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CEO career horizon and innovation: A u-shaped tale of short-term profits and long-term legacy☆

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ABSTRACT

In strategic-leadership research, there is much interest in the influence of CEO's career horizon (CCH) on firm's resource investments and performance. While one line of CCH research, the traditional view, suggests that the shortening of CCH will reduce CEO risk-taking and firm's investments in radical innovation, intriguingly, a second emerging line of CCH research suggests the very opposite. The traditional view rests on the idea that CEO behavior is driven by the potential of personal gains through short-term profit optimization. Contrarily, the emerging view reflects the position that CEO behavior is driven by the potential of leaving long-term legacy by setting societal interests above personal ones. Reconciling these views, we theorize a U-shaped relationship between CCH and the pursuit of radical innovations, which recognizes that CEO motivations do not stay constant or fixed over their career trajectory. We also theorize two boundary conditions likely to attenuate this relationship: busyness of firm's board directors and firm's ownership by dedicated institutional investors. The study tests these ideas in the oil and gas industry, in which firms have opportunity to pursue radical innovations centering on renewable energies as well as incremental innovations centering on pollution reduction using traditional fossil fuels. Analysis of fifteen years of patent data for a panel of 105 firms shows support for our predictions. We discuss the study's contributions to research and practice, and its implications for policymaking to speed up transition to net-zero solutions.

1. Introduction

For a long time, innovation, especially of the radical or breakthrough type, has been viewed as the driver of growth in private wealth and public wellbeing (Perra et al., 2017; Schumpeter, 1950). The current environment of impassioned calls to *purpose*, exhorting firms to pursue not only short-term profit maximization but also long-term value creation for society (Battilana et al., 2022; Henderson, 2021), has fueled intense interest in the influence of corporate leaders on the innovation investments of firms (Cortes and Herrmann, 2021; Kurzhals et al., 2020). In response to this interest, we examine in this article how the pursuit of radical innovations by companies is affected by their CEO's career horizon (CCH), a crucial variable in research on strategic leadership (Hambrick and Mason, 1984; Heyden et al., 2017). CCH is theorized to matter for a firm's strategy and performance because it presumably regulates the CEO's risk-taking, and therefore the firm's resource allocations (Kang, 2016; Lee et al., 2018).

Interestingly, CCH literature contains two divergent views. The relatively older, traditional perspective maintains that as CCH shortens, the CEO will opt for short-term profit optimization over risky investments with uncertain returns, which may not materialize till after the CEO has retired. A core premise of the traditional perspective is that CEO actions are motivated by the lure of personal gains through, say, positive evaluations and legacy conservation (Cho and Kim, 2017; Matta and Beamish, 2008). The relatively younger, emerging perspective holds, however, that as CCH shortens, the CEO will become less short-term oriented and more open to risky investments that might not yield returns till after the CEO's departure. A core premise of the emerging perspective is that CEO actions are not motivated by the desire for immediate pecuniary and reputational personal gains but by the prospect of building and leaving legacy through investments that could benefit society (Kang, 2016; Ortiz-de-Mandojana et al., 2019).

The traditional and the emerging perspectives lead to opposing theoretical predictions regarding the effect of CCH on firm's innovation allocations. In particular, because the pursuit of radical innovations entails substantial risk and uncertainty about the size and the

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distribution of returns to investment over time (March, 1991; McDermott and O'Connor, 2002), according to the traditional perspective, a shortening career horizon will mean less emphasis on radical innovations – the emerging perspective suggests just the opposite. Notably, the two studies that have directly examined the topic report contradictory effects (cf. Cho and Kim, 2017; Ortiz-de-Mandojana et al., 2019). We offer new theory that helps reconcile the two perspectives and the mixed empirical results of past work. In this regard, instead of assuming a constantly positive or negative effect of CCH over the CEO's full career trajectory, we integrate the arguments of the traditional and the emerging perspectives to argue for a nonlinear, U-shaped effect. Our theory, as we discuss further in the article, is based on the insight that a CEO's mindset and motivations do not remain invariable or fixed over their career trajectory.

Drawing on research on corporate governance and strategic-leadership interfaces, we also specify two boundary conditions that one would expect to attenuate the theorized U-shaped relationship between CCH and firm's pursuit of radical innovations – namely, the busyness of the firm's board directors and the firm's ownership by dedicated institutional investors (Heyden et al., 2024; Oehmichen et al., 2021). We test our theory in the U.S. oil and gas (O&G) industry, which offers an ideal empirical setting for our purpose. O&G CEOs can lead their firms towards the pursuit of radical innovations centering on renewable energies as well as incremental innovations centering on pollution reduction in the fossil-fuel context. Radical renewable-energy innovations entail more risk as compared to incremental pollution-reduction innovations. As well, while the returns from the former are less certain and more distant in time than those from the latter, through the pursuit of the former CEOs have a shot at legacy construction by virtue of having dedicated themselves to the finding of sustainable, low-carbon solutions for society. Results of GEE and instrumental variables analysis of patent data (2003–2017) for a panel of 105 firms provide support for our theory.

This article makes a novel contribution to research on strategic leadership and innovation by theorizing and validating a U-shaped relationship between CCH and radical innovation. It shows that CCH matters but differently than what past work suggests (cf. Cho and Kim, 2017; Ortiz-de-Mandojana et al., 2019). In doing so, the article helps unite seemingly conflicting scholarly views on CCH, offering in the process a richer conceptualization of the interplay between CEO's shortening career horizon and a change over time in their mindset, motivation, and inclination towards risk-taking and radical innovations (cf. Lee et al., 2018; Matta and Beamish, 2008). The article thus furnishes a fertile platform for future research. It contributes further by showing that the exercise of corporate governance via the CEO – board and the CEO – institutional-investors interface can temper the effect of CCH on radical innovations. The moderating influence of board busyness and dedicated institutional investors we identify suggests that there are material consequences to both weak governance (because of board directors not having sufficient time) and strong governance (because of dedicated institutional owners focus on long-term value creation) (cf. Kang, 2016; Lee et al., 2018). These results call practitioners' attention to the challenging task of organizing governance adroitly for radical innovation (cf. Genin et al., 2023). The article also has significance for policy discussions and frameworks concerning how to spur the pursuit of radical innovations to replace fossil-fuel technologies and products with net-zero alternatives (Costantini et al., 2015; Veugelers, 2012). Because CEO and firm-level contingencies play a key role in this regard, the article suggests that it could help to supplement the use of industry-wide policies and instruments with those focusing particularly on the incentivization of CEOs with longer career horizons. We discuss the contributions and implications for research, practice, and policy in more detail in the concluding section.

2. Theory and hypotheses

In the strategic management domain, firms' strategic decisions and performance outcomes are ascribed to their chief executive officers (CEOs) (Hambrick and Mason, 1984; Hambrick and Quigley, 2014). This research field has hence generated a rich literature studying the effects of CEO cognition, emotions, personality, and physical and social traits on firms' fortunes (e.g., Huy and Zott, 2019; Kiss et al., 2020; Turner et al., 2024). With this as the context, researchers have started to show much interest in the role a CEO's career horizon (CCH) plays in affecting the firm's strategies and financial results (e.g., Krause and Semadeni, 2014; Matta and Beamish, 2008). Defined as the number of years remaining until a CEO's natural retirement, CCH is suggested to be influential because it can affect the CEO's inclination to take risks by shaping their mindset and emotional needs (Heyden et al., 2017; Lee et al., 2018; Ortiz-de-Mandojana et al., 2019; Strike et al., 2015).

The CCH literature is, however, divided on whether a shortening of the career horizon will increase or decrease the CEO's appetite for risk. One line of research, which we refer to as the traditional perspective, maintains that CEOs, to the potential detriment of their company, will avoid risk-taking as their career horizons shorten – a phenomenon that some have labeled as the horizon problem (e.g., Cho and Kim, 2017; Matta and Beamish, 2008). A second line of research, which we refer to as the emergent perspective, maintains that CEOs, driven by a desire to build legacy through valuable contributions to society, will in fact become more inclined to take risks as career horizons shorten (e.g., Ortiz-de-Mandojana et al., 2019; Strike et al., 2015). We review both perspectives in more detail in the following subsections, paying particular attention to their arguments regarding the pursuit of innovation by firms. Hereafter, we synthesize the two sets of arguments to hypothesize a more complex relationship between CCH and radical innovation than that suggested by either perspective alone.

To foreshadow our discussion below, we follow the literature in distinguishing between radical and incremental innovations (Abernathy and Clark, 1985; Acemoglu et al., 2022). At the industry level, we view radical innovations as path-breaking novel product or service solutions to the market's needs that have the potential to replace prior industry recipes. Sometimes referred to as breakthrough innovations, radical innovations follow from new-to-the-world effective re-combinations of old and new scientific and technical knowledge (Ahuja and Morris Lampert, 2001; Nerkar, 2003). Because the pursuit of radical innovations necessitates nonlocal exploratory search and experimentation along untested pathways, they entail significant risk-taking and there is no certainty about the size and the temporal distribution of eventual returns from the efforts and resources expended (March, 1991; Sidhu et al., 2007). In contrast, we view incremental innovations as path-following gradual improvements in products and services that add value for the market through improved efficiency and functionality (Heyden et al., 2012; Wojan et al., 2018). Because the pursuit of incremental innovations involves local exploitative search that builds on existing knowledge and competencies to introduce relatively minor product or service improvements, they entail less risk-taking and there is greater certainty about returns (March, 1991; Sidhu et al., 2007).

To add to the above, past research indicates that the characteristics of a company's executives can influence the company's focus on incremental versus radical innovations. Several studies find, for example, that the educational background and the functional and industry experiences of executives determine the relative emphasis on pursuing incremental and radical innovations (Heyden et al., 2012; Sidhu et al., 2020). Furthermore, studies suggest that psychological factors such as the CEO's cognitive style (e.g., De Visser and Faems, 2015) and regulatory focus (e.g., Tuncdogan et al., 2015) can affect the attention paid to incremental versus radical innovations. Furthermore, new research indicates that aspects of the CEO's personality such as humility and narcissism may also matter for incremental versus radical innovations (e.g., Nie et al., 2022;You et al., 2023). We complement this body of

work by examining the effect of CEO's career horizon (CCH) on innovation.

2.1. A traditional view of legacy conservation, myopic short-termism, and CEO risk-taking

In the wake of Hambrick and Mason's (1984) foundational upper-echelons framework, it has often been suggested that as CEOs' career horizon (CCH) becomes shorter, they start to eschew risk-taking. Researchers typically invoke the ideas of legacy conservation and myopic short-termism to motivate this behavioral tendency. Hambrick and Mason (1984: 198) put it thus when reflecting on the reasons why older CEOs tend to take less risks: "[They] may be at a point in their lives at which financial security and career security are important. Their social circles, their spending traits, and their expectations about retirement income are established. Any risky actions that might disrupt these generally are avoided." Building on this, some scholars surmise that because CEOs' will want to protect their existing legacy and short-term performance successes, both of which can be expected to yield positive labor-market evaluations, they will avoid risky investments involving performance uncertainty. In support of this thesis, Matta and Beamish (2008) find that CEOs with shorter career horizons, who have high levels of in-the-money unexercised options and equity holdings, are less likely to engage in international acquisitions. Kang (2016) shows further that CEOs who are nearing retirement and face weak labor-market pressure, are likely to conserve their established legacy by minimizing commitment to CSR, an investment with an uncertain payoff.

One strand of the CCH literature maintains, thus, that as career horizons shorten, CEOs will prefer strategies that improve current performance and will avoid the riskier ones, the returns from which are uncertain, likely too distant in time to be of personal gain, and which may adversely affect existing legacy. One implication of this is that because the pursuit of radical innovation entails substantial risk, CEOs who are approaching retirement will have greater aversion to it than CEOs with longer career horizons. There is some support for this theory. Dechow and Sloan (1991) show that CEOs spend less on R&D in their final years in office, an effect that is lessened however by CEO stock ownership. Cho and Kim (2017) show moreover that CEOs with shorter career horizons produce fewer breakthrough innovations, an effect that is partially mediated by R&D spending (cf. Cazier, 2011). Akin to this, Lee et al. (2018) show that CEOs with shorter career horizons are less inclined to make real options investments, because they may not reap the rewards of investing in long-term goals during their tenure. Adding to this, Aktas et al. (2021) show that even exogenous shocks which shorten CCH (e.g., serious illness) are related to cuts in R&D, consistent with the view that retirement proximity engenders short termism.

While shorter career horizons are expected to be linked to less risk-taking and the pursuit of radical innovations, it is accepted that the relationship may depend on other corporate leadership and governance variables, such as, TMT age and tenure (e.g., Heyden et al., 2017) and block-holder stock ownership (e.g., Oh et al., 2016). Furthermore, notably, everyday observation and anecdotal evidence indicate that not all CEOs nearing retirement are risk averse, as evident in their willingness to pursue radical innovations. As a case in point, Bill McNabb, the former CEO of Vanguard (a large U.S. investment advisor), vigorously pursued radical change in the firm's business model when he was close to retirement in 2018. When asked about this, he is said to have replied: "You have to be willing to give things up that really are painful in the short run if you want long term success" (Reiss, 2021). Likewise, Ben van Beurden, the ex-CEO of Royal Dutch Shell, invested substantially in risky renewable-energy patents when nearing his retirement age (Reuters, 2017; Shell, 2022). Yet another example, Boone Pickens, former Chairman of BP Capital Management, "underwent a conversion to [risky] renewables in later life", after a 50-year career in the O&G industry (Times, 2019:1).

2.2. An emerging view of legacy building, long-termism, and CEO risk-taking

A nascent stream of research suggests, however, that shorter career horizons do not necessarily incline CEOs towards less risk-taking. Indeed, this research holds that the desire to build legacy, through actions that could provide long-term benefits to humanity, can foster greater risk-taking as CEOs near retirement. Illustrating this, the CEOs of power plants have been noted to have made investments in renewable energy, even though they knew that these would not increase short-term performance (Ortiz-de-Mandojana and Aragon-Correa, 2015; Ortiz-de-Mandojana et al., 2019). To explain CEOs' appetite for building legacy rather than simply conserving existing legacy and enhancing current performance, CCH researchers draw on the concept of people's time perspective (e.g., Wang and Bansal, 2012; Zimbardo and Boyd, 2008). This work suggests that as career horizons shorten and people have longer lengths of time they can look back over (i.e., people have greater temporal depth), they simultaneously tend to look farther into the future (Bluedorn, 2002; Zimbardo and Boyd, 2008). Ortiz-de-Mandojana et al. (2019) argue cogently that executives who have a future time orientation because of greater temporal depth, will pay more attention to the long-term societal implications of their actions and will be less concerned about immediate financial results.

The emergent CCH literature holds, thus, that as career horizons shorten, CEOs will show more interest in building fresh legacies through decisions that have beneficial consequences for society, even if the decisions are risky and do not serve the executives' self-interests (Ortiz-de-Mandojana et al., 2019; Wade-Benzoni et al., 2010). Besides the time perspective's effect, additional reasons have been identified for this behavioral tendency. As people grow older, their emotional needs get prioritized. Thus, as CEOs approach retirement age, one can expect greater salience of the emotional meaning they derive from legacy-building actions of value to society (Carstensen et al., 2003; Strike et al., 2015). These can engender emotional satisfaction because the CEO can expect a positive post-retirement impact on the generations to come and be remembered in a favorable light (see also, Carstensen et al., 2003; Doerwald et al., 2021). A similar focus on legacy building by retiring CEOs is indicated by research that draws on the psychosocial concept of generativity, which refers to one's outlook towards future generations (e.g., Doerwald et al., 2021; Joshi et al., 2021). This work suggests that CEOs become more altruistic and other-oriented as their careers head towards closure, which makes myopic short-termism less likely; rather, retirement approaching CEOs should be more willing to take risky decisions that can yield benefits for the next generation.

As regards CEOs' inclination towards radical innovation, the above discussion implies that the traditional view of CCH stands in contrast to the emergent CCH view. The latter perspective suggests that CEOs with shorter career horizons will exhibit less aversion to investing in radical innovations than CEOs with longer career horizons, especially if the innovations have potential to improve societal welfare. Several studies offer some indirect and direct support for this theory. Wade-Benzoni et al. (2010) show in a set of experiments that, indeed, concern for one's legacy and a self-other tradeoff are related to greater affinity with future generations. Complementing this study, Strike et al. (2015) show that CEOs nearing retirement in family firms continue to be innovative, in that, they are willing to engage in risky entry into new markets through international acquisitions. In addition, Kang (2016) finds that the building of legacy matters for CEOs, in that, the negative effect of CEO retirement on firm's commitment to CSR, a long-term investment, is weakened when CEOs retire at relatively older ages.

Although the traditional and the emergent CCH perspectives give rise to opposing predictions, they both present compelling underlying arguments. In the light of the mixed empirical results to date, which provide some support for both viewpoints, we maintain that an integration of the two should lead to more refined theory and a set of more clear-cut findings regarding the relationship between career horizons of

CEOs and firms' innovation investments. In particular, we submit that the CCH – radical innovation relationship is likely to be more complex than the linear one suggested individually by the two perspectives. In line with this, below we hypothesize a nonlinear U-shaped relationship based on a synthesis of the two perspectives. We also hypothesize two boundary conditions that can be expected to influence the U-shaped relationship.

2.3. CCH and radical innovation

Whereas the traditional perspective suggests a CCH – radical innovation relationship that is continually negative or downward sloping as the career horizon shortens, the emergent CCH perspective suggests a continually positive or upward sloping relationship. On their own, these contradictory linear-relationship predictions overlook the fact that because the mindset, the needs, and the motivations of a CEO are unlikely to remain constant over their career trajectory, CEO's willingness to take risks and invest in radical innovations can be expected to change over the course of a shortening career horizon. To illustrate, as the career horizon of a new CEO shortens initially, their need for short-term successes to, say, get positive shareholder and labor-market evaluations, may trump their emotional need to build legacy via actions that benefit society and future generations. However, as the same CEO's career horizon shortens further, the self-other tradeoff can be expected to change, such that, the CEO's concern for the long-term societal implications of their decisions may become more salient and begin to trump the concern for short-term results.

The arguments of the proponents of the traditional and the emergent CCH perspectives, when assimilated, seem to suggest a U-shaped relationship between CCH and the firm's pursuit of radical innovations. When CEO retirement is still a while away, it is easy to envision that a CEO would prioritize short-term profitability gains over risky investments that may or may not deliver positive returns (see also, Cho and Kim, 2017; Dechow and Sloan, 1991). As such, the CEO is likely to direct the firm towards the pursuit of relatively safer incremental innovations rather than the pursuit of experimental, commercially unproven ideas. This strategy offers the CEO a more certain, self-serving pathway to favorable evaluations that increase their CEO labor-market attractiveness and safeguard their legacy as an effective executive (cf. Kang, 2016; Matta and Beamish, 2008). However, over time, as the CEO becomes well established and can take some risks without the fear of jeopardizing their reputation and career prospects should an investment strategy fail, the CEO's openness to radical innovations should grow gradually. The potential for bigger gains from riskier strategies can motivate longer tenured CEOs – who have a mid-range career horizon and a more fine-tuned understanding of industry risk-return payoffs than CEOs whose career end is further away – to explore path-breaking avenues (cf. Sidhu et al., 2020; Simsek, 2007). As such, while continuing to champion the pursuit of incremental innovations at the mid-range stage, the CEO can also be expected to stimulate their firm to go after innovations that are more radical.

With the additional passage of time, as the CEO's career advances and retirement appears on the radar and draws ever closer, the appetite for radical innovations should be fueled further by changes in the CEO's time perspective, the emotional need to build legacy, and the relative concern for society versus an attachment to self-interest (e.g., Ortiz-de-Mandojana et al., 2019; Wade-Benzoni et al., 2010). In this last stretch of a CEO's career, as the focus on personal gains become less salient, the pursuit of radical innovations, especially if society stands to benefit from them, offers an alluring pathway to fulfill the need for leaving a lasting mark and be memorialized in good light by posterity. This theory is consistent with the traditional CCH perspective as regards the initial shortening of CCH, and is in line with the emergent CCH perspective as regards the subsequent shortening of CCH.

To illustrate the U-shaped relationship in the context of the oil and gas (O&G) industry, O&G executives can invest in incremental as well as radical innovations (Perrons, 2014; Yin, 1994). The pursuit of incremental innovations centers routinely on achieving advances in pollution reduction, fossil-fuel extraction, and safety by investing in path-following additive improvements in processes and technologies (cf. Alagoz et al., 2023; Hurley and Hunter, 2014). It carries lesser risk of failure and offers greater certainty regarding an increase in short-term performance than the pursuit of radical innovations. The latter entails path-breaking nonlocal search and experimentation along technically, technologically, and economically unproven avenues to develop green renewable-energy solutions to replace fossil-fuel based products – it is riskier as there is uncertainty about whether it will bear fruit and the expected value and timing of returns (cf. Hartmann et al., 2021; Perrons, 2023). Also, pursuing renewable-energy innovations is more difficult than pursuing pollution-reduction innovations because firms must build the essential breadth and depth of knowledge internally and/or source it by collaborating with external partners (see also, Doblinger et al., 2019; Fabrizi et al., 2018). Importantly, while incremental O&G innovations offer a route to self-serving short-term financial successes, radical O&G innovations offer a route to long-term legacy by birthing society-serving solutions for the pressing need to reduce carbon emissions for sustainable development (Ortiz-de-Mandojana et al., 2019; United Nations, 2015).

The relationship we theorize predicts that as O&G CEOs' career horizons shorten initially, O&G firms will be less focused on pursuing radical renewable-energy innovations and will be more focused on pursuing incremental pollution-reduction innovations to score short-term successes. As career horizons shorten further, however, the balance will change to include more pursuit of radical innovations as the CEOs become established and their careers are less vulnerable should riskier ventures fail. With the career horizons shortening still further and retirement coming much closer, the firms should become progressively more attentive to radical renewable-energy innovations to establish CEOs' long-term legacy and should become less attentive to incremental pollution-reduction innovations. Many anecdotal examples seem to support the theorized relationship. For instance, at the Chevron Corporation, the innovation-portfolio mix started to lean more towards renewable energy patents nearer to the retirement of Dave O'Reily, the company's chairman and CEO (Chevron, 2008). Similarly, Archie Dunham, the former CEO of ConocoPhillips, when approaching retirement at the age of 63 years, spurred his company to pursue renewable energy patents instead of patents connected to fossil-fuel innovations (Transformation, 2023). We anticipate a similar relationship between CCH and innovation in other industries as well. Summing up our discussion, we formally propose the following hypothesis:

Hypothesis 1. *There is a U-shaped relationship between CEO's career horizon (CCH) and firm's pursuit of radical innovations, such that, the pursuit of radical innovations relative to incremental innovations will first decrease and then increase as CCH shortens.*

2.4. Boundary conditions for the CCH – radical innovation relationship

The upper-echelons literature as well as the literature on strategic governance maintain that internal and external corporate governance actors such as boards and investors have considerable sway over firm's strategy (Bosboom et al., 2019; Shi and Hoskisson, 2021). In this context, research on strategic-leadership interfaces, the purposive contact points where the separate worlds of corporate leaders intersect (Georgakakis et al., 2022; Simsek et al., 2018), suggests the busyness of the directors of the firm's board and firm's ownership by dedicated institutional investors as two important variables that could affect the U-shaped relationship between CCH and radical innovation. We discuss this next.

2.4.1. CCH, radical innovation, and board busyness

The firm's board collectively and the board directors individually,

advice and monitor the executive function and can be a valuable source of informational and relational assets because of directors' inter and intra-industry experiences, knowledge, and networks (Hillman and Dalziel, 2003; Simsek et al., 2018). Indeed, researchers have theorized and found that the board's strategic advice to the CEO and the provision of access to informational and relational assets can promote innovation, including breakthrough innovation (Helmers et al., 2017; Robeson and O'Connor, 2013). Studies indicate further that the more the ties directors have to other firms and outside organizations, the more the breadth and depth of externally located resources available to the focal firm, which can be helpful from the viewpoint of pursuing radical as well as incremental innovations (Chang and Wu, 2021; Li, 2021). However, there is a downside to directors' outside ties – if the board's directors have an excessive number of external positions and roles, a possibility captured by the concept of board busyness (Harris and Shimizu, 2011; Heyden et al., 2024), the limits on time and energy are likely to translate into less opportunity to advice and guide the CEO (cf. Ferris et al., 2003; Field et al., 2013). We expect board busyness to be especially detrimental for the pursuit of radical innovations for two related reasons.

First, because the pursuit of radical innovations customarily requires new-to-the-firm scientific, technical, and organizational knowledge and insights from beyond the firm and industry boundaries (Balachandran and Hernandez, 2018; Rosenkopf and Nerkar, 2001), more board busyness will mean lesser engagement and input from board directors to inform the CCH driven focus on radical innovations. In fact, it is plausible that very busy directors may not even have the time to develop a proper understanding of the firm's competencies, and its further knowledge needs for pursuing radical innovations. When board busyness is less, conversely, board directors are better placed to contribute their expertise through more extensive and frequent interpersonal interactions, strengthening the CCH – radical innovation relationship. Second, as more board busyness reduces the board's ability to effectively monitor the executive function (Fich and Shivdasani, 2006), the board can become outcome oriented in its evaluation of the CEO (Boivie et al., 2016; Makri et al., 2006). Because outcome-oriented boards lay more emphasis on short-term financial returns instead of risky future-oriented ventures (Shi and Hoskisson, 2021), we expect board busyness to weaken the CCH – radical innovation relationship due to directors' preference for the less risky incremental innovations. Formally we propose the following hypothesis:

Hypothesis 2. *As board busyness increases, the U-shaped relationship between CCH and firm's pursuit of radical innovations will weaken, such that, the pursuit of radical innovations relative to incremental innovations will increase less as CCH shortens.*

2.4.2. CCH, radical innovation, and dedicated institutional-investor ownership

Institutional investors, such as, banks, hedge funds, insurance companies, mutual funds, and pension funds are said to be dedicated when they have a long investment horizon and display high stability in their continued ownership of a firm's stock (Bushee, 1998; Connelly et al., 2010). Increase in firm's dedicated institutional ownership, increases their influence on CEO's strategic decisions because they can exercise more voice through voting rights, collective actions, and the threat of exit by selling their holdings (David et al., 1998; Parrino et al., 2003). In view of their substantive stake in the firm, dedicated institutional owners monitor the CEO scrupulously and are closely attuned to the firm's R&D activities and performance, providing counsel and guidance through direct conversations as well as by voting for or against executive proposals (e.g., David et al., 2001; Shi et al., 2017). They are widely accepted to attach less importance to short-term financial results and to put more emphasis on strategic investments that could create long-term value by virtue of being path-breaking and unique (David et al., 2001; Oehmichen et al., 2021). Towards this end, dedicated institutional owners invest intensively in developing a thorough understanding of the firm's competencies and value-creating opportunities and processes (Connelly et al., 2010; Shi et al., 2017).

Furthermore, studies find that dedicated institutional owners shield the CEO from short-term shareholder pressures and increase the CEO's tolerance for failure of riskier, exploratory ventures (Connelly et al., 2019; Zhang and Gimeno, 2016). In the light of the above points, more of dedicated institutional ownership should promote CEO's willingness to pursue radical innovations that have the potential to increase long-term value in line with the dedicated institutional owners' investment horizon. Indeed, even a CEO who is at an early stage of their career and whose retirement is a long way off, should be less concerned about scoring short-term performance successes should a greater portion of the firm's shareholding be with future oriented investors. In effect, by alleviating the CEO's fear of personal loss to reputation and career prospects, greater dedicated institutional ownership should encourage the CEO to stimulate firm's pursuit of radical innovations despite the higher risk involved as compared to the pursuit of incremental innovations. The foregoing implies an attenuation of the U-shaped relationship between CCH and radical innovation. In particular, as compared to less dedicated institutional ownership, more ownership will result in less initial decline in the emphasis on radical innovations as CCH contracts after CEO's appointment in the role. There will thus be a smoothening of the U-shaped relationship as dedicated institutional ownership increases. Formally we propose the following hypothesis:

Hypothesis 3. *As dedicated institutional ownership increases, the U-shaped relationship between CCH and firm's pursuit of radical innovations will weaken, such that, the pursuit of radical innovations relative to incremental ones will decrease less at first as CCH shortens.*

3. Methods

3.1. Research setting and operationalization of radical and incremental innovations

The empirical setting of this study is the U.S. oil and gas (O&G) industry. It presents an ideal context to test our hypotheses because O&G CEOs have abundant opportunity to lead their firms towards the pursuit of radical as well as incremental innovations. In particular, the industry offers opportunity to pursue path-breaking radical innovations centering on renewable energies as well as path-following incremental innovations centering on pollution reduction in the context of traditional fossil fuel usage. As per our conceptualization of radical and incremental innovations, radical renewable-energy innovations depend on boundary-spanning search and experimentation, the returns from which are less certain and more distant in time as compared to those from incremental pollution-reduction innovations. Even though the radical renewable-energy innovations based on, say, the use of solar, water, and wind power may not contribute to the firm's performance in the near term, they hold the promise of affordable, clean, and reliable energy for future generations, and thus afford the chance to build and leave legacy. On the other hand, incremental pollution-reduction innovations related to, say, drilling techniques, leak detections and repairs, and pollution control through improvements in soil vapor extraction and other means carry less risk and more guarantee of contributing to the firm's short-term profitability.

The description of the research setting makes it clear that any effect of CCH on the pursuit of radical and incremental innovations should be identifiable in the O&G industry. We relied on patent data to operationalize the firms' pursuit of innovations. There is a caveat to using patent data as indicator of inventive activity, i.e., pursuit of innovations, because not all innovations are necessarily patented (e.g., Jaffe and Trajtenberg, 2002). However, this is less so the case in industries with high capital expenditures, such as chemicals, oil and gas, and pharmaceuticals, where firms vigorously file patents to protect their discoveries, inventions, and knowledge from competitors (e.g., Arundel and Kabla,

1998). Also, as our focus here is not in firms' absolute levels of innovation but on firms' relative emphasis on radical and incremental innovation, patent data provides an objective, useful approach for longitudinal cross-sectional studies such as ours. We collated data on patents filed by U.S. firms from 2003 to 2017. We decided on the year 2003 because of the enactment of the Sarbanes-Oxley Act (SOX) in 2002. As the impact of this on corporate governance might have influenced the risk appetite of CEOs, we considered it prudent to focus on the post-SOX period. We decided on the year 2017 because of the U.S. presidential election in 2016. As the new administration's agenda and goals vis-à-vis environmental regulations and sustainability could have influenced innovation activity after 2017, we concluded 2017 to be a good cut-off point.

3.2. Data sources

To assemble patent data, we used the CleanTech PatentEdge database, NBER Patent Project data, Harvard Patent Dataverse data, and WRDS Patent data. For data on firms' CEOs and board directors, we used the BoardEx database. For firm-level and industry-level data, we used multiple sources. In this context, the procedure we followed was to first match the BoardEx database with the Compustat database, and then match this with the data on institutional ownership from Thomson Reuters. We included all firms in our dataset that had filed at least one successful patent application between 2003 and 2017 – we used this inclusion criterion with a view to exclude O&G firms whose business was solely the sales, storage, and transportation of oil and gas. Our data sample comprised 105 firms and 962 firm-year observations.

3.3. Variables

3.3.1. Dependent, independent and moderator variables

As our dependent variable is a firm's pursuit of radical innovations relative to incremental innovations, we proceeded as follows to establish, per firm-application year (Griliches, 1990; Lee et al., 2020), whether there was greater or lesser propensity towards radical innovation. From a firm's number of renewable-energy patents, we subtracted the number of pollution-reduction patents, and then divided this figure by the sum of the two patent types. Using this measure, higher positive values indicate greater propensity towards radical innovation, higher negative values indicate lesser propensity towards radical innovation, and a zero value indicates equal propensity towards radical and incremental innovation. We should note that renewable-energy and pollution-reduction patents were identified based on the matching of keywords developed by the Cleantech Group with those contained in the title, abstract, and claims of patents. For example, US7851936B2 (*Water current power generation system*) and US7867457B2 (*Plasma reactor for the production of hydrogen-rich gas*) were identified as renewable-energy patents; and US8439648B2 (*Process water lift station apparatus*) to detect leaks and US7901486B2 (*Removal of heavy metals from hydrocarbon gases*) to prevent contamination were identified as pollution-reduction patents.

As for our independent variable, CEO career horizon, we followed precedent in measuring it as the number of years remaining before a CEO turned 70 years old, the presumed average age of retirement (Krause and Semadeni, 2014; Matta and Beamish, 2008). Lower values of the CCH measure indicate a shorter career horizon. As for our moderator variable, board busyness, we used the proportion of independent directors holding three or more directorships outside the O&G industry as our indicator (Fich and Shivdasani, 2006; Oehmichen et al., 2021). As regards dedicated institutional ownership, the second moderator variable, we measured this as the percentage of firm's shares held by institutional investors having a low portfolio turnover, low earnings sensitivity, and focused portfolio holdings (Bushee, 1998; Connelly et al., 2019).

3.3.2. Control variables

We included a comprehensive set of control variables in our analysis. Specifically, we controlled for CEO – board power-differential (measured as the difference between CEO tenure and independent directors' average tenure) (Graf-Vlachy et al., 2020), CEO duality (Kavadis et al., 2022), and the proportion of independent directors (David et al., 2001), because these variables can affect strategic decisions. We also included controls for firm's size and slack resources using, respectively, the natural logarithm of the number of employees and the natural logarithm of cash holdings (Matta and Beamish, 2008). To account for the potential effects of capital investments and investments in non-environmental innovations, we used the natural logarithm of capital expenditures and the standardized number of non-environmental patent applications per firm year (Berrone et al., 2013). We also included the debt-to-equity ratio and the earnings per share (EPS) in our models to control for the effects of financial risk and performance respectively. In addition, to account for macroeconomic effects, we included three-digit SIC dummies and year dummies.

3.4. Estimation technique

We used generalized estimating equations (GEE), a widely used estimation technique in the context of strategic-leadership research (Henderson et al., 2006; Heyden et al., 2017; Sidhu et al., 2020). It is especially well suited for examining cross-sectional time-series data such as ours, because non-independent repeated observations of firms can be handled by specifying the correlation structure of the error term. As our dependent variable was distributed normally, we used a Gaussian distribution and an identity link function to estimate models. Regarding the structure of the error term, we opted for exchangeable correlation to account for the possibility that observations of firms in different years might not be fully independent. To capture causality, we lagged the independent, moderator, and control variables by one year. To correct for potential autocorrelation and heteroscedasticity, we used robust standard errors clustered at the firm level.

3.4.1. Correcting for potential endogeneity

Endogeneity is a key concern in management research. In our context, CCH and innovation could, for example, covary because of unobserved latent factors and lead to biased parameter estimates. To correct for this, we conducted instrumental variables (IV) analysis. IV quality depends on the availability of instruments that satisfy the criteria of relevance and exogeneity. In this respect, we identified three variables that, prima facie, seemed satisfactory: (i) the US consumer price index (CPI) in the year of birth of a CEO, (ii) the US male and female body mass indices (BMI) in the year of birth of a CEO, and (iii) the US male and female blood pressure indices (BP) in the year a CEO turned 40-years old. Intuitively, all three variables seem to satisfy the relevance criterion because they are exogenously determined. As CPI (a macroeconomic factor) and BMI (a social, genetic factor) tend to increase over time, they can be expected to show positive covariation with longer CCH; thus, CPI and BMI should be higher for CEOs born later in time, who have longer to go before retirement. And as BP (a human age-related factor) tends to increase as CCH wanes, it should show negative covariation with longer CCH. Moreover, while we can expect CPI, BMI, and BP to correlate with CCH, we can expect them to be orthogonal to the dependent variable.

To establish the statistical relevance and exogeneity of CPI, BMI, and BP as instruments, we performed a range of diagnostic checks. In support of the relevance of the instruments, we could rule out under-identification because the Kleibergen-Paap rk LM statistic indicated that the instruments were significantly correlated with CCH ($p < 0.001$). Furthermore, we could rule out weak-identification because the Kleibergen-Paap Wald rk statistic (F-value: 154.2) exceeded Stock-Yogo critical value of 13.4 for a relative bias of 10 % or less. Furthermore, providing support for the instruments exogeneity, the Hansen J-statistic

could not reject the null hypothesis of the instruments being exogenous and uncorrelated with the error term ($p = 0.557$). These results strongly supported the use of the three as instruments. On a practical note, data for the three variables was available for almost all observations in the dataset (viz. 945 out of 962 observations). We thus used the three to instrument CCH and conducted a two-stage IV analysis. The results of both GEE and IV analyses are shown in Table 2.

4. Results

4.1. Main results

Table 1 shows the descriptive statistics and correlations. Inspection of the table does not indicate any unusual values. As all correlations are at $r < 0.70$, and as all variance inflation factors were below the threshold value of 10 (the maximum value being 3.94), multicollinearity is not indicated. Table 2 shows the regression results. Model 1 in the table is based on the inclusion of only the control variables; Model 2 includes additionally the CCH linear term; next, Model 3 includes also the squared CCH term to test the predicted U-shaped effect of CCH. Models 4 and 5 include further the terms relevant for testing the two predicted moderation effects one by one. Model 6, the full model, includes all the main and interaction terms. Lastly, Model 7 is the IV estimation of Model 3 using the instrumented CCH variable to correct for potential bias due to endogeneity.

In Model 2, the CCH coefficient is not statistically significant at the 0.1 level, indicating the absence of a significant linear effect of CCH. In Model 3, however, with the inclusion of the squared CCH term, the negative coefficient of the CCH term becomes significant ($p < 0.01$). Moreover, the positive coefficient of the squared CCH term is significant ($p < 0.001$) as well.[1] These two statistically significant coefficients, together, support Hypothesis 1, which predicted a U-shaped relationship between CCH and firm's pursuit of radical innovations. The finding is presented visually in Fig. 1. Notably, Model 7 results, which are based on IV analysis, also show a statistically significant negative coefficient for the CCH term ($p < 0.10$) and a statistically significant positive coefficient for the CCH squared term ($p < 0.05$). The U-shaped relationship is thus again supported. In terms of effect size, while this is 0.89 for the downward sloping part of CCH, it is 1.14 for the upward sloping part of CCH.[2] Thus, CCH change from its minimum to its mean value decreases the dependent variable by a factor of 3.16. This means that in the case of CEOs at the minimum CCH level, firms are 3.16 times more likely to pursue radical innovations as compared to those whose CEOs are at the average CCH level. Further, CCH change from its mean to its maximum value increases the dependent variable by a factor of 7.24, which implies that firms whose CEOs have shorter career horizons are more likely to pursue radical innovations as compared to those whose CEOs are at the average CCH level. These results can be interpreted to indicate an economically meaningful relationship.

The results of Model 4 support Hypothesis 2, which predicted that the U-shaped relationship between CCH and firm's pursuit of radical innovations will weaken as board busyness increases. Both the relevant interaction terms are significant ($p < 0.05$). To facilitate interpretation, Fig. 2 displays the relationship visually. It shows that while the CCH – radical innovation is U-shaped when board busyness is low, the relationship flattens when board busyness is high, such that, the pursuit of radical innovations (relative to incremental innovations) increases less as CCH shortens. Furthermore, the results of Models 5 and 6 support Hypothesis 3, which predicted that the U-shaped relationship between CCH and firm's pursuit of radical innovations will weaken with an increase in firm's ownership by dedicated institutional investors. Both the relevant interaction terms are significant in the full model ($p < 0.05$). Fig. 3 displays the relationship visually, showing a smoothening of the U-shaped CCH – radical innovation relationship when ownership by dedicated institutional investors is high.

4.2. Supplementary analysis

We performed several tests to establish the robustness of our findings. First, we repeated the analysis using different measures of CCH. In this regard, we calculated the mean CCH by industry – at the (i) SIC 3-digit level, and (ii) SIC 4-digit level – and year, creating industry-adjusted measures to test the robustness of the observed main effect of CCH on radical innovation. The results, in the case of (i) as well as (ii), were similar to the one reported above, indicating a statistically significant U-shaped relationship – see Models 1 and 2 in Table A1 in the Appendix. Next, we constructed a CCH measure incorporating the dimensions of CEO age and tenure, and adjusted by industry – at the (i) SIC 3-digit level, and (ii) SIC 4-digit level – and year (Lee et al., 2018). Again, the results for the U-shaped relationship were the same – see Models 3 and 4 in Table A1 in the Appendix. Next, using the *textual network industry classification* (TNIC) database (Hoberg and Phillips, 2016), we constructed a CCH measure incorporating the dimensions of CEO age and tenure, adjusted by the mean values for peer firms. The TNIC database, which draws from firms' 10-K product descriptions to establish which firms are alike at a given point in time, identifies a time-varying peer group of firms. Again, we found a statistically significant U-shaped relationship – see Model 5 in Table A1 in the Appendix. These tests attest to the robustness of the curvilinear relationship we report.

We conducted a further series of analyses to enhance confidence in our findings. First, we tested our hypotheses using 65 years (instead of 70 years) as the CEO age cut-off point to compute CCH (Cho and Kim, 2017; Oh et al., 2016). Recent studies have at times taken 65 years as the cut-off point to measure CCH, which is in line with the CEO retirement age identified by the Conference Board in the U.S. Second, we tested the robustness of the findings using alternative time-lags. For this, we computed the dependent variable by averaging the propensity towards radical innovation over the two years that followed the year of observation of the CCH and other predictors. Third, we restricted our sample to include only those firms that had a prior record of either radical or incremental environmental innovations (i.e., total environmental patents ÷ total patents >10 %) during the sampling period. In the case of all three analyses, the results, which are available upon request, indicated a U-shaped CCH – radical innovation relationship. Furthermore, we also examined whether the results were sensitive to changes in the set of control variables. Thus, we ran the regression models after including bonuses and CEO pension packages to control for a potential effect of compensation on innovation. We also estimated the regression models after including CEO tenure in the firm as a control variable. The results, which are available upon request, were consistent with those obtained without the inclusion of these additional controls.

This study drew a distinction between radical and incremental innovations at the industry level, viewing renewable-energy innovations as radical and pollution-reduction innovations as incremental (cf., Hartmann et al., 2021; Katila, 2000). This distinction follows the literature since the two differ in terms of the nature of search and experimentation they involve (exploratory versus exploitative), the risk they entail (more versus less), and the temporal distribution of returns (short term versus distant future). It would also be of value however to ascertain whether the renewable-energy and pollution-reduction

[1] We also tested curvilinearity to establish that the slopes on both sides of the turning point were statistically significant (Haans et al., 2016). Both the lower bound ($p = 0.001$) and the upper bound ($p = 0.001$) of the observed relationship were significant, and the overall presence of a U-shaped relationship was also confirmed ($p = 0.001$). We checked additionally whether our data suggested a cubic (S-shaped) relationship rather than a quadratic relationship. The cubic term for CCH was not statistically significant.

[2] Effect size is calculated as the exponent (to base 10) of 1 S.D. change in the explanatory variable multiplied by the relevant estimated coefficient (Narayan et al., 2021).

Table 1
Descriptive statistics and correlations.

		1	2	3	4	5	6	7	8	9	10	11	12	13
1	Radical innovation	1												
2	CEO – board power difference	−0.011	1											
3	CEO duality	0.012	0.099	1										
4	Board independence	−0.007	−0.042	0.238	1									
5	Firm size	−0.043	−0.111	0.171	0.417	1								
6	Firm slack	0.005	−0.154	0.103	0.426	0.681	1							
7	Capital expenditure	0.026	−0.139	0.111	0.333	0.563	0.652	1						
8	Non-environmental innovations	−0.073	−0.038	−0.012	0.054	0.016	0.041	0.041	1					
9	Financial risk	0.027	0.051	0.016	−0.021	−0.042	−0.067	0.025	−0.026	1				
10	Financial performance	0.014	−0.092	0.105	0.107	0.349	0.291	0.296	−0.022	−0.087	1			
11	Board busyness	0.049	−0.139	0.075	0.116	0.401	0.363	0.329	−0.044	−0.034	0.167	1		
12	Dedicated institutional ownership	0.001	0.082	0.045	−0.078	0.065	0.085	0.104	0.012	−0.021	0.087	0.197	1	
13	CEO's career horizon	0.034	−0.018	−0.298	−0.021	−0.075	−0.032	−0.106	−0.018	−0.048	−0.036	−0.055	0.059	1
	Mean	−0.007	−0.831	0.447	0.745	1.484	4.458	5.781	0.023	0.780	1.415	0.092	0.031	12.344
	SD	0.322	4.801	0.497	0.162	1.184	2.523	2.385	0.954	3.125	3.811	0.153	0.076	6.805
	Min	−1.000	−19.200	0.000	0.143	0.000	−4.343	−0.111	−1.785	−15.691	−13.030	0.000	0.000	−11.600
	Median	0.000	−0.912	0.000	0.800	1.362	4.484	6.054	−0.292	0.469	1.035	0.000	0.000	12.500
	Max	1.000	18.263	1.000	0.941	4.820	10.434	10.545	4.007	21.520	11.290	1.000	0.638	35.300

N = 962; Correlations above |0.060| are significant at $p < 0.05$.

Table 2
CEO's career horizon and radical innovation.

				GEE			IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
CEO – board power difference	−0.002	−0.002	−0.003	−0.003	−0.003	−0.003	−0.003
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
CEO duality	0.021	0.026*	0.026*	0.021	0.025*	0.020	0.026*
	(0.015)	(0.016)	(0.015)	(0.016)	(0.015)	(0.016)	(0.015)
Board independence	0.113	0.107	0.123	0.121	0.124	0.123	0.124
	(0.083)	(0.085)	(0.083)	(0.083)	(0.082)	(0.082)	(0.083)
Firm size	−0.037	−0.037	−0.039*	−0.039*	−0.039*	−0.039*	−0.040*
	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)
Firm slack	−0.004	−0.004	−0.003	−0.002	−0.003	−0.002	−0.002
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Capital expenditure	0.014**	0.014**	0.014**	0.012**	0.014**	0.013**	0.014**
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Non-environmental innovations	−0.019*	−0.019*	−0.019*	−0.018*	−0.019*	−0.019*	−0.018*
	(0.011)	(0.011)	(0.010)	(0.010)	(0.010)	(0.010)	(0.011)
Financial risk	0.001	0.002	0.001	0.002	0.001	0.001	0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Financial performance	0.000	0.000	0.000	0.000	0.000	0.000	0.001
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Board busyness	0.146	0.147	0.151	−0.167	0.154	−0.185	0.148
	(0.101)	(0.101)	(0.100)	(0.272)	(0.100)	(0.269)	(0.101)
Dedicated institutional ownership	0.017	0.008	0.024	0.013	−0.183	−0.350	0.028
	(0.095)	(0.098)	(0.097)	(0.096)	(0.380)	(0.371)	(0.097)
CEO's Career horizon (CCH)		0.001	−0.007***	−0.012***	−0.008***	−0.014***	−0.007*
		(0.001)	(0.003)	(0.004)	(0.003)	(0.004)	(0.004)
CCH squared			0.000***	0.001***	0.000***	0.001***	0.000**
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
CCH X Board busyness				0.063**		0.063**	
				(0.030)		(0.029)	
CCH squared X Board busyness				−0.002**		−0.002**	
				(0.001)		(0.001)	
CCH X Dedicated institutional ownership					0.068	0.086**	
					(0.043)	(0.042)	
CCH squared X Dedicated institutional ownership					−0.003**	−0.004**	
					(0.002)	(0.002)	
Wald chi-square	68.908***	69.813***	75.899***	79.197***	77.031***	80.103***	73.717***

For (1)–(6), N = 962; For (7), $N = 945$.
All models estimated with industry dummies, year dummies, and intercept.
Robust standard errors adjusted for firm-level clustering are presented in brackets.
* $p < 0.1$
** $p < 0.05$
*** $p < 0.01$.

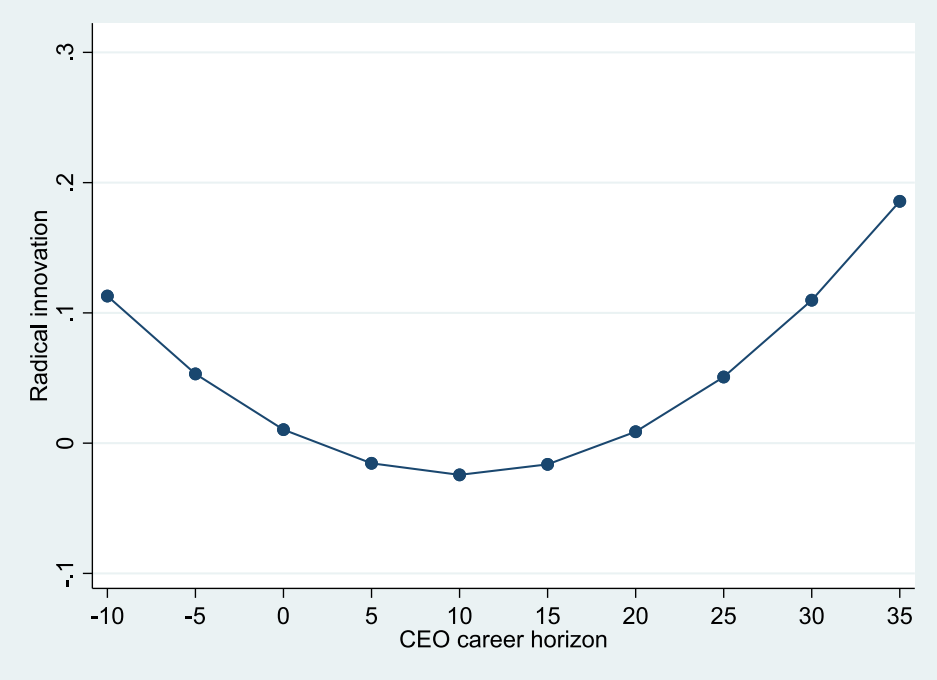

Fig. 1. CEO's career horizon and radical innovation.

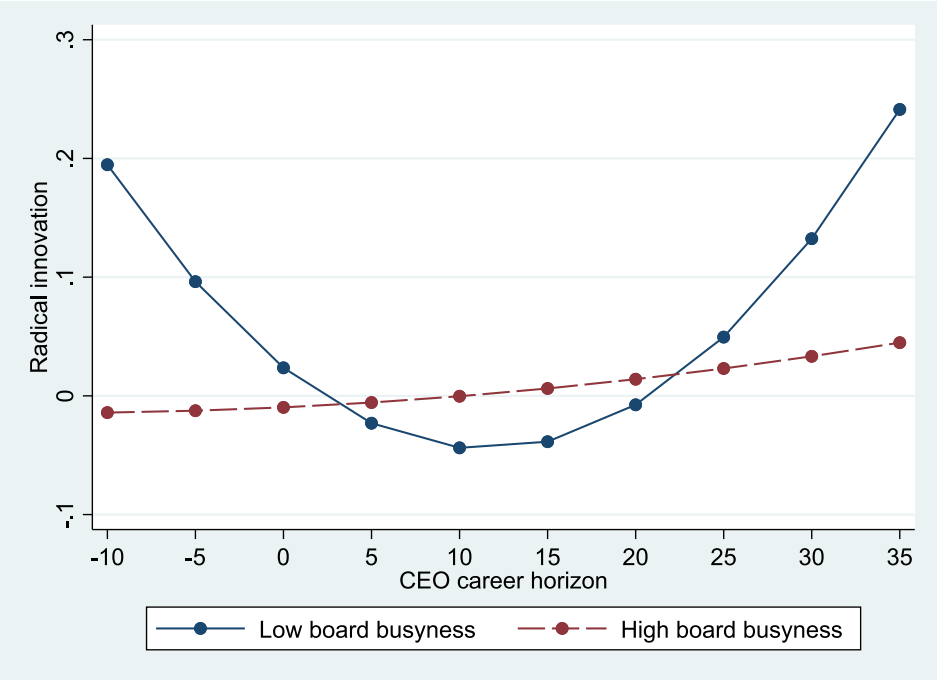

Fig. 2. Moderating effect of board busyness.

innovations differ in terms of degree of novelty, an often-used factor to categorize innovations as radical or incremental. Towards this end, we did additional analysis. To evaluate patent novelty, we looked at the impact of patents on citation flows by subsequent patents using Funk and Owen-Smith's (2017) CD index. This captures whether a focal patent *consolidates* or *destabilizes* extant trajectories of technology development. It indicates on a continuous scale (from −1 to +1) the degree to which a focal patent increases or decreases the use of prior technological knowledge by subsequent patents. For example, if all subsequent patents citing the focal patent completely ignore (i.e., fail to cite) its references (i.e., backward cites by the focal patent), the focal patent is assigned a value of +1 in the CD index, and it can be regarded as having high novelty by virtue of being most destabilizing. On the contrary, if all subsequent patents citing the focal patent also cite its references to some extent, the focal patent is assigned a value of −1 in the CD index, and it can be regarded as having low novelty by virtue of being most consolidating.

Recent studies have used this approach or its variants to establish the novelty or radicalness of patents and publications (e.g., Genin et al., 2023). For our indexing, we looked at the backward cites in the forward

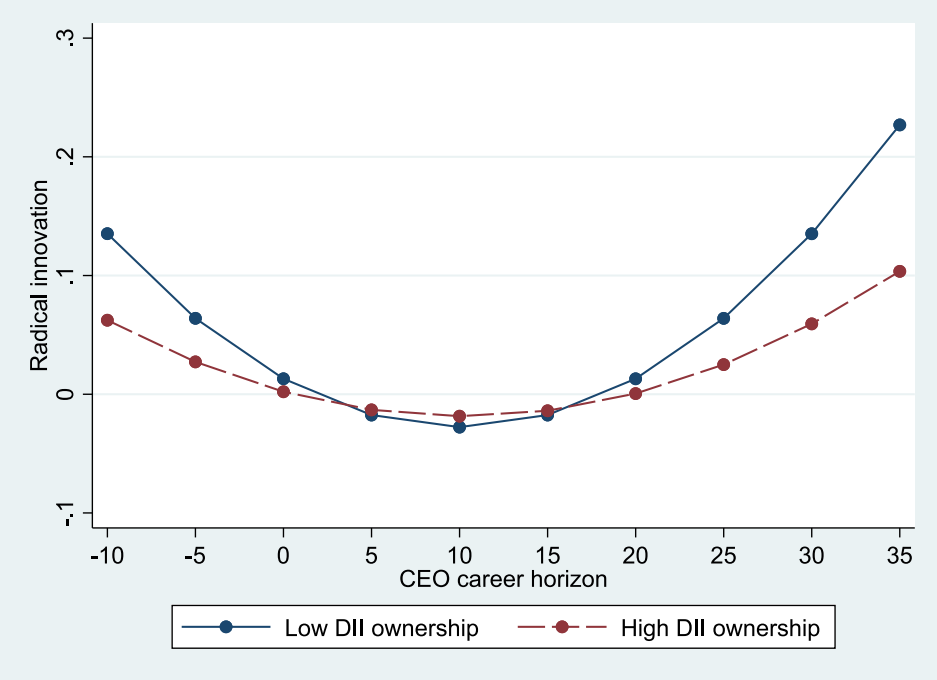

Fig. 3. Moderating effect of dedicated institutional investor ownership.

citations of patents in the five years following their grant. We then conducted a univariate test to establish whether there was a significant statistical difference between the index values of renewable-energy patents and pollution-reduction patents. The test showed renewable-energy patents to entail more novelty than pollution-reduction patents ($t = 3.47$; $p = 0.00$). Additionally, we computed firm-level index values by aggregating across all firm patents in a specific year. This variable showed a significant statistical correlation with our measure of radical innovation ($r = 0.60$; $p = 0.00$). These results provide support for the operationalization of our dependent variable, indicating that the renewable-energy patents which we categorized as radical, entailed more novelty than the incremental pollution-reduction innovations as per flow of patent citations.

5. Discussion

The article's purpose was to take forward research on corporate leaders and innovation by studying the influence of the shortening of CEO's career horizon (CCH) on the commitment of company's resources to the pursuit of radical innovations. To do so, the article builds on strategic leadership literature (Hambrick and Mason, 1984; Heyden et al., 2017). It integrates two divergent scholarly perspectives to theorize that after a CEO has stepped into their role, the shortening of CCH will at first decrease and later, as retirement draws nearer, increase the firm's pursuit of radical innovations. This U-shaped relationship recognizes that CEO mindset, motivation, and inclination towards risk-taking are not a static factor – they vary over time, as CEO's career progresses. The article also identifies two boundary conditions for the relationship, viz. board busyness and firm's ownership by dedicated institutional investors. Furthermore, it reports support for the theory based on the analysis of renewable-energy and pollution-reduction patents filed by firms in the U.S. oil and gas (O&G) industry.

The U-shaped CCH effect this article reports offers a basis for reconciling the inconsistent results of the two prior studies on the topic – while Cho and Kim (2017) report a negative effect of CCH (measured using CEO age as indicator) on radical innovations, Ortiz-de-Mandojana et al. (2019) report a positive effect. As both these studies presumed the focal relationship to be a linear one, it is plausible that the full, nonlinear effect remained unearthed. More broadly, the U-shaped relationship we report suggests a revisit of the effect of CCH on R&D intensity as well. While R&D intensity is a variable which does not distinguish between allocations to radical and incremental innovations, to the extent that more R&D means greater willingness to take risk, it may be that the CCH – R&D relationship is also nonlinear (cf. Dechow and Sloan, 1991; Heyden et al., 2017). At a still more general level, the U-shaped relationship articulated here presents a fuller picture of the dynamics of a shortening career horizon and CEO mindset, motivation, and inclination towards risk-taking. CEOs are probably not, either simply short-term oriented and out for personal gains or long-term oriented and driven by altruistic goodwill for future generations and society – they may be both, depending on the context and time. If CEOs' mindset and priorities change as their career advances, this article provides fertile ground for new CCH theory building and testing.

The article shows further that, as posited, the board busyness and dedicated institutional ownership boundary conditions are relevant for CCH's influence on radical innovation. The effect of board busyness, while in line with what earlier studies indicate regarding the advice and monitoring capabilities of cognitively overloaded directors, brings to light for the first time the variable's significance for radical innovation. This last suffers, arguably because time-constrained directors lack the space to meaningfully support firm's pursuit of radical innovations through the sharing of ideas and knowledge. Additionally, as busyness reduces the ability to effectively monitor the CEO (e.g., Boivie et al., 2016), radical innovation may suffer as the board becomes outcome-oriented and begins to attach importance to short-term financial results (cf. Makri et al., 2006). As for the effect of ownership by dedicated institutional investors, this too is consistent with earlier studies which indicate that they shield the CEO from pressure to produce immediate results (Connelly et al., 2019) and set stock in long-term value creation (Oehmichen et al., 2021). Here, the article advances understanding by showing that besides moderating the effect of CCH on real option intensity (Lee et al., 2018), dedicated institutional ownership also impacts the firm's pursuit of radical innovations. These results speak also to research on strategic-leadership interfaces by showing that the CEO – board and the CEO – institutional-investors interface matter for firm outcomes (Georgakakis et al., 2022; Simsek et al., 2018).

The article also speaks to and enriches the literature on radical innovation by showing that a company's CEO and corporate governance can be influential for the firm's attention and commitment to alternative search and innovation pathways. In this respect, the article bridges research on strategic leadership with innovation scholarship, providing a platform to theorize the role of the executive and governance functions in driving radical innovation through investments in variables of interest to innovation researchers, such as artificial intelligence, digital infrastructures and technologies, and open sourcing (Bahemia et al., 2018; Nambisan et al., 2019; Verganti et al., 2020). Furthermore, the article casts light on the importance of accounting for both the CEO and governance factors for a more fine-tuned understanding of radical innovation. Past work has tended to look at the effect of the two in isolation of one another. For example, whereas research on the influence of a CEO on the adoption of disruptive technologies and radical innovation overlooks the effect of corporate governance (e.g., Gerstner et al., 2013), research on the influence of corporate governance has discounted the impact a CEO can have (e.g., de Vasconcelos Gomes et al., 2025). By being attentive to the influence of the executive as well as the non-executive leaders of a company, future work can provide valuable insights regarding the effective management of radical innovation.

This article has implications for practice as well. It is widely accepted in the management and organization literature that both incremental and radical learning and innovation are vital, as they create short-term and long-term economic value respectively (March, 1991; Tushman and O'Reilly, 2002). The importance of careful management of allocation of resources to the innovation mix is also underscored by researchers (Brasil et al., 2021; Klingebiel and Rammer, 2014). CCH, however, can induce undue emphasis on either incremental or radical innovations – CEO short-termism may tip the balance too much towards the former; CEO long-termism may tip it the other way. The board's advice and control can play a salient role in ensuring a balance, but this requires that directors are not too busy to monitor and guide the executive function. We found a negative moderating effect of board busyness. One message to come from this is that when appointing directors, companies should be wary about the number of external positions they hold. Access to external resources because of directors' ties can be expedient, but not if outside roles keep directors from conscientiously assessing and enabling the focal firm's innovation efforts. An engaged board with sufficient time on hand could look towards executive compensation as one route to achieve a balance – for example, adjustments in CEO stock options and bonus pay could counter CEO short-termism, incentivizing more attention to radical innovations (see also, Flammer et al., 2019).

The findings of this research are based on O&G patents. CEOs in the O&G industry can direct their companies to focus on both pollution-reduction and renewable-energy innovations, or more on one innovation type than the other. As discussed, while the pursuit of pollution-reduction innovations involves less risk and more certainty of profits in the short term, the pursuit of renewable-energy innovations offers a shot at leaving a legacy. Notably, in view of the urgency surrounding the grand challenge of climate change, governments and regulators attach particular importance to O&G innovations that harness energy from natural resources to offer effective solutions for the market's needs (Doblinger et al., 2019; Hartmann et al., 2021). To stimulate their pursuit, technology-push as well as demand-pull policies and instruments can be used. Broadly, whereas the former seek to galvanize renewable-energy innovations by reducing their cost to firms, the latter seek to do so by creating or shaping markets to increase returns to firms. With studies suggesting that renewable-energy innovation may be more responsive to technology-push rather than demand-pull policies and instruments (Hoppmann et al., 2013; Nemet, 2009), we note that both types of industry-wide interventions do not consider intra-industry variation in CEOs' motivations and firms' actions.

In this context, our article brings to light an important point of attention – as firms tend to pursue radical innovations less than incremental innovations when CEOs have a longer career horizon, policy makers could contemplate including in their portfolio, instruments that specifically target these firms. This would seem to constitute astute policymaking, especially when one juxtaposes our finding with the axiom that learning and innovation of the incremental kind tends to crowd out that of the non-incremental kind (Levinthal and March, 1993). By keeping firms from getting locked into routines of continual over-emphasis on incremental innovations because of the CEO's mindset (March, 1991; Perra et al., 2017), stimulating the motivation of long career horizon CEOs to pursue radical renewable-energy innovations could speed up the industry's transition to net-zero solutions. In this regard, policy makers could consider deploying instruments that help (e.g., R&D support to enable capital-intensive technology development) and reward (e.g., special remuneration and even prizes and recognitions) (see also, Nuñez-Jimenez et al., 2022; Schmidt and Sewerin, 2019) these CEOs in ways that add to their reputation and labor-market prospects, which are for them important motivators.

5.1. Limitations and future research

This study's findings are based on data from a single industry. As such, they cannot be taken to hold for other contexts as well. This leaves an opportunity open for researchers to explore the CCH – radical innovation relationship in other industries. Such research would help to establish the generalizability of the current results and should facilitate further refinement of the theory for settings where future results diverge from the present ones. It is also conceivable that besides the industry setting, other contextual factors such as country-level differences and private versus public ownership have a bearing on the relationship (see also Hartmann et al., 2021; Strike et al., 2015). On another note, our empirical context facilitated the distinction between the pursuit of radical and incremental innovations by looking at renewable-energy and pollution-reduction patents (Costantini et al., 2015; Hoppmann et al., 2013) – a distinction that we validated by comparing the relative novelty of the two. In industries in which the distinction between radical and incremental change is not readily apparent, future studies could verify the current results by using other measures of novelty (see e.g., Funk and Owen-Smith, 2017). Furthermore, we only theorized and tested two boundary conditions suggested by research on corporate governance and strategic-leadership interfaces. In this regard, scholars can take forward our work by examining other variables on which the CCH-radical innovation relationship is potentially contingent.

As observed earlier, this article lays the groundwork for new CCH theory building and testing. For instance, future research can study how CEO personality (e.g., Turner et al., 2024) and values (e.g. Narayan et al., 2021) interact with the length of the CEO career horizon to affect short- and long-term value creation. Another important avenue of research concerns the challenges and opportunities for corporate governance. Should, for example, board structure and composition be adjusted as the CEO career horizon shortens to promote the balanced pursuit of radical and incremental innovation (cf. Genin et al., 2023)? As another example, it would be of value to investigate the effect of differences in CEOs' compensation packages at different stages of the career horizon on firms' risk-taking and innovation (see also, Flammer et al., 2019). Furthermore, we need a better understanding of the policy instruments that can effectively persuade CEOs and firms to pursue nonlocal search, experimentation, and radical innovations to confront the grand challenges society faces. It is our hope that this article, by showing that the career horizon of executives matters for renewable-energy innovations in the O&G industry, will inspire further inquiry into the role strategic leaders play in the taking of decisions and the adoption of practices consequential for the health of our planet.

CRediT authorship contribution statement

Youngbin Joo: Writing – review & editing, Writing – original draft, Resources, Methodology, Investigation, Formal analysis, Data curation,

Conceptualization. **Dimitrios Georgakakis:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Jatinder S. Sidhu:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Conceptualization.

Declaration of competing interest

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

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Appendix A

Table A1
Alternative measures of CEO's career horizon (CCH).

	(1)	(2)	(3)	(4)	(5)
CEO – board power difference	−0.003	−0.003			
	(0.002)	(0.002)			
Board independence			−0.001	−0.001	−0.000
			(0.003)	(0.003)	(0.003)
CEO duality	0.028*	0.029*	0.027*	0.027*	0.028*
	(0.015)	(0.015)	(0.015)	(0.015)	(0.014)
Board independence	0.120	0.116	0.110	0.106	0.106
	(0.083)	(0.083)	(0.081)	(0.081)	(0.082)
Firm size	−0.039*	−0.038*	−0.039*	−0.038	−0.037
	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)
Firm slack	−0.003	−0.003	−0.003	−0.003	−0.004
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Capital expenditure	0.014**	0.013**	0.016**	0.016**	0.016**
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Non-environmental innovations	−0.018*	−0.019*	−0.018*	−0.018*	−0.019*
	(0.010)	(0.010)	(0.010)	(0.010)	(0.011)
Financial risk	0.001	0.001	0.001	0.001	0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Financial performance	0.000	0.000	0.001	0.001	0.001
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Board busyness	0.149	0.146	0.156	0.153	0.150
	(0.099)	(0.100)	(0.101)	(0.101)	(0.102)
Dedicated institutional ownership	0.023	0.020	−0.001	−0.006	−0.007
	(0.095)	(0.095)	(0.091)	(0.091)	(0.092)
CCH (SIC 3-digit adjusted)	0.002*				
	(0.001)				
CCH squared (SIC 3-digit adjusted)	0.000***				
	(0.000)				
CCH (SIC 4-digit adjusted)		0.002*			
		(0.001)			
CCH squared (SIC 4-digit adjusted)		0.000***			
		(0.000)			
CCH (age & tenure, SIC 3-digit adjusted)			0.003**		
			(0.001)		
CCH squared (age & tenure, SIC 3-digit adjusted)			0.000***		
			(0.000)		
CCH (age & tenure, SIC 4-digit adjusted)				0.003**	
				(0.001)	
CCH squared (age & tenure, SIC 4-digit adjusted)				0.000***	
				(0.000)	
CCH (age & tenure, TNIC 3-level adjusted)					0.003**
					(0.001)
CCH squared (age & tenure, TNIC 3-level adjusted)					0.000***
					(0.000)
Wald chi-square	77.083***	76.445***	75.996***	75.305***	76.192***

$N = 962$.
All models estimated with industry dummies, year dummies, and intercept.
Robust standard errors adjusted for firm-level clustering are presented in brackets.
* $p < 0.1$
** $p < 0.05$
*** $p < 0.01$.

Data availability

The authors do not have permission to share data.

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