0.734	2.296	22.469	25.842	65.466

green invention innovation remains robust, whereas the corresponding effect on green utility model patents continues to be statistically weak.

In summary, the results from the instrumental variable approach indicate that the positive effect of CEO political connections on green invention patents is unlikely to be an endogenous outcome driven solely by firms with a pre-existing preference for green innovation choosing politically connected CEOs. The placebo results further show that IV_Size does not significantly explain pre-period green innovation outcomes, which strengthens the plausibility of the exclusion restriction underlying the IV design. Rather, the IV estimates reinforce the view that CEO political connections play a substantive causal role in facilitating high-quality green innovation.

4.6.2 Self-Selection Bias: Two-Step Treatment Effect Model

To further address the concern that the potential self-selection bias in the appointment of politically connected CEOs, this section employs a two-step treatment effect model. Firms with stronger unobservable preferences for government ties, policy access, or strategic green transformation may be more likely to appoint politically connected CEOs in the first place. If such endogenous treatment assignment is ignored, the estimated effect of CEO political connections on green innovation may be biased. The treatment effect model addresses this concern by first estimating the probability that a firm appoints a politically connected CEO and then incorporating the resulting inverse Mills ratio (IMR) into the second-stage green innovation regression. This procedure accounts for non-random treatment assignment and allows the estimated effect of political connections to be separated from firms' self-selection into politically connected leadership.

Because the treatment equation concerns the appointment decision itself, this robustness check is implemented using the binary indicator PC rather than the rank-based measure PCL. The purpose is to model whether a firm appoints a politically connected CEO at all, and then to assess whether selection into such appointments materially affects the baseline conclusions. To identify the first-stage treatment equation, this study uses one exclusion restriction variable: DIST_BJ, defined as the natural logarithm of the geographic distance between the firm's headquarters and

Beijing, calculated from latitude and longitude coordinates. DIST_BJ is theoretically well suited to the CEO appointment decision in the Chinese institutional context. Beijing is the national political centre, where core policy information, regulatory signals, and high-level political resources are concentrated. Greater distance from Beijing increases the spatial and relational costs of accessing such resources, thereby strengthening firms' incentives to appoint CEOs with political experience in order to mitigate these disadvantages. At the same time, DIST_BJ is determined by the geographic location of the firm's headquarters rather than by the firm's contemporaneous green innovation choices. It is a pre-existing spatial characteristic rather than an outcome of the firm's current innovation strategy and cannot be driven by short-run fluctuations in patent output or patent quality. Moreover, the empirical specification already controls for firm-level characteristics, corporate governance factors, regional context, and industry and year fixed effects. Conditional on these controls, DIST_BJ influences green innovation only through its effect on the likelihood of appointing a politically connected CEO, rather than through a direct channel. DIST_BJ therefore satisfies the exclusion restriction required for identification in the treatment equation.

The first stage is the treatment equation, estimated using a probit model to determine the probability that a firm appoints a politically connected CEO (PC). The inverse Mills ratio (IMR) is then calculated from the probit model and incorporated into the second-stage regression to adjust for non-random treatment assignment. The probit model can be formally specified as follows:

$$\Pr\left(PC_{i,t} = 1\right) = \Phi(\alpha_0 + \alpha_1 DIST\_BJ_{i,t} + \alpha_2 X_i + \varepsilon_i) \tag{4-5}$$

In the second stage, the inverse Mills ratio (IMR) obtained from the first stage is included in the OLS regression:

$$\begin{aligned} GCite_{i,t+2} = \beta_0 + \beta_1 PC_{i,t} + \beta_2 Contral\ Variables_{i,t} + \beta_3 IMR_i \\ + i.year + i.industry + \mu_{it} \end{aligned} \tag{4-6}$$

Table 4-11, Column (1) presents the probit treatment equation, in which DIST_BJ is used as the exclusion restriction to explain the likelihood that a firm

Table 4-11. Two-Step Treatment Effect Model: CEO Political Connections and Green Innovation

This table reports results from a two-step treatment effect model to address potential self-selection bias in estimating the impact of CEO political connections (PC) on corporate green innovation. Column (1) reports the first-stage probit treatment equation, where the likelihood of appointing a politically connected CEO is modelled as a function of the exclusion restriction variable DIST_BJ, defined as the natural logarithm of the geographic distance from the firm's headquarters to Beijing. Columns (2) and (3) display the second-stage OLS outcome equations, where the dependent variables are the natural logarithms of forward citations for green invention patents (GCiteI) and green utility model patents (GCiteU), each adjusted by a two-year lead. The inverse Mills ratio (IMR) calculated from the first-stage treatment equation is included to adjust for non-random treatment assignment. All regressions control for firm-level characteristics, corporate governance factors, and regional context, and include industry and year fixed effects. Standard errors are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	First-stage	Second-stage (OLS)	
	(1)	(2)	(3)
	Probit	GCiteI	GCiteU
DIST_BJ	0.051***		
	(0.013)		
PC		1.203**	0.075
		(0.516)	(0.517)
IMR		-0.715**	-0.023
		(0.291)	(0.291)
TA	-0.010	0.315***	0.402***
	(0.017)	(0.012)	(0.012)
ROA	0.413	1.303***	1.833***
	(0.310)	(0.201)	(0.201)
D/A	-0.168*	0.047	0.420***
	(0.094)	(0.064)	(0.064)
AGE	-0.161***	-0.093**	-0.136***
	(0.038)	(0.036)	(0.036)
Q	-0.071***	0.037**	0.023
	(0.015)	(0.014)	(0.014)
HHI	-0.048	0.153	0.113
	(0.165)	(0.243)	(0.243)
IND_DIR	1.150***	0.894***	0.077
	(0.259)	(0.236)	(0.237)
CEO_GEN		0.042	-0.037
		(0.035)	(0.035)
DUAL		0.047**	0.025
		(0.020)	(0.020)
PGDP		-0.017	-0.127***
		(0.033)	(0.033)
EPR		-0.496	-0.875**
		(0.384)	(0.385)
Industry FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	10588	10588	10588
R-squared		0.202	0.308

appoints a politically connected CEO (PC). The coefficient on DIST_BJ is 0.051 and statistically significant at the 1% level, indicating that firms located farther from Beijing are more likely to appoint CEOs with political backgrounds. This result is consistent with the theoretical expectation that greater geographic distance from the national political centre increases firms' incentives to rely on politically connected executives to compensate for weaker direct access to policy information, regulatory signals, and political resources. As such, the first-stage evidence provides strong support for the use of DIST_BJ as the exogenous determinant in the treatment equation. Columns (2) and (3) report the second-stage OLS outcome equations for green invention patent citations (GCiteI) and green utility model patent citations (GCiteU), respectively, after adjusting for non-random treatment assignment. In Column (2), the coefficient on PC is 1.203 and statistically significant at the 5% level, indicating that the appointment of a politically connected CEO remains positively associated with green invention innovation after correcting for endogenous treatment assignment. By contrast, in Column (3), the coefficient on PC is 0.075 and statistically insignificant, suggesting that politically connected CEOs do not exert a meaningful effect on green utility model innovation. These findings remain broadly consistent with the earlier OLS and IV results, in that CEO political connections matter primarily for higher-barrier and more substantive green invention activities, whereas their effect on lower-threshold utility model innovation is limited.

Overall, after accounting for firms' endogenous appointment of politically connected CEOs through the two-step treatment effect model, the core conclusion of this study remains intact: political connections contribute to high-quality green invention innovation, while their influence on green utility model innovation is weak. Therefore, although self-selection is present in the treatment assignment process, it does not fundamentally confound the main findings.

4.6.3 Alternative Measures of Green Innovation

In the baseline models and a series of robustness checks presented earlier, this study primarily used green patent citation counts as the main indicator for measuring corporate green innovation. However, patent citations are not the sole method for

Table 4-12. Robustness Check Using Alternative Green Innovation Measures

This table reports robustness checks using alternative measures of corporate green innovation. The dependent variables in columns (1)–(3) are the natural logarithms of the number of granted green invention patents (GPatI), green utility model patents (GPatU), and their sum (GPatIU), each adjusted by a two-year lead. The key independent variable is PCL, an index ranging from 0 to 10 that reflects the CEO's political connection level based on civil service rank during political tenure. All regressions control for firm-level characteristics, corporate governance factors, and regional context, and include industry and year fixed effects. Standard errors are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)
	GPatI	GPatU	GPatIU
PCL	0.008***	0.005	0.009**
	(0.002)	(0.003)	(0.004)
TA	0.212***	0.367***	0.422***
	(0.007)	(0.010)	(0.010)
ROA	0.259***	0.690***	0.752***
	(0.071)	(0.103)	(0.110)
D/A	0.063***	0.235***	0.224***
	(0.022)	(0.032)	(0.034)
AGE	-0.032*	-0.122***	-0.142***
	(0.017)	(0.025)	(0.026)
Q	0.023***	0.020***	0.027***
	(0.004)	(0.006)	(0.006)
HHI	0.106	-0.045	-0.120
	(0.151)	(0.219)	(0.234)
IND_DIR	0.310***	0.002	0.096
	(0.105)	(0.153)	(0.164)
CEO_GEN	0.030	-0.019	-0.006
	(0.022)	(0.032)	(0.034)
DUAL	0.017	0.014	0.015
	(0.012)	(0.018)	(0.019)
PGDP	0.004	-0.123***	-0.083***
	(0.019)	(0.028)	(0.030)
EPR	-0.153	-0.861**	-0.807**
	(0.230)	(0.335)	(0.358)
Industry FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	10588	10588	10588
R-squared	0.203	0.316	0.322

capturing innovation outcomes, particularly in certain technological fields or for short-term research cycles, where citations may be subject to time lags or limitations due to external factors. To further test the generalisability and robustness of the findings, this section adopts the number of green patent grants as the alternative dependent variable. Specifically, it examines green invention patent grants (GPatI), green utility model grants (GPatU), and their combined total (GPatIU) to assess whether the relationship between CEO political connections and green innovation remains consistent when assessed using this different metric.

Table 4-12 reports the regression results using these alternative outcome variables. Column (1) uses GPatI as the dependent variable, while Columns (2) and (3) examine GPatU and GPatIU, respectively. The coefficients show that CEO political connection level (PCL) has a significantly positive effect at the 1% or 5% level in the invention and combined patent models (Columns 1 and 3), but is statistically insignificant in the utility model regression (Column 2). These findings are highly consistent with earlier analyses based on citation data. This pattern indicates that CEOs with political backgrounds are more strongly associated with high-tech, long-cycle green invention output than with lower-threshold green utility model innovation. Overall, the regression results using green patent grant counts as an alternative measure are consistent with the main findings based on citation data. This further confirms that CEO political connections significantly promote green invention innovation, reinforcing their crucial role in shaping firms' strategies for high-end, long-term environmental technology development.

4.7 Conclusion

This study systematically investigates the impact and underlying mechanisms of CEO political connections on corporate green innovation, using data from Chinese A-share listed private firms from 2008 to 2021. The baseline regression results show that CEOs with higher levels of political connections significantly enhance firms' innovation output in green invention patents, which are characterized by high technological and institutional barriers, while the effect on utility model patents is relatively insignificant. This discrepancy suggests that political connections primarily provide firms with long-term R&D funding, policy communication channels, and administrative conveniences, thereby facilitating breakthroughs in environmentally demanding areas such as clean energy, energy conservation, and pollution control. Building on this foundation, this study conducts a series of heterogeneity analyses to explore the scope and marginal effects of political connections under different external contexts. By categorizing cities into direct-administered municipalities, sub-provincial cities, quasi-sub-provincial cities, and ordinary prefecture-level cities, the study finds that the positive effect of political connections on green innovation is especially pronounced in quasi-sub-provincial and ordinary prefecture-level cities. In contrast, in municipalities and sub-provincial cities, where firms already have relatively easier access to administrative resources and policy support channels, the added value brought by politically connected CEOs is comparatively limited. Further distinguishing between key environmental protection cities and others, this study finds that CEO political connections exert a stronger positive effect on high-tech green innovation in key cities, where stricter environmental regulations and more comprehensive green industrial policies create synergistic effects. In non-key cities, political connections are less effective in driving advanced green innovation but still offer moderate support for lower-barrier environmental innovations. A comparison between high-polluting and non-high-polluting industries reveals that political connections provide more comprehensive incentives for green innovation in high-polluting firms. These connections contribute both to technological upgrades in invention patents and to moderate improvements in utility model patents. In contrast, non-high-polluting industries focus more on deep-level innovation driven by invention patents. To ensure the robustness of these findings, the study also addresses potential endogeneity and non-random CEO appointment through multiple approaches. Using a lagged size-based instrumental variable together with placebo tests, this study shows that the positive effect of political connections on high-barrier green invention innovation is not driven by reverse causality or pre-existing innovation conditions. A two-step treatment effect model is also employed to account for potential self-selection in firms' appointment of politically connected CEOs.

It is important to emphasise that this study also specifically considered the promotion window of local government officials to identify how mayors' career incentives influence the relationship between CEO political connections and corporate green innovation. The results indicate that in quasi-sub-provincial and ordinary prefecture-level cities, the positive relationship between CEO political connections and high-barrier green invention patent output becomes significantly stronger when mayors have stronger incentives to secure promotion. On the one hand, mayors who are under stronger pressure to secure promotion are more likely to pursue visible achievements in environmental governance; on the other hand, CEOs with prior political backgrounds can mobilise resources from government departments more effectively. This synergy creates a 'demand for political achievements meets resource mobilisation' dynamic, allowing firms to secure greater facilitation or policy support for green invention patents, which are typically characterized by high R&D costs and substantial technological content. In contrast, the impact on utility model patents is relatively independent; mayoral promotion pressure and CEO political connections do not generate additional impetus for this type of innovation. Overall, CEOs possessing stronger political connections can utilise their well-developed policy communication and resource coordination skills to play a pivotal role in advancing corporate green innovation, especially concerning invention patents that require high technological capabilities and long-term R&D investment. This effect of political connections is particularly strong when mayors face stronger incentives to secure promotion. Conversely, the influence on green utility model patents, which typically involve lower technological thresholds and shorter development cycles, is considerably more restricted.

Aligning with current green trends and the emphasis on social responsibility, this study attempts to examine the impact of CEO political connections on corporate green innovation from a more comprehensive perspective, specifically identifying the direction in which political connections drive corporate green innovation. Second, by systematically examining the moderating effects of multiple contextual factors, this research significantly enriches the contingency theory of the value of political connections. These findings collectively reveal that political connections are not universally effective; their driving force for corporate green strategy is deeply embedded in local administrative hierarchies, environmental governance intensity, and industry characteristics. This provides more nuanced empirical evidence and theoretical explanations for understanding how firms utilise political networks to implement their green strategies in different institutional and market environments. A key innovative aspect is that this study attempts to integrate the promotion incentive mechanisms of local officials into the analytical framework of CEO political connections and corporate green innovation. Existing literature often studies officials' behaviour, government-business relations, or drivers of green innovation in isolation.

By integrating these three areas, this study reveals how local officials' promotion pressure, by amplifying the resource mobilisation capabilities associated with CEO political connections, significantly promotes firms' breakthroughs in the high-risk, high-investment field of green invention patents. This finding offers a novel mechanistic explanation for how macroeconomic political incentives are transmitted to micro-level corporate environmental behaviour in a transitional economy. In summary, by focusing on the heterogeneity of green innovation, examining diverse contextual factors, and integrating the perspective of officials' promotion incentives, this study provides important theoretical insights and empirical evidence for understanding the complex mechanisms through which political connections promote corporate sustainable development.

It must be acknowledged that this study still has several limitations. Although the study rigorously differentiated between the level of CEO political connections and the binary distinction of having a political background, it was unable to definitively ascertain whether an individual's political status was acquired prior to or subsequent to their corporate appointment. For instance, while holding a representative position in the People's Congress or the Chinese People's Political Consultative Conference, sometimes attained by executives from prominent firms, can confer political advantages, this differs from political advantages established before joining the firm. This study did not exclude or separately analyse such cases, which might introduce some ambiguity regarding the precise timing of political resource accumulation. Furthermore, the identification of local officials’ promotion incentives in this study was derived primarily from age-based career patterns documented in the literature. Although this follows the mainstream practice in existing literature and provides a tractable proxy for officials’ promotion incentives, it cannot exhaustively cover other considerations in the officials' promotion process, such as factional ties, diversified performance indicators for tenure assessment, and personal professional backgrounds. Therefore, future research, contingent on data availability, could more precisely define the timing of CEO political connection formation and more broadly incorporate multiple dimensions of local officials' selection systems. This would allow for a more comprehensive institutional context in which to assess the dual impacts of political connections and performance incentives on corporate green innovation.

In conclusion, by adopting a multi-dimensional measurement of green patent output and incorporating the interaction effects of CEO political connections and local officials' incentives to secure promotion, this study offers a systematic explanation of how private enterprises can pursue more advanced and valuable green innovation under the joint influence of institutional environment and political factors. Future research could extend this analysis to larger samples or cross-national contexts, or introduce dynamic tracking of corporate internal governance and innovation investment structures at the micro level. Such extensions would help capture the complex interplay between political connections and sustainable development more precisely and provide richer policy and managerial implications.

Chapter 5
General Conclusion

5.1 Recap of Thesis Aim and Scope

This thesis focuses on China, a globally prominent transitional economy, and aims to systematically investigate several key drivers influencing corporate innovation output, including both general and green innovation. Specifically, through three independent empirical studies, this thesis provides an in-depth analysis of the complex effects of these factors on the innovation output of Chinese listed companies from multiple dimensions: the personal traits of senior executives (CEO overconfidence), internal incentive mechanisms (equity incentives), and the interplay between corporate political connections and local officials' promotion incentives.

5.2 Summary of Main Findings

Chapter Two focuses on the behavioural biases of senior executives, exploring the mechanisms through which CEO overconfidence affects corporate innovation. The study finds that, in the Chinese context, CEO overconfidence is positively associated with subsequent corporate technological innovation outcomes, as reflected in higher patent citation performance for invention patents, utility model patents, and their aggregate measure. This positive association is particularly pronounced in state-owned enterprises (SOEs), suggesting that the institutional and resource environment of SOEs may facilitate the translation of managerial overconfidence into observable innovation outcomes. However, the moderating role of power concentration is not uniform across patent types. Although CEO duality is itself positively associated with several innovation outcomes, there is no robust evidence that it systematically weakens the innovation effect of CEO overconfidence; rather, the interaction is mainly concentrated in utility model patent citations, while the corresponding effects for invention patents and the aggregate citation measure are not statistically significant. An important contribution of this study is that, drawing on the identification logic of the mainstream Holder 67 approach while adapting it to the Chinese market context, it develops a holdings-based revealed-beliefs proxy of CEO overconfidence. Specifically, the measure combines stockholding concentration, a normative portfolio-choice benchmark, a China-specific expected-return benchmark, and repeated non-selling behaviour, thereby addressing the limited applicability of traditional option-exercise-based measures in China's data environment. Additional analyses further show that the main conclusion remains robust when corporate innovation is alternatively measured by R&D intensity and granted patents, and when CEO overconfidence is proxied by earnings forecast bias. In this respect, the chapter not only strengthens the credibility of the empirical evidence but also extends the local applicability of behavioural-finance research on the relationship between executive psychological bias and corporate decision-making.

Chapter Three analyses the impact of equity incentive mechanisms on corporate innovation behaviour. Drawing on the heterogeneity of different incentive tools, incentive recipients, and firm types, the study finds a significant positive association between equity incentives and corporate innovation output among Chinese A-share listed companies. Whether measured by plan adoption or by incentive intensity, equity incentives are positively associated with patent citations, patent grants, and R&D investment. Both option-based incentives tied to stock price appreciation and restricted stock oriented towards direct ownership are linked to improved innovation outcomes. However, in terms of higher-value innovation, instruments more closely linked to stock price growth, including stock options and stock appreciation rights, exhibit a more pronounced association with invention patent performance, whereas restricted stock remains positively associated with utility model patent outcomes. Moreover, the incentive effects for core technical and business personnel are significantly stronger than those for senior executives, suggesting that greater attention should be paid to the crucial role of frontline technical teams in the design of incentive mechanisms. Regarding firm characteristics, non-SOEs and technology-intensive firms are more responsive to incentives, indicating the differentiated impact of ownership structure and industry background on incentive effectiveness. In terms of empirical identification, the study combines matched comparisons, a size-based instrumental-variable design for incentive intensity, and a cohort-stacked PSM-DID analysis around the first observable adoption of equity incentive plans. The consistency of the results across these complementary designs further strengthens the conclusion that equity incentives are closely related to subsequent corporate innovation in the Chinese market.

Chapter Four further extends the institutional environment perspective, examining the mechanisms by which CEO political connections drive corporate green innovation. It innovatively introduces local officials' promotion incentives as a moderating variable, analysing how political incentives interact with corporate non-market resources to jointly affect green technological innovation behaviour. The research finds that, among privately-owned enterprises, CEOs with higher levels of political connections can drive breakthroughs in high-quality green invention patents, whereas the corresponding effect on green utility model patents is comparatively limited. This positive relationship becomes stronger as the level of political connection increases and is especially pronounced in quasi-sub-provincial and ordinary prefecture-level cities. Conversely, in municipalities directly under the central government and sub-provincial cities, where channels for accessing policy resources are already relatively unobstructed, the marginal value of political connections is somewhat weaker. In addition to variations across different administrative levels of cities, the positive impact of political connections is more pronounced in regions with stricter environmental regulations and in highly polluting industries, indicating that the value of political ties is contingent upon local governance pressure and industrial context. More importantly, the study shows that in quasi-sub-provincial and ordinary prefecture-level cities, stronger promotion-window intensity among local officials significantly amplifies the positive relationship between CEO political connections and green invention patent output, thereby forming a linked mechanism of "demand for political achievements meets resource mobilisation". By contrast, mayoral promotion pressure and CEO political connections do not appear to generate additional impetus for green utility model patents. These findings remain broadly consistent after addressing potential endogeneity and self-select CEO appointment. In this sense, the chapter integrates the incentive mechanisms of local politics into the research framework of green innovation from a corporate finance perspective, offering a clearer mechanistic explanation of how macro-level political incentives are transmitted to micro-level corporate environmental behaviour in a transitional economy.

5.3 Integrated Discussion and Synthesis of Findings

In summary, this thesis enriches the theoretical literature on corporate innovation behaviour in emerging market economies, particularly with regard to how innovation is shaped by the interplay of government and market, institutions and strategy, and individuals and organisations. With respect to upper echelons theory, the localised measurement of CEO overconfidence through a holdings-based revealed-beliefs proxy, together with the differentiated analysis of its innovation consequences across ownership and governance settings, deepens the understanding of how managerial beliefs and behavioural biases shape corporate strategy. In terms of agency theory and incentive theory, the long-span and fine-grained examination of equity incentive practices in China, combined with multiple complementary identification strategies, provides empirical evidence from a major emerging market for the theory on the relationship between long-term compensation design and innovation. Regarding resource dependence theory and institutional theory, by revealing the differentiated impact of CEO political connections on different forms of green innovation, and particularly by integrating the political economy perspective of local officials' promotion-window intensity, this research opens new avenues for understanding the interplay between government-business relations, institutional pressures, and corporate sustainable development strategies. The findings of this thesis consistently indicate that whether the focus is on executive beliefs, internal incentive mechanisms, or external political embeddedness, their effects on corporate innovation are not monolithic, but are highly contingent upon ownership structure, governance arrangements, industry characteristics, innovation type, and the broader institutional and policy environment. These findings engage in an effective dialogue with established theories such as upper echelons theory, agency theory, resource dependence theory, and institutional theory, while also testing and extending the applicability boundaries of these theories in transitional economies. Furthermore, the explorations undertaken in this thesis regarding the localised measurement of key variables, such as the holdings-based proxy of CEO overconfidence and the operationalisation of officials' promotion-window intensity, and the identification of complex empirical relationships can offer valuable methodological references for future research.

5.4 Overall Limitations of the Research

Although this thesis strives for rigour, it inevitably has some limitations, which future research could seek to address. First, the three studies are primarily based on Chinese A-share listed companies, with the analysis of political connections further focusing on private listed enterprises. This means that the generalisability of the research conclusions to non-listed companies requires further examination, particularly for small and medium-sized enterprises (SMEs), younger high-tech entrepreneurial firms, and other innovative firms outside the capital market, which may exhibit markedly different governance structures, financing channels, managerial discretion, and talent-incentive needs. This limitation is especially relevant to the study of equity incentives, where the proportion of firms implementing such plans remains relatively low within the listed-company sample and where equity-based compensation may play a more salient role in attracting, retaining, and motivating innovative employees in younger private firms than in mature listed companies. Future research could therefore extend the sample to include non-listed firms, firms from alternative trading and financing platforms such as the National Equities Exchange and Quotations, and cross-market comparative settings, so as to examine the external validity of the findings more systematically. A study on European SMEs by Salimi and Della Torre (2021) confirmed that adopting collective equity incentives, such as profit-sharing or employee stock ownership plans, can significantly enhance corporate innovation capability by fostering internal cooperation and knowledge sharing. The applicability of such mechanisms in the context of China's SME sector represents a promising avenue for future research.

Second, challenges persist in the measurement of key variables. More broadly, while this thesis operationalises corporate innovation primarily through patent-based outcomes such as patent forward citations and patent grants, these indicators inevitably emphasise codified and patentable outputs and may not fully capture the breadth of innovative activities. Future research could complement the current analyses by introducing a framework that jointly considers innovation inputs and patent-based outcomes, thereby allowing a more direct evaluation of how efficiently firms translate innovation resources into innovative outputs. This thesis operationalises CEO overconfidence through a holdings-based revealed-beliefs proxy rather than a direct replication of the original option-exercise measure, because detailed executive option grant, vesting, exercise, and moneyness data are not sufficiently complete or continuously observable for long-horizon analysis in the Chinese setting. Although the proxy is designed to preserve the identification spirit of Malmendier and Tate (2005a) by combining a normative portfolio benchmark, a China-specific expected-return benchmark, and repeated non-selling behaviour, the quantification of managerial psychological traits remains inherently difficult. In particular, the measure still relies on maintained assumptions about risk aversion and outside wealth and may therefore be subject to calibration error. Moreover, persistent non-reduction of company stock may reflect not only optimistic beliefs, but also other motives or constraints, such as control considerations, trading restrictions, liquidity needs, or compensation design. The measure should therefore be interpreted as a revealed-beliefs proxy for persistent firm-specific over-optimism rather than as a direct observation of managerial psychology. Future research could further enhance measurement reliability and validity by incorporating more objective and multidimensional data sources. Hatoum et al. (2022), for example, proposed a new overconfidence indicator constructed from field research and cognitive bias questionnaires, which enhances the empirical explanatory power of psychological trait variables by linking behavioural experiments with corporate decision-making outcomes. Meanwhile, the rise of Large Language Models (LLMs) is opening up a new technological frontier for the measurement of behavioural finance variables. Recent studies have begun to demonstrate the powerful ability of LLMs to accurately capture market sentiment and behavioural signals from unstructured text. Zhuang et al. (2025) innovatively constructed a two-stage LLM framework: first, leveraging the in-context learning capability of GPT-4 to generate 'weak labels' for a vast number of stock forum comments, and subsequently using these labels to fine-tune a more efficient open-source model, LLaMA. Through this method, they successfully extracted investor sentiment from noisy online discussions and constructed a comprehensive sentiment index comprising both direct sentiment indicators and indirect market indicators. This research validates the advantages of LLMs in automated and fine-grained sentiment analysis. Similarly, the study by Kirtac and Germano (2024) directly compared the performance of various LLMs (such as OPT and BERT) against traditional financial dictionaries in analysing news sentiment. Their findings reveal that the GPT-3-based OPT model significantly outperforms traditional dictionary methods in predicting stock returns driven by news sentiment. This finding provides strong evidence that advanced LLMs can interpret complex sentiment in financial texts more effectively than conventional methods. These methods suggest that future research on psychological trait measurement could integrate multi-source information, such as AI-driven semantic recognition, questionnaire-based behavioural data, and natural language processing, to drive methodological innovation in the field of behavioural finance.

Regarding political connections, this study also faces some measurement limitations. Although it rigorously differentiates between the level of CEO political connections and the binary distinction of having a political background, it is unable to definitively ascertain whether an individual's political status was acquired prior to or subsequent to their corporate appointment. For instance, holding a representative position in the People's Congress or the Chinese People's Political Consultative Conference can itself confer political advantages, but this differs from political advantages established before joining the firm. This study does not exclude or separately analyse such cases, which may introduce some ambiguity regarding the precise timing of political resource accumulation. Furthermore, the construction of local officials' promotion incentives relies mainly on critical age thresholds and administrative rank, failing to incorporate more complex political dimensions such as factional affiliation, loyalty, historical performance, or personal family background. As a result, the measurement fails to fully capture the institutional complexities of China’s promotion system and restricts the analysis to mid-level officials, excluding those at higher administrative levels. Wang et al. (2022) highlight that, under China’s cadre management system, promotion to senior positions often involves a trade-off between administrative competence and political loyalty. Their study constructs a set of loyalty indicators (e.g., whether an official has worked alongside key central leaders) and reveals the significant impact of factional affiliation and central-level personal networks on promotion trajectories. This perspective suggests that future research could expand the measurement of promotion incentive variables by introducing indicators such as 'central-local co-working experience', 'performance visibility', or 'factional media evaluation'. Such an approach would more closely align with China's unique promotion logic, thereby improving the explanatory power and validity of political incentive variables within the model.

Regarding the identification strategy, although this thesis employs multiple approaches including instrumental-variable designs, treatment-effect corrections, matched comparisons and stacked PSM-DID analyses to mitigate potential endogeneity bias, challenges in causal identification inevitably remain. Recent research indicates that, in scenarios where strong instrumental variables are difficult to obtain, the Copula correction method can serve as a useful supplementary approach. Eckert and Hohberger (2022) point out that the Gaussian Copula method corrects for endogeneity by modelling the joint distribution of the endogenous explanatory variable and the error term, without requiring strong exogenous instrumental variables. This approach is particularly relevant to studies of executive behaviour, incentive arrangements, and political connections, where fully convincing exclusion restrictions are often difficult to identify. Future research could therefore employ the GC approach for robustness checks and triangulate it with existing IV, treatment-effect, and quasi-experimental designs, thereby further enhancing the credibility of causal identification and methodological diversity.

Finally, the conclusions of this thesis are primarily grounded in the Chinese institutional context. Although the three studies speak to broader theoretical debates on managerial beliefs, incentive design, and political embeddedness, the magnitude and boundary conditions of the identified relationships are likely to depend on features of China’s transitional economy. Their applicability to other emerging markets or developed economies with different ownership systems, capital-market structures, state-business relations, and broader institutional and cultural backgrounds should therefore be treated with caution.

References

Adams, R.B., Almeida, H. and Ferreira, D. (2005) 'Powerful CEOs and their impact on corporate performance', *The Review of Financial Studies*, 18(4), pp. 1403-1432.

Aghion, P., Bloom, N., Blundell, R., Griffith, R. and Howitt, P. (2005) 'Competition and innovation: An inverted-U relationship', *The Quarterly Journal of Economics*, 120(2), pp. 701-728.

Ahuja, G. and Lampert, C.M. (2001) 'Entrepreneurship in the large corporation: A longitudinal study of how established firms create breakthrough inventions', *Strategic Management Journal*, 22(6-7), pp. 521-543.

Alcacer, J. and Gittelman, M. (2006) 'Patent citations as a measure of knowledge flows: The influence of examiner citations', *The Review of Economics and Statistics*, 88(4), pp. 774-779.

Aldatmaz, S., Ouimet, P. and Van Wesep, E.D. (2018) 'The option to quit: The effect of employee stock options on turnover', *Journal of Financial Economics*, 127(1), pp. 136-151.

Amore, M.D. and Bennedsen, M. (2016) 'Corporate governance and green innovation', *Journal of Environmental Economics and Management*, 75, pp. 54-72.

Armstrong, C., Larcker, D.F. and Su, C.L. (2007) 'Stock options and chief executive officer compensation', *Operations Research*, 58(4 Part 2), pp. 1090-1106.

Armstrong, C.S. and Vashishtha, R. (2012) 'Executive stock options, differential risk-taking incentives, and firm value', *Journal of Financial Economics*, 104(1), pp. 70-88.

Artz, K.W., Norman, P.M., Hatfield, D.E. and Cardinal, L.B. (2010) 'A longitudinal study of the impact of R&D, patents, and product innovation on firm performance', *Journal of Product Innovation Management*, 27(5), pp. 725-740.

Bakke, T.E., Mahmudi, H., Fernando, C.S. and Salas, J.M. (2016) 'The causal effect of option pay on corporate risk management', *Journal of Financial Economics*, 120(3), pp. 623-643.

Bansal, P. and Roth, K. (2000) 'Why companies go green: A model of ecological responsiveness', *Academy of Management Journal*, 43(4), pp. 717-736.

Barber, B.M. and Odean, T. (2000) 'Trading is hazardous to your wealth: The common stock investment performance of individual investors', *The Journal of Finance*, 55(2), pp. 773-806.

Barber, B.M. and Odean, T. (2001) 'Boys will be boys: Gender, overconfidence, and common stock investment', *The Quarterly Journal of Economics*, 116(1), pp. 261-292.

Barker III, V.L. and Mueller, G.C. (2002) 'CEO characteristics and firm R&D spending', *Management Science*, 48(6), pp. 782-801.

Barnard, C.I. (1968) *The functions of the executive*. Cambridge, MA: Harvard University Press.

Barnett, M.L. and Salomon, R.M. (2012) 'Does it pay to be really good? Addressing the shape of the relationship between social and financial performance', *Strategic Management Journal*, 33(11), pp. 1304-1320.

Baysinger, B.D., Kosnik, R.D. and Turk, T.A. (1991) 'Effects of board and ownership structure on corporate R&D strategy', *Academy of Management Journal*, 34(1), pp. 205-214.

Bebchuk, L.A., Fried, J.M. and Walker, D.I. (2002) 'Managerial power and rent extraction in the design of executive compensation', *The University of Chicago Law Review*, 69(3), pp. 751-846.

Bell, B., Pedemonte, S. and Van Reenen, J. (2021) 'CEO pay and the rise of relative performance contracts: a question of governance?', *Journal of the European Economic Association*, 19(5), pp. 2513-2542.

Ben-Amar, W., Chang, M. and McIlkenny, P. (2017) 'Board gender diversity and corporate response to sustainability initiatives: Evidence from the carbon disclosure project', *Journal of Business Ethics*, 142(2), pp. 369-383.

Ben-David, I., Graham, J.R. and Harvey, C.R. (2013) 'Managerial miscalibration', *The Quarterly Journal of Economics*, 128(4), pp. 1547-1584.

Bergman, N.K. and Jenter, D. (2007) 'Employee sentiment and stock option compensation', *Journal of Financial Economics*, 84(3), pp. 667-712.

Berrone, P., Fosfuri, A. and Gelabert, L. (2017) 'Does greenwashing pay off? Understanding the relationship between environmental actions and environmental legitimacy', *Journal of Business Ethics*, 144, pp. 363-379.

Bettis, J.C., Bizjak, J.M., Coles, J.L. and Kalpathy, S. (2018) 'Performance-vesting provisions in executive compensation', *Journal of Accounting and Economics*, 66(1), pp. 194-221.

Biggerstaff, L., Blank, B. and Goldie, B. (2019) 'Do incentives work? Option-based compensation and corporate innovation', *Journal of Corporate Finance*, 58, pp. 415-430.

Boubakri, N., Cosset, J.C. and Saffar, W. (2012) 'The impact of political connections on firms' operating performance and financing decisions', *Journal of Financial Research*, 35(3), pp. 397-423.

Brockner, J. (1992) 'The escalation of commitment to a failing course of action: Toward theoretical progress', *Academy of Management Review*, 17(1), pp. 39-61.

Brown, J.R., Fazzari, S.M. and Petersen, B.C. (2009) 'Financing innovation and growth: Cash flow, external equity, and the 1990s R&D boom', *The Journal of Finance*, 64(1), pp. 151-185.

Burns, N. and Kedia, S. (2006) 'The impact of performance-based compensation on misreporting', *Journal of Financial Economics*, 79(1), pp. 35-67.

Bushee, B.J. (1998) 'The influence of institutional investors on myopic R&D investment behavior', *The Accounting Review*, 73(3), pp. 305-333.

Cai, J. and Vijh, A.M. (2007) 'Incentive effects of stock and option holdings of target and acquirer CEOs', *The Journal of Finance*, 62(4), pp. 1891-1933.

Calza, F., Parmentola, A. and Tutore, I. (2020) 'Types of green innovations: Ways of implementation in a mature industrial region', *Journal of Cleaner Production*, 275, 124077.

Camerer, C. and Lovallo, D. (1999) 'Overconfidence and excess entry: An experimental approach', *American Economic Review*, 89(1), pp. 306-318.

Cameron, A.C., Gelbach, J.B. and Miller, D.L. (2011) 'Robust inference with multiway clustering', *Journal of Business & Economic Statistics*, 29(2), pp. 238-249.

Cao, X., Kostka, G. and Xu, X. (2019) 'Environmental political business cycles: The case of PM2.5 air pollution in Chinese prefectures', *Environmental Science & Policy*, 93, pp. 92-100.

Carpenter, M.A., Geletkanycz, M.A. and Sanders, W.G. (2004) 'Upper echelons research revisited: Antecedents, elements, and consequences of top management team composition', *Journal of Management*, 30(6), pp. 749-778.

Chan, H.S. and Li, L.C. (2007) 'Civil service law in the People's Republic of China: A return to cadre personnel management', *Public Administration Review*, 67(3), pp. 383-398.

Chang, L., Li, W. and Lu, X. (2015) 'Government engagement, environmental policy, and environmental performance: Evidence from the most polluting Chinese listed firms', *Business Strategy and the Environment*, 24(1), pp. 1-19.

Chang, X., Fu, K., Low, A. and Zhang, W. (2015) 'Non-executive employee stock options and corporate innovation', *Journal of Financial Economics*, 115(1), pp. 168-188.

Chen, Y.R., Chen, C.R. and Chu, C.K. (2014) 'The effect of executive stock options on corporate innovative activities', *Financial Management*, 43(2), pp. 271-290.

Chen, Y.S. (2008) 'The driver of green innovation and green image-green core competence', *Journal of Business Ethics*, 81, pp. 531-543.

Chen, Y.S., Lai, S.B. and Wen, C.T. (2006) 'The influence of green innovation performance on corporate advantage in Taiwan', *Journal of Business Ethics*, 67, pp. 331-339.

Cheng, Q. and Warfield, T.D. (2005) 'Equity incentives and earnings management', *The Accounting Review*, 80(2), pp. 441-476.

Cheng, R., Frijns, B., Kim, H. and Ryu, D. (2024) 'Effects of option incentive compensation on corporate innovation: The case of China', *Economic Systems*, 48(1), 101171.

Cheng, S. (2004) 'R&D expenditures and CEO compensation', *The Accounting Review*, 79(2), pp. 305-328.

Chin, M.K., Hambrick, D.C. and Treviño, L.K. (2013) 'Political ideologies of CEOs: The influence of executives' values on corporate social responsibility', *Administrative Science Quarterly*, 58(2), pp. 197-232.

China National Intellectual Property Administration (CNIPA) (n.d.) *Patents*. Available at: https://english.cnipa.gov.cn/col/col2995/index.html.

Chu, Y., Liu, M., Ma, T. and Li, X. (2020) 'Executive compensation and corporate risk-taking: Evidence from private loan contracts', *Journal of Corporate Finance*, 64, 101683.

Claessens, S., Feijen, E. and Laeven, L. (2008) 'Political connections and preferential access to finance: The role of campaign contributions', *Journal of Financial Economics*, 88(3), pp. 554-580.

Clarkson, P.M., Li, Y., Richardson, G.D. and Vasvari, F.P. (2011) 'Does it really pay to be green? Determinants and consequences of proactive environmental strategies', *Journal of Accounting and Public Policy*, 30(2), pp. 122-144.

Cohen, W.M. and Klepper, S. (1996) 'Firm size and the nature of innovation within industries: The case of process and product R&D', *Review of Economics and Statistics*, 78(2), pp. 232-243.

Cohen, W.M. and Levinthal, D.A. (1990) 'Absorptive capacity: A new perspective on learning and innovation', *Administrative Science Quarterly*, 35(1), pp. 128-152.

Coles, J.L., Daniel, N.D. and Naveen, L. (2006) 'Managerial incentives and risk-taking', *Journal of Financial Economics*, 79(2), pp. 431-468.

Conyon, M.J. and He, L. (2011) 'Executive compensation and corporate governance in China', *Journal of Corporate Finance*, 17(4), pp. 1158-1175.

Core, J. and Guay, W. (1999) 'The use of equity grants to manage optimal equity incentive levels', *Journal of Accounting and Economics*, 28(2), pp. 151-184.

Core, J.E. and Guay, W.R. (2001) 'Stock option plans for non-executive employees', *Journal of Financial Economics*, 61(2), pp. 253-287.

Daniel, K., Hirshleifer, D. and Subrahmanyam, A. (1998) 'Investor psychology and security market under- and overreactions', *The Journal of Finance*, 53(6), pp. 1839-1885.

de Villiers, C., Naiker, V. and van Staden, C.J. (2011) 'The effect of board characteristics on firm environmental performance', *Journal of Management*, 37(6), pp. 1636-1663.

Delmas, M.A. and Toffel, M.W. (2008) 'Organizational responses to environmental demands: Opening the black box', *Strategic Management Journal*, 29(10), pp. 1027-1055.

Deshmukh, S., Goel, A.M. and Howe, K.M. (2013) 'CEO overconfidence and dividend policy', *Journal of Financial Intermediation*, 22(3), pp. 440-463.

Dosi, G. (1988) 'Sources, procedures, and microeconomic effects of innovation', *Journal of Economic Literature*, 26(3), pp. 1120-1171.

Dougherty, D. (1992) 'Interpretive barriers to successful product innovation in large firms', *Organization Science*, 3(2), pp. 179-202.

Doukas, J.A. and Petmezas, D. (2007) 'Acquisitions, overconfident managers and self-attribution bias', *European Financial Management*, 13(3), pp. 531-577.

Du, J. and Yi, H. (2022) 'Target-setting, political incentives, and the tricky trade-off between economic development and environmental protection', *Public Administration*, 100(4), pp. 923-941.

Du, K., Cheng, Y. and Yao, X. (2021) 'Environmental regulation, green technology innovation, and industrial structure upgrading: The road to the green transformation of Chinese cities', *Energy Economics*, 98, 105247.

Du, S., Bhattacharya, C.B. and Sen, S. (2011) 'Corporate social responsibility and competitive advantage: Overcoming the trust barrier', *Management Science*, 57(9), pp. 1528-1545.

Eccles, R.G., Ioannou, I. and Serafeim, G. (2014) 'The impact of corporate sustainability on organizational processes and performance', *Management Science*, 60(11), pp. 2835-2857.

Eckert, C. and Hohberger, J. (2022) 'Addressing endogeneity without instrumental variables: An evaluation of the gaussian copula approach for management research', *Journal of Management*, 49(4), pp. 1460-1495.

Ederer, F. and Manso, G. (2013) 'Is pay for performance detrimental to innovation?', *Management Science*, 59(7), pp. 1496-1513.

Edmans, A., Gabaix, X. and Jenter, D. (2017) 'Executive compensation: a survey of theory and evidence', in Hermalin, B.E. and Weisbach, M.S. (eds.) *The Handbook of the Economics of Corporate Governance*, Vol. 1. Amsterdam: Elsevier, pp. 383–539.

Faccio, M. (2006) 'Politically connected firms', *American Economic Review*, 96(1), pp. 369-386.

Faleye, O., Mehrotra, V. and Morck, R. (2006) 'When labor has a voice in corporate governance', *Journal of Financial and Quantitative Analysis*, 41(3), pp. 489-510.

Fama, E.F. and Jensen, M.C. (1983) 'Separation of ownership and control', *The Journal of Law and Economics*, 26(2), pp. 301-325.

Fan, J.P., Wong, T.J. and Zhang, T. (2007) 'Politically connected CEOs, corporate governance, and post-IPO performance of China's newly partially privatized firms', *Journal of Financial Economics*, 84(2), pp. 330-357.

Farza, K., Ftiti, Z., Hlioui, Z., Louhichi, W. and Omri, A. (2021) 'Does it pay to go green? The environmental innovation effect on corporate financial performance', *Journal of Environmental Management*, 300, 113695.

Finkelstein, S. and D'Aveni, R.A. (1994) 'CEO duality as a double-edged sword: How boards of directors balance entrenchment avoidance and unity of command', *Academy of Management Journal*, 37(5), pp. 1079-1108.

Firth, M., Fung, P.M. and Rui, O.M. (2006) 'Corporate performance and CEO compensation in China', *Journal of Corporate Finance*, 12(4), pp. 693-714.

Fischhoff, B., Slovic, P. and Lichtenstein, S. (1977) 'Knowing with certainty: The appropriateness of extreme confidence', *Journal of Experimental Psychology: Human Perception and Performance*, 3(4), pp. 552-564.

Fisman, R. (2001) 'Estimating the value of political connections', *American Economic Review*, 91(4), pp. 1095-1102.

Flammer, C. (2013) 'Corporate social responsibility and shareholder reaction: The environmental awareness of investors', *Academy of Management Journal*, 56(3), pp. 758-781.

Flammer, C. (2015) 'Does corporate social responsibility lead to superior financial performance? A regression discontinuity approach', *Management Science*, 61(11), pp. 2549-2568.

Francis, B.B., Hasan, I., Sharma, Z. and Waisman, M. (2019) 'Motivating high-impact innovation: Evidence from managerial compensation contracts', *Financial Markets, Institutions & Instruments*, 28(3), pp. 291-318.

Friede, G., Busch, T. and Bassen, A. (2015) 'ESG and financial performance: Aggregated evidence from more than 2000 empirical studies', *Journal of Sustainable Finance & Investment*, 5(4), pp. 210-233.

Galasso, A. and Simcoe, T.S. (2011) 'CEO overconfidence and innovation', *Management Science*, 57(8), pp. 1469-1484.

Gao, X. (2017) 'Promotion prospects and career paths of local party-government leaders in China', *Journal of Chinese Governance*, 2(2), pp. 223-234.

García-Granero, A., Llopis, Ó., Fernández-Mesa, A. and Alegre, J. (2015) 'Unraveling the link between managerial risk-taking and innovation: The mediating role of a risk-taking climate', *Journal of Business Research*, 68(5), pp. 1094-1104.

Gervais, S. and Odean, T. (2001) 'Learning to be overconfident', *The Review of Financial Studies*, 14(1), pp. 1-27.

Gillan, S.L., Koch, A. and Starks, L.T. (2021) 'Firms and social responsibility: A review of ESG and CSR research in corporate finance', *Journal of Corporate Finance*, 66, 101889.

Goel, A.M. and Thakor, A.V. (2008) 'Overconfidence, CEO selection, and corporate governance', *The Journal of Finance*, 63(6), pp. 2737-2784.

Goldman, E., Rocholl, J. and So, J. (2009) 'Do politically connected boards affect firm value?', *The Review of Financial Studies*, 22(6), pp. 2331-2360.

Graham, J.R., Harvey, C.R. and Puri, M. (2013) 'Managerial attitudes and corporate actions', *Journal of Financial Economics*, 109(1), pp. 103-121.

Griffin, D. and Tversky, A. (1992) 'The weighing of evidence and the determinants of confidence', *Cognitive Psychology*, 24(3), pp. 411-435.

Grinstein, Y., Lauterbach, B. and Yosef, R. (2022) 'Benchmarking of pay components in CEO compensation design', *Journal of Corporate Finance*, 77, 102308.

Hackbarth, D. (2008) 'Managerial traits and capital structure decisions', *Journal of Financial and Quantitative Analysis*, 43(4), pp. 843-881.

Hall, B.H. and Lerner, J. (2010) 'The financing of R&D and innovation', in Hall, B.H. and Rosenberg, N. (eds) *Handbook of the Economics of Innovation*, Vol. 1. Amsterdam: North-Holland, pp. 609-639.

Hall, B.H. (2002) 'The financing of research and development', *Oxford Review of Economic Policy*, 18(1), pp. 35-51.

Hall, B.H., Jaffe, A.B. and Trajtenberg, M. (2005) 'Market value and patent citations', *The RAND Journal of Economics*, 36(1), pp. 16–38.

Hall, B.H., Mairesse, J. and Mohnen, P. (2010) 'Measuring the returns to R&D', in Hall, B.H. and Rosenberg, N. (eds.) *Handbook of the Economics of Innovation*, Vol. 2. Amsterdam: North-Holland, pp. 1033-1082.

Hall, B.J. and Liebman, J.B. (1998) 'Are CEOs really paid like bureaucrats?', *The Quarterly Journal of Economics*, 113(3), pp. 653-691.

Hall, B.J. and Murphy, K.J. (2002) 'Stock options for undiversified executives', *Journal of Accounting and Economics*, 33(1), pp. 3-42.

Hall, B.J. and Murphy, K.J. (2003) 'The trouble with stock options', *Journal of Economic Perspectives*, 17(3), pp. 49-70.

Hambrick, D.C. (2007) 'Upper echelons theory: An update', *Academy of Management Review*, 32(2), pp. 334-343.

Hambrick, D.C. and Finkelstein, S. (1987) 'Managerial discretion: A bridge between polar views of organizational outcomes', *Research in Organizational Behavior*, 9, pp. 369-406.

Hambrick, D.C. and Fukutomi, G.D. (1991) 'The seasons of a CEO's tenure', *Academy of Management Review*, 16(4), pp. 719-742.

Hambrick, D.C. and Mason, P.A. (1984) 'Upper echelons: The organization as a reflection of its top managers', *Academy of Management Review*, 9(2), pp. 193-206.

Hart, S.L. (1995) 'A natural-resource-based view of the firm', *Academy of Management Review*, 20(4), pp. 986-1014.

Hart, S.L. and Dowell, G. (2011) 'Invited editorial: A natural-resource-based view of the firm: Fifteen years after', *Journal of Management*, 37(5), pp. 1464-1479.

Hatoum, K., Moussu, C. and Gillet, R. (2022) 'CEO overconfidence: Towards a new measure', *International Review of Financial Analysis*, 84, 102367.

Haunschild, P.R. (1994) 'How much is that company worth?: Interorganizational relationships, uncertainty, and acquisition premiums', *Administrative Science Quarterly*, 39(3), pp. 391-411.

Hawn, O., Chatterji, A.K. and Mitchell, W. (2018) 'Do investors actually value sustainability? New evidence from investor reactions to the Dow Jones Sustainability Index (DJSI)', *Strategic Management Journal*, 39(4), pp. 949-976.

Hayward, M.L. and Hambrick, D.C. (1997) 'Explaining the premiums paid for large acquisitions: Evidence of CEO hubris', *Administrative Science Quarterly*, 42(1), pp. 103-127.

Heaton, J.B. (2002) 'Managerial optimism and corporate finance', *Financial Management*, 31(2), pp. 33-45.

Heitz, A., Wang, Y. and Wang, Z. (2023) 'Corporate political connections and favorable environmental regulatory enforcement', *Management Science*, 69(12), pp. 7838-7859.

Hillman, A.J. (2005) 'Politicians on the board of directors: Do connections affect the bottom line?', *Journal of Management*, 31(3), pp. 464-481.

Hillman, A.J., Zardkoohi, A. and Bierman, L. (1999) 'Corporate political strategies and firm performance: Indications of firm-specific benefits from personal service in the US government', *Strategic Management Journal*, 20(1), pp. 67-81.

Hirshleifer, D., Low, A. and Teoh, S.H. (2012) 'Are overconfident CEOs better innovators?', *The Journal of Finance*, 67(4), pp. 1457-1498.

Hochberg, Y.V. and Lindsey, L. (2010) 'Incentives, targeting, and firm performance: An analysis of non-executive stock options', *The Review of Financial Studies*, 23(11), pp. 4148-4186.

Hofstede, G. (1980) *Culture's consequences: International differences in work-related values*. Beverly Hills: Sage Publications.

Holmstrom, B. (1979) 'Moral hazard and observability', *The Bell Journal of Economics*, 10(1), pp. 74-91.

Holmstrom, B. (1989) 'Agency costs and innovation', *Journal of Economic Behavior & Organization*, 12(3), pp. 305-327.

Horbach, J. (2008) 'Determinants of environmental innovation-New evidence from German panel data sources', *Research Policy*, 37(1), pp. 163-173.

Hribar, P. and Yang, H. (2016) 'CEO overconfidence and management forecasting', *Contemporary Accounting Research*, 33(1), pp. 204-227.

Huang, J. and Kisgen, D.J. (2013) 'Gender and corporate finance: Are male executives overconfident relative to female executives?', *Journal of Financial Economics*, 108(3), pp. 822-839.

Huang, J.W. and Li, Y.H. (2017) 'Green innovation and performance: The view of organizational capability and social reciprocity', *Journal of Business Ethics*, 145, pp. 309-324.

Huang, M., Li, M. and Liao, Z. (2021) 'Do politically connected CEOs promote Chinese listed industrial firms' green innovation? The mediating role of external governance environments', *Journal of Cleaner Production*, 278, 123634.

Huang, W., Jiang, F., Liu, Z. and Zhang, M. (2011) 'Agency cost, top executives' overconfidence, and investment-cash-flow sensitivity: Evidence from listed companies in China', *Pacific-Basin Finance Journal*, 19(3), pp. 261-277.

Huang, X., Teoh, S.H. and Zhang, Y. (2014) 'Tone management', *The Accounting Review*, 89(3), pp. 1083-1113.

Ittner, C.D., Lambert, R.A. and Larcker, D.F. (2003) 'The structure and performance consequences of equity grants to employees of new economy firms', *Journal of Accounting and Economics*, 34(1-3), pp. 89-127.

Jaffe, A.B., Trajtenberg, M. and Henderson, R. (1993) 'Geographic localization of knowledge spillovers as evidenced by patent citations', *The Quarterly Journal of Economics*, 108(3), pp. 577-598.

Jang, S., Kovacs, T. and Choi, H. (2026) 'Employee stock options and innovation: Evidence from an exogenous shock to employee intellectual property rights', *Journal of Corporate Finance*, 96, 102911.

Jensen, M.C. (1993) 'The modern industrial revolution, exit, and the failure of internal control systems', *The Journal of Finance*, 48(3), pp. 831-880.

Jensen, M.C. and Meckling, W.H. (1976) 'Theory of the firm: Managerial behavior, agency costs and ownership structure', *Journal of Financial Economics*, 3(4), pp. 305-360.

Jensen, M.C. and Murphy, K.J. (1990) 'Performance pay and top-management incentives', *Journal of Political Economy*, 98(2), pp. 225-264.

Jia, N. (2016) 'Political strategy and market capabilities: Evidence from the Chinese private sector', *Management and Organization Review*, 12(1), pp. 75-102.

Jiang, L., Kling, G., Bo, H. and Driver, C. (2017) 'Why do firms adopt stock options and who benefits? A natural experiment in China', *Pacific-Basin Finance Journal*, 46, pp. 124-140.

John, T.A. and John, K. (1993) 'Top-management compensation and capital structure', *The Journal of Finance*, 48(3), pp. 949-974.

Johnson, S. and Mitton, T. (2003) 'Cronyism and capital controls: Evidence from Malaysia', *Journal of Financial Economics*, 67(2), pp. 351-382.

Johnstone, N., Haščič, I. and Popp, D. (2010) 'Renewable energy policies and technological innovation: Evidence based on patent counts', *Environmental and Resource Economics*, 45, pp. 133-155.

Jones, D.C. and Kato, T. (1995) 'The productivity effects of employee stock-ownership plans and bonuses: Evidence from Japanese panel data', *The American Economic Review*, 85(3), pp. 391-414.

Khanra, S., Kaur, P., Joseph, R.P., Malik, A. and Dhir, A. (2022) 'A resource-based view of green innovation as a strategic firm resource: Present status and future directions', *Business Strategy and the Environment*, 31(4), pp. 1395-1413.

Kim, E.H. and Ouimet, P. (2014) 'Broad-based employee stock ownership: Motives and outcomes', *The Journal of Finance*, 69(3), pp. 1273-1319.

Kim, Y.A. (2024) 'Blue goes green: The impact of the chief executive officer and board of directors' political ideology on corporate environmental performance', *Business Strategy and the Environment*, 33(2), pp. 134-148.

Kirtac, K. and Germano, G. (2024) 'Sentiment trading with large language models', *Finance Research Letters*, 62, p. 105227.

Klein, K.J. (1987) 'Employee stock ownership and employee attitudes: A test of three models', *Journal of Applied Psychology*, 72(2), pp. 319-332.

Kornai, J. (1986) 'The soft budget constraint', *Kyklos*, 39(1), pp. 3-30.

Krasteva, S., Sharma, P. and Wagman, L. (2015) 'The 80/20 rule: Corporate support for innovation by employees', *International Journal of Industrial Organization*, 38, pp. 32-43.

Kreilkamp, N., Matanovic, S., Schmidt, M. and Wöhrmann, A. (2023) 'How executive incentive design affects risk-taking: a literature review', *Review of Managerial Science*, 17(7), pp. 2349-2374.

Landry, P.F. (2008) *Decentralized authoritarianism in China: The Communist Party's control of local elites in the post-Mao era*. Cambridge: Cambridge University Press.

Lang, L., Ofek, E. and Stulz, R.M. (1996) 'Leverage, investment, and firm growth', *Journal of Financial Economics*, 40(1), pp. 3-29.

Lang, L.H.P., Stulz, R.M. and Walkling, R.A. (1989) 'Managerial performance, Tobin's Q, and the gains from successful tender offers', *Journal of Financial Economics*, 24(1), pp. 137-154.

Langer, E.J. (1975) 'The illusion of control', *Journal of Personality and Social Psychology*, 32(2), pp. 311-328.

Langer, E.J. and Roth, J. (1975) 'Heads I win, tails it's chance: The illusion of control as a function of the sequence of outcomes in a purely chance task', *Journal of Personality and Social Psychology*, 32(6), pp. 951-955.

Laux, V. (2015) 'Executive pay, innovation, and risk-taking', *Journal of Economics & Management Strategy*, 24(2), pp. 275-305.

Lerner, J. and Wulf, J. (2007) 'Innovation and incentives: Evidence from corporate R&D', *The Review of Economics and Statistics*, 89(4), pp. 634-644.

Leutert, W. (2018) 'The political mobility of China's central state-owned enterprise leaders', *The China Quarterly*, 233, pp. 1-21.

Lewellen, K. (2006) 'Financing decisions when managers are risk averse', *Journal of Financial Economics*, 82(3), pp. 551-589.

Li, H. and Atuahene-Gima, K. (2001) 'Product innovation strategy and the performance of new technology ventures in China', *Academy of Management Journal*, 44(6), pp. 1123-1134.

Li, H. and Zhou, L.A. (2005) 'Political turnover and economic performance: The incentive role of personnel control in China', *Journal of Public Economics*, 89(9-10), pp. 1743-1762.

Li, H., Meng, L., Wang, Q. and Zhou, L.A. (2008) 'Political connections, financing and firm performance: Evidence from Chinese private firms', *Journal of Development Economics*, 87(2), pp. 283-299.

Li, J. and Tang, Y.I. (2010) 'CEO hubris and firm risk taking in China: The moderating role of managerial discretion', *Academy of Management Journal*, 53(1), pp. 45-68.

Li, M., Sun, X., Wang, Y. and Song-Turner, H. (2019) 'The impact of political connections on the efficiency of China's renewable energy firms', *Energy Economics*, 83, pp. 467-474.

Li, W. and Zhang, R. (2010) 'Corporate social responsibility, ownership structure, and political interference: Evidence from China', *Journal of Business Ethics*, 96, pp. 631-645.

Lichtenstein, S., Fischhoff, B. and Phillips, L.D. (1982) 'Calibration of probabilities: The state of the art to 1980', in Kahneman, D., Slovic, P. and Tversky, A. (eds.) *Judgment under uncertainty: Heuristics and biases*. Cambridge: Cambridge University Press, pp. 306–334.

Lin, C., Lin, P., Song, F.M. and Li, C. (2011) 'Managerial incentives, CEO characteristics and corporate innovation in China's private sector', *Journal of Comparative Economics*, 39(2), pp. 176-190.

Lin, H., Zeng, S.X., Ma, H.Y., Qi, G.Y. and Tam, V.W. (2014) 'Can political capital drive corporate green innovation? Lessons from China', *Journal of Cleaner Production*, 64, pp. 63-72.

Lin, K.J., Tan, J., Zhao, L. and Karim, K. (2015) 'In the name of charity? Political connections and strategic corporate social responsibility in a transition economy', *Journal of Corporate Finance*, 32, pp. 327-346.

Lin, K.Z., Mills, L.F., Zhang, F. and Li, Y. (2018) 'Do political connections weaken tax enforcement effectiveness?', *Contemporary Accounting Research*, 35(4), pp. 1941-1972.

Lin, Y.H., Hu, S.Y. and Chen, M.S. (2005) 'Managerial optimism and corporate investment: Some empirical evidence from Taiwan', *Pacific-Basin Finance Journal*, 13(5), pp. 523-546.

Liu, D., Chen, J. and Zhang, N. (2021) 'Political connections and green technology innovations under an environmental regulation', *Journal of Cleaner Production*, 298, 126778.

Liu, J., Stambaugh, R.F. and Yuan, Y. (2019) 'Size and value in China', *Journal of Financial Economics*, 134(1), pp. 48-69.

Liu, X. and White, S. (2001) 'Comparing innovation systems: A framework and application to China's transitional context', *Research Policy*, 30(7), pp. 1091-1114.

Malmendier, U. and Tate, G. (2005a) 'CEO overconfidence and corporate investment', *The Journal of Finance*, 60(6), pp. 2661-2700.

Malmendier, U. and Tate, G. (2005b) 'Does overconfidence affect corporate investment? CEO overconfidence measures revisited', *European Financial Management*, 11(5), pp. 649-659.

Malmendier, U. and Tate, G. (2008) 'Who makes acquisitions? CEO overconfidence and the market's reaction', *Journal of Financial Economics*, 89(1), pp. 20-43.

Malmendier, U. and Tate, G. (2009) 'Superstar CEOs', *The Quarterly Journal of Economics*, 124(4), pp. 1593-1638.

Malmendier, U. and Tate, G. (2015) 'Behavioral CEOs: The role of managerial overconfidence', *Journal of Economic Perspectives*, 29(4), pp. 37-60.

Manso, G. (2011) 'Motivating innovation', *The Journal of Finance*, 66(5), pp. 1823-1860.

Mao, C.X. and Zhang, C. (2018) 'Managerial Risk-Taking Incentive and Firm Innovation: Evidence from FAS 123R', *Journal of Financial and Quantitative Analysis*, 53(2), pp. 867-898.

March, J.G. (1991) 'Exploration and exploitation in organizational learning', *Organization Science*, 2(1), pp. 71-87.

March, J.G. and Simon, H.A. (1958) *Organizations*. New York: John Wiley & Sons.

Marquis, C. and Qian, C. (2014) 'Corporate social responsibility reporting in China: Symbol or substance?', *Organization Science*, 25(1), pp. 127-148.

Maung, M., Wilson, C. and Tang, X. (2016) 'Political connections and industrial pollution: Evidence based on state ownership and environmental levies in China', *Journal of Business Ethics*, 138, pp. 649-659.

Megginson, W.L. and Netter, J.M. (2001) 'From state to market: A survey of empirical studies on privatization', *Journal of Economic Literature*, 39(2), pp. 321-389.

Mehran, H. (1995) 'Executive compensation structure, ownership, and firm performance', *Journal of Financial Economics*, 38(2), pp. 163-184.

Mei, C. and Wang, X. (2017) 'Political incentives and local policy innovations in China', *Journal of Chinese Political Science*, 22, pp. 519-547.

Merton, R.C. (1969) 'Lifetime portfolio selection under uncertainty: The continuous-time case', *The Review of Economics and Statistics*, 51(3), pp. 247-257.

Merton, R.C. (1971) 'Optimum consumption and portfolio rules in a continuous-time model', *Journal of Economic Theory*, 3(4), pp. 373-413.

Ministry of Environmental Protection (MEP) (2008) *Classification management catalogue for environmental verification of listed enterprises*. Beijing: Ministry of Environmental Protection.

Moore, D.A. and Healy, P.J. (2008) 'The trouble with overconfidence', *Psychological Review*, 115(2), pp. 502-517.

Murphy, K.J. (1985) 'Corporate performance and managerial remuneration: An empirical analysis', *Journal of Accounting and Economics*, 7(1-3), pp. 11-42.

Murphy, K.J. (2013) 'Executive compensation: where we are, and how we got there', in Constantinides, G.M., Harris, M. and Stulz, R.M. (eds) *Handbook of the economics of finance*. Vol. 2. Amsterdam: Elsevier, pp. 211-356.

Myers, S.C. (1977) 'Determinants of corporate borrowing', *Journal of Financial Economics*, 5(2), pp. 147-175.

National Bureau of Statistics of China (2018) *Classification of strategic emerging industries (2018) (Guo Tong Zi [2018] No. 23)*. Beijing: National Bureau of Statistics of China.

Odean, T. (1998) 'Volume, volatility, price, and profit when all traders are above average', *The Journal of Finance*, 53(6), pp. 1887-1934.

O'Reilly, C.A. and Tushman, M.L. (2013) 'Organizational ambidexterity: Past, present, and future', *Academy of Management Perspectives*, 27(4), pp. 324-338.

Organisation for Economic Co-operation and Development (OECD) (2016) *OECD taxonomy of economic activities based on R&D intensity*. OECD Science, Technology and Industry Working Papers, No. 2016/04. Paris: OECD Publishing.

Oyer, P. and Schaefer, S. (2005) 'Why do some firms give stock options to all employees?: An empirical examination of alternative theories', *Journal of Financial Economics*, 76(1), pp. 99-133.

Peng, M.W. and Luo, Y. (2000) 'Managerial ties and firm performance in a transition economy: The nature of a micro-macro link', *Academy of Management Journal*, 43(3), pp. 486-501.

Peng, M.W., Bruton, G.D., Stan, C.V. and Huang, Y. (2016) 'Theories of the (state-owned) firm', *Asia Pacific Journal of Management*, 33(2), pp. 293-317.

People's Republic of China (1997) *Criminal Law of the People's Republic of China*. Beijing: National People's Congress.

People's Republic of China (2005) *Civil Servant Law of the People's Republic of China*. Beijing: National People's Congress.

People's Republic of China (2018) *Supervision Law of the People's Republic of China*. Beijing: National People's Congress.

Petersen, M.A. (2009) 'Estimating standard errors in finance panel data sets: Comparing approaches', *The Review of Financial Studies*, 22(1), pp. 435-480.

Pfeffer, J. and Salancik, G.R. (1978) *The external control of organizations: A resource dependence perspective*. New York: Harper & Row.

Popp, D. (2005) 'Lessons from patents: Using patents to measure technological change in environmental models', *Ecological Economics*, 54(2-3), pp. 209-226.

Porter, M.E. and Van der Linde, C. (1995) 'Green and competitive: ending the stalemate', *Harvard Business Review*, 73(5), pp. 120-134.

Qin, X., Muskat, B., Ambrosini, V., Mair, J. and Chih, Y.Y. (2026) 'Green innovation implementation: A systematic review and research directions', *Journal of Management*, 52(1), pp. 255-282.

Ran, R. (2017) 'Understanding blame politics in China's decentralized environmental enforcement', *The China Quarterly*, 230, pp. 195-218.

Rao, Y. and Wang, J. (2010) 'CEO overconfidence, board structure and firm performance', *Journal of Management Science*, 5(23), pp. 2-12.

Ren, S., Liu, D. and Yan, J. (2024) 'How officials' political incentives influence corporate green innovation', *Journal of Business Ethics*, 194(3), pp. 633-653.

Roll, R. (1986) 'The hubris hypothesis of corporate takeovers', *Journal of Business*, 59(2), pp. 197-216.

Rosenbaum, P.R. and Rubin, D.B. (1983) 'The central role of the propensity score in observational studies for causal effects', *Biometrika*, 70(1), pp. 41-55.

Saich, T. (2015) *Governance and politics of China*. New York: St Martin's Press.

Salimi, M. and Della Torre, E. (2021) 'Pay incentives, human capital and firm innovation in smaller firms', *International Small Business Journal*, 40(4), pp. 507-530.

Scheinkman, J.A. and Xiong, W. (2003) 'Overconfidence and speculative bubbles', *Journal of Political Economy*, 111(6), pp. 1183-1220.

Serfling, M.A. (2014) 'CEO age and the riskiness of corporate policies', *Journal of Corporate Finance*, 25, pp. 251-273.

Shih, V., Adolph, C. and Liu, M. (2012) 'Getting ahead in the communist party: Explaining the advancement of central committee members in China', *American Political Science Review*, 106(1), pp. 166-187.

Shleifer, A. and Vishny, R.W. (1994) 'Politicians and firms', *The Quarterly Journal of Economics*, 109(4), pp. 995-1025.

Simon, H.A. (1955) 'A behavioral model of rational choice', *The Quarterly Journal of Economics*, 69(1), pp. 99-118.

Simon, H.A. (1957) *Administrative behavior: A study of decision-making processes in administrative organization*. New York: Free Press.

Simon, M. and Houghton, S.M. (2002) 'The relationship among biases, misperceptions, and the introduction of pioneering products: Examining differences in venture decision contexts', *Entrepreneurship Theory and Practice*, 27(2), pp. 105-124.

Simon, M. and Houghton, S.M. (2003) 'The relationship between overconfidence and the introduction of risky products: Evidence from a field study', *Academy of Management Journal*, 46(2), pp. 139-149.

Sørensen, J.B. and Stuart, T.E. (2000) 'Aging, obsolescence, and organizational innovation', *Administrative Science Quarterly*, 45(1), pp. 81-112.

State Council of China (2007) *The 11th Five-Year Plan for Environmental Protection (2006-2010)*. Beijing: The State Council of the People's Republic of China.

State Council of China (2010) *Decision of the State Council on accelerating the cultivation and development of strategic emerging industries (Guo Fa [2010] No. 32)*. Beijing: State Council of the People's Republic of China.

Staw, B.M. (1976) 'Knee-deep in the big muddy: A study of escalating commitment to a chosen course of action', *Organizational Behavior and Human Performance*, 16(1), pp. 27-44.

Sualihu, M.A., Rankin, M. and Haman, J. (2021) 'The role of equity compensation in reducing inefficient investment in labor', *Journal of Corporate Finance*, 66, 101788.

Svenson, O. (1981) 'Are we all less risky and more skillful than our fellow drivers?', *Acta Psychologica*, 47(2), pp. 143-148.

Tang, P., Jiang, Q. and Mi, L. (2021) 'One-vote veto: The threshold effect of environmental pollution in China's economic promotion tournament', *Ecological Economics*, 185, 107069.

Tang, Y., Li, J. and Yang, H. (2015) 'What I see, what I do: How executive hubris affects firm innovation', *Journal of Management*, 41(6), pp. 1698-1723.

Taylor, S.E. and Brown, J.D. (1988) 'Illusion and well-being: A social psychological perspective on mental health', *Psychological Bulletin*, 103(2), pp. 193-210.

Tellis, G.J., Prabhu, J.C. and Chandy, R.K. (2009) 'Radical innovation across nations: The preeminence of corporate culture', *Journal of Marketing*, 73(1), pp. 3-23.

Thompson, S.B. (2011) 'Simple formulas for standard errors that cluster by both firm and time', *Journal of Financial Economics*, 99(1), pp. 1-10.

Tian, X. and Wang, T.Y. (2014) 'Tolerance for failure and corporate innovation', *The Review of Financial Studies*, 27(1), pp. 211-255.

Walls, J.L., Berrone, P. and Phan, P.H. (2012) 'Corporate governance and environmental performance: Is there really a link?', *Strategic Management Journal*, 33(8), pp. 885-913.

Wang, D. and Luo, X.R. (2019) 'Retire in peace: Officials' political incentives and corporate diversification in China', *Administrative Science Quarterly*, 64(4), pp. 773-809.

Wang, M., Li, Y., Li, J. and Wang, Z. (2021) 'Green process innovation, green product innovation and its economic performance improvement paths: A survey and structural model', *Journal of Environmental Management*, 297, 113282.

Wang, X. and Lei, P. (2020) 'Does strict environmental regulation lead to incentive contradiction?-Evidence from China', *Journal of Environmental Management*, 269, 110632.

Wang, Z., Yao, Y. and Zhang, J. (2022) 'The competence-loyalty tradeoff in China's political selection', *Journal of Comparative Economics*, 50(2), pp. 369-393.

Wang, Z.R., Fu, H.Q. and Ren, X.H. (2023) 'The impact of political connections on firm pollution: New evidence based on heterogeneous environmental regulation', *Petroleum Science*, 20(1), pp. 636-647.

Weinstein, N.D. (1980) 'Unrealistic optimism about future life events', *Journal of Personality and Social Psychology*, 39(5), pp. 806-820.

World Intellectual Property Organization (WIPO) (2010) *IPC Green Inventory*. Geneva: WIPO.

Wruck, K.H. and Wu, Y. (2021) 'The relation between CEO equity incentives and the quality of accounting disclosures: New evidence', *Journal of Corporate Finance*, 67, 101895.

Wu, M. and Cao, X. (2021) 'Greening the career incentive structure for local officials in China: Does less pollution increase the chances of promotion for Chinese local leaders?', *Journal of Environmental Economics and Management*, 107, 102440.

Xin, K.K. and Pearce, J.L. (1996) 'Guanxi: Connections as substitutes for formal institutional support', *Academy of Management Journal*, 39(6), pp. 1641-1658.

Xin, Q., Bao, A. and Hu, F. (2019) 'West meets east: Understanding managerial incentives in Chinese SOEs', *China Journal of Accounting Research*, 12(2), pp. 177-189.

Yi, R. (2025) 'Political structure and balance of power: Evidence from mid-level officials' promotion in China', *Job Market Paper*. Available at: https://harris.uchicago.edu/files/inline-files/Yi_job%20market%20paper.pdf

Zhang, C., Zhou, B. and Tian, X. (2022) 'Political connections and green innovation: The role of a corporate entrepreneurship strategy in state-owned enterprises', *Journal of Business Research*, 146, pp. 375-384.

Zhang, D., Rong, Z. and Ji, Q. (2019) 'Green innovation and firm performance: Evidence from listed companies in China', *Resources, Conservation and Recycling*, 144, pp. 48-55.

Zhang, H., Xiong, L., Li, L. and Zhang, S. (2018) 'Political incentives, transformation efficiency and resource-exhausted cities', *Journal of Cleaner Production*, 196, pp. 1418-1428.

Zheng, S., Kahn, M.E., Sun, W. and Luo, D. (2014) 'Incentives for China's urban mayors to mitigate pollution externalities: The role of the central government and public environmentalism', *Regional Science and Urban Economics*, 47, pp. 61-71.

Zheng, W., Singh, K. and Mitchell, W. (2015) 'Buffering and enabling: The impact of interlocking political ties on firm survival and sales growth', *Strategic Management Journal*, 36(11), pp. 1615-1636.

Zhong, Z. and Peng, B. (2022) 'Can environmental regulation promote green innovation in heavily polluting enterprises? Empirical evidence from a quasi-natural experiment in China', *Sustainable Production and Consumption*, 30, pp. 815-828.

Zhou, B., Li, Y.M., Sun, F.C. and Zhou, Z.G. (2021) 'Executive compensation incentives, risk level and corporate innovation', *Emerging Markets Review*, 47, p. 100798.

Zhou, F., Fan, Y., An, Y. and Zhong, L. (2017) 'Independent directors, non-controlling directors, and executive pay-for-performance sensitivity: Evidence from Chinese non-state owned enterprises', *Pacific-Basin Finance Journal*, 43, pp. 55-71.

Zhou, K.Z. and Wu, F. (2010) 'Technological capability, strategic flexibility, and product innovation', *Strategic Management Journal*, 31(5), pp. 547-561.

Zhou, K.Z., Gao, G.Y. and Zhao, H. (2017) 'State ownership and firm innovation in China: An integrated view of institutional and efficiency logics', *Administrative Science Quarterly*, 62(2), pp. 375-404.

Zhuang, Y., Wang, F., Chiu, D.K.W. and Ho, K.K.W. (2025) 'Leveraging large language models to examine the interaction between investor sentiment and stock performance', *Engineering Applications of Artificial Intelligence*, 150, p. 110602.