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Climate impact, institutional context, and national climate change adaptation IP protection rates

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ABSTRACT

We study how the physical effects of climate change motivate entrepreneurs to develop and protect climate change adaptation (CCA) intellectual property (IP) in heterogeneous ways across countries. Integrating the sustainable entrepreneurship literature with the attention-based view, we show that country-level climate impact redirects managerial attention to the disruptive potential of climate change and spurs the sector into action to pursue and protect CCA-related IP. We also find that strong intellectual-property rights regulations and environmental movements in countries strengthen this effect. Our results extend the sustainable entrepreneurship literature by showing how the geography of climate impact explains how CCA IP protection efforts are distributed globally.

Executive summary: Why do entrepreneurs in some countries engage in more climate change adaptation (CCA) intellectual property (IP) protection than others? We postulate that entrepreneurs' attention is simultaneously situated in their country's climatic and institutional environments, and that these contexts shape the salience of CCA IP protection. Formally, we predict that entrepreneurs who would normally deprioritize CCA IP protection as an opportunity in the face of more urgent socioeconomic issues become more attuned to it as their country's climate impact increases. We then theorize institutional conditions that influence entrepreneurs' responsiveness to climate impact. First, we predict that stronger intellectual property rights institutions reduce entrepreneurs' uncertainty in capturing rents from their CCA IP and hence strengthen the relationship between climate impact and CCA IP protection. Second, we predict that informal institutions aligned with environmental movements increase the salience of climate impacts to corporate entrepreneurs by spurring their interests in environmental issues and hence also strengthen the climate impact-CCA IP protection relationship. Our empirical analyses using 689 country-year observations consisting of 95 countries over the period 2005 to 2015 reveal that country-level climate impact drives CCA IP protection, especially when there are strong intellectual property rights (IPR) regimes and environmental movements.

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1. Introduction

> "The water is coming. There's no longer much doubt about that, as scientists have increasingly documented how the warming of the planet has accelerated sea level rise along coasts around the world. But an analysis published Thursday by the research nonprofit Climate Central reveals a troubling dimension of the economic toll that could unfold in the United States, as hundreds of thousands of homes, offices and other privately owned properties slip below swelling tide lines over the next few decades."

(Excerpt from "Rising seas could swallow millions of U.S. acres within decades," Brady Dennis, Washington Post, September 8, 2022)

It is well established that global *climate impact*, defined as economic and human losses that result from the physical impacts of climate change (Adger et al., 2018; Figge and Hahn, 2021; Huang et al., 2018; Huang et al., 2022), will be both detrimental to business and society and unevenly distributed across geographies (Dechezleprêtre et al., 2020; Koubi, 2019; Pinkse and Gasbarro, 2019). Accordingly, entrepreneurship scholars have been called upon to consider how firms seize climate change adaptation opportunities (CCA) (Fernhaber and Zou, 2022), since novel technologies will be necessary to help humanity cope with these effects (George et al., 2021; Howard-Grenville and Lahneman, 2021). This form of innovation is, however, still in its infancy with relatively few CCA inventions reaching the commercialization stage (Dechezleprêtre et al., 2020). One issue that may be constraining this form of innovation is that it often produces public goods' spillovers to society-at-large that are difficult for entrepreneurs to internalize (Doh et al., 2019; Jaffe et al., 2002).[1] Thus, the protection of their IP using patents becomes a particularly salient consideration. Still, the sustainable entrepreneurship literature has yet to systematically consider whether climate impact can drive CCA-related entrepreneurship, and specifically CCA IP protection. Instead, much of this literature continues to focus on studying how institutional mechanisms and market failures generate entrepreneurial opportunities to address climate change (e.g., Berrone et al., 2013; Doh et al., 2019; Fabrizi et al., 2018; Meek et al., 2010). To address this gap, we study how the geography of climate impact can drive CCA IP protection (Dechezleprêtre et al., 2020).

To this end, we integrate the sustainable entrepreneurship literature with the concept of situated attention from the attention-based view (ABV) to argue that corporate entrepreneurs' attention is simultaneously situated in their country's climatic and institutional environments, and that these contexts shape the salience of CCA IP protection as both an essential response to climate change and an entrepreneurial opportunity. We begin by predicting that corporate entrepreneurs who would normally deprioritize CCA IP protection in the face of more urgent socioeconomic issues become more attuned to it as their country's climate impact increases. We then predict that stronger IP-rights institutions reduce corporate entrepreneurs' uncertainty in capturing rents through legal mechanisms that give them exclusivity and protect them from expropriation (Granstrand, 2005; Williamson, 1988), thereby strengthening the relationship between climate impact and CCA IP protection. Such institutions are especially salient to CCA-related entrepreneurship as products and services designed to support CCA often take the form of public goods that make the society more resilient to climate change (Jaffe et al., 2002; Ostrom, 2010). Finally, we predict that informal institutions aligned with environmental movements increase the salience of climate impacts to corporate entrepreneurs by spurring their interests in environmental issues (Hoffman and Jennings, 2021; Hoffman and Ocasio, 2001; Palazzo and Scherer, 2008) and hence also strengthen the climate impact-CCA IP protection relationship.

We focus on the country level because the markets for such CCA-related IP are still undeveloped, which suggests that national political economy characteristics that spur market formation are critical drivers for this form of IP (Fredström et al., 2021; Webb et al., 2013). Accordingly, we test our hypotheses on a sample that includes 689 country-year observations consisting of 95 countries over the period 2005 to 2015.

We make multiple contributions to the literature. First, our results extend the sustainable entrepreneurship literature by showing that CCA entrepreneurial efforts can be primarily influenced by the geography of climate impact and secondarily by formal institutions and well-organized environmental movements. As such, our study departs from most of the sustainable entrepreneurship research, which has largely focused on how institutions and market failures determine opportunities for climate action (Vedula et al., 2022). Our study instead suggests that perceptions about the importance of CCA IP protection depend on where climate impacts happen. We also highlight how sustainable entrepreneurship should not only consider efforts to mitigate environmental degradation but also build resilience against the ecological impacts that such degradation causes (Cohen and Winn, 2007). Second, we contribute to the ABV by showing that attention can be simultaneously situated in multiple environments, namely its climatic, formal, and informal institutional contexts. More specifically, we offer evidence that attention to emergent and potentially disruptive issues can be concurrently situated in climate events, formal institutional, and informal institutional environments.

Finally, our study extends research on CCA, which has found that localized and non-systemic climate change effects can drive managerial attention to non-innovative CCA responses (Hoffmann et al., 2009; Linnenluecke et al., 2011; Pinkse and Gasbarro, 2019; Tashman and Rivera, 2016). Our study shows that corporations pursue CCA IP protection when climate events signal a strong need – and potential demand – for it and their institutional environments are supportive of such efforts.

[1] Given the view of Schumpeter (1934: 78) that "everyone is an entrepreneur only when he[/she] actually carries out new combinations" of resources, we define corporate entrepreneurs as those generating novel intellectual property, which requires an act of combining resources and knowledge in untried ways (Link and Ruhm, 2011). As such, our view on entrepreneurs is congruent with Baumol's (2010) definition of innovative entrepreneurs who come up with novel ideas and puts them into practice.

2. Climate impact and climate change adaptation IP protection: theory and hypotheses

The sustainable entrepreneurship literature focuses on the study of entrepreneurs who seek to achieve multiple objectives, namely the "preservation of nature, life support, and community in the pursuit of perceived opportunities to bring into existence future products, processes, and services for gain, where gain is broadly construed to include economic and non–economic gains to individuals, the economy, and society" (Shepherd and Patzelt, 2011: 142). As such, sustainable entrepreneurship is characterized by the "planet and profit" motive whereby these entrepreneurs pursue commercial success by developing and commercializing products and services that reduce environmental degradation. Conceptually, the opportunities for this type of entrepreneurship are "present in environmentally relevant market failures" (Dean and McMullen, 2007: 58). Given that these opportunities need to be actively exploited (Cohen and Winn, 2007; Dean and McMullen, 2007), much of the literature has focused on identifying antecedents of sustainable entrepreneurship at different levels of analysis. For instance, at the individual level, scholars have suggested that entrepreneurs' prior knowledge about natural and communal environments is positively related to sustainable entrepreneurship (Patzelt and Shepherd, 2011), whereas, at the ecosystem level, research has identified the ability to leverage partner resources and technologies as a key facilitator for sustainable entrepreneurs' ability to growth their ventures (Pankov et al., 2021). At the country level, market failures from institutional voids have also been identified as drivers of sustainable entrepreneurship (e.g., Migendt et al., 2017; York et al., 2018).

On climate change, sustainable entrepreneurship research highlights different roles for market failures and institutions. It has generated evidence that environmental market failures alone may not spur sustainable entrepreneurship (Veugelers, 2012) and found that sticky market institutions that deprioritize environmental issues often act as barriers to meaningful climate action (e.g., Berrone et al., 2013; Fabrizi et al., 2018). Such institutions allow entrepreneurs to externalize the (social) costs of environmental degradation, which (dis)incentivizes investments into sustainable entrepreneurship (Schaltegger and Wagner, 2011) and constrains demand for climate change-related entrepreneurship (Berrone et al., 2013). In addition, they can prevent entrepreneurs from appropriating returns from their climate change strategies (e.g., Cainelli et al., 2020; Doblinger et al., 2019; Doblinger et al., 2022), which are particularly salient for CCA as it is nascent in practice, and supportive institutions can help spur market development and allow entrepreneurs to claim and enforce exclusivity to IP that is likely to create public goods.

CCA warrants research attention from a conceptual but also from a phenomenological perspective. According to the sixth assessment report of the Intergovernmental Panel on Climate Change (IPCC, 2022), the physical effects of climate change have already caused adverse impacts to myriad natural and social systems, including rising sea levels, infrastructure damage, forest loss, global food and water insecurity, and new disease vectors, to name a few of the panel's 127 "reasons for concern." Many of these effects are irreversible and will become substantially more intense in the near term (until 2040) as the climate adapts to current levels of greenhouse gas emissions in the atmosphere. Beyond 2040, the adverse effects of climate change are expected to accelerate rapidly unless significant climate change mitigation measures can be enacted in the short term. While non-innovative forms of CCA have helped (Winn et al., 2011), hard limits to adaptation are emerging because the severity of climate impacts are growing rapidly (Howard-Grenville and Lahneman, 2021). As a result, a consensus in the scientific community is emerging that CCA entrepreneurship and innovation are critical for helping business and society develop some resilience to climate change (IPCC, 2022; EEA, 2017; Hötte and Jee, 2022; Howard-Grenville and Lahneman, 2021; Woetzel et al., 2020).

Even though calls for novel forms of CCA have accelerated, attention to it has stagnated. Growth in CCA patent activity has progressed at a rate of only 6.7 % per year between 1995 and 2015, which is comparable to the average growth rate of all technologies (5.6 %) and substantially lower than the 10.9 % annual growth rate of climate change mitigation (CCM) patents (Dechezleprêtre et al., 2020: 19). Further, patents for CCA technologies generated a relatively small and stable proportion of global patent activity of around 0.3 % per year during this timeframe (Dechezleprêtre et al., 2020: 19). The result is that CCA entrepreneurship and innovation are still nascent in practice, with most efforts in the non-commercial stages of the innovation lifecycle, notably including IP protection (Dechezleprêtre et al., 2020). While there is no guarantee of commercial success, IP protection mechanisms (e.g. patents, copyrights, trademarks) give inventors concrete and exclusive legal mechanisms for safeguarding their rights to use and appropriate value from their efforts. They can also help entrepreneur/inventors attract capital, lure potential business partners, and earn legitimacy with a range of stakeholders (Fischer and Ringler, 2014; Fisher et al., 2017; Renko et al., 2022; Tumasjan et al., 2021). Accordingly, our study focuses on CCA IP protection, which we define as efforts to protect exclusive rights to appropriate value from — and claim credit for — developing technology that facilitates CCA.

Examples of CCA IP protection efforts include patenting of novel water conservation technologies for agriculture such as micro-irrigation and reuse of wastewater to help address water scarcity (Conway et al., 2015; Patle et al., 2020); the use of artificial intelligence in predictive models for identifying geotemporal patterns of climate impact (Hötte and Jee, 2022); novel construction materials that make buildings more resilient to extreme weather (Berkhout, 2012); desalination technologies that produce freshwater with fewer carbon emissions (Mito et al., 2019); and new medicines and preventive public health inventions for infectious diseases that are borne from changing weather patterns (Caminade et al., 2019).

2.1. Toward an attentional view on climate change-adaptation IP protection

We argue that CCA IP protection has stagnated, in part, because entrepreneurs' attention is elsewhere. Attention refers to the process through which decision-makers notice, interpret, prioritize, and respond to issues they deem salient (Ocasio, 1997). Because entrepreneurs are individuals with cognitive limitations that prevent them from attending to every possible important issue, they rely on heuristics when they allocate their attention, which cause them to focus on some and ignore others (Hoffman and Ocasio, 2001).

While streamlined attention is critical for making effective decisions, it constrains perceptions and responses to weak cues about "emerging issues, for which they have no available repertoire of categories" (Rerup, 2009: 877). As discussed above, CCA IP protection appears to be one such area. At the same time, there is visible cross-country variation in CCA IP protection rates. To explain this variation, we draw on the ABV to describe how entrepreneurial attention can be concurrently situated in their country's climate events as well as formal and informal institutional environments.

The ABV provides three general principles for explaining managerial attention: it is (1) selective, (2) structured, and (3) situated (Ocasio, 1997; Hoffman and Ocasio, 2001). Selective attention describes how decision-makers use heuristics and pre-existing schema and repertoires of action to identify and respond to stimuli (March and Simon, 1958). Structured attention explains how attention depends on the composition groups, organizations, industries, and organizational fields, which govern how stimuli are prioritized by decision-makers (Hoffman and Ocasio, 2001). Situated attention explains how decision-makers' focus on any given stimuli depends upon the context or situation in which they find themselves (Ocasio, 1997). Since we focus on country characteristics that drive CCA IP protection activities, we rely on the principle of situated attention and its emphasis on contextual factors that affect how decision-makers allocate their attention. Our general argument is that attention to CCA IP protection depends on the strength of cues from their source contexts, i.e., the climate and institutions in the countries where they obtained CCA IP protection.

2.2. Climate impact and climate change adaptation IP protection

We expect corporate entrepreneurs within countries to increase attention on CCA IP as climate impact grows and generates stronger cues for its salience. As discussed, climate impact generates systematic effects on the national political economy, including damage to privately held assets, supply chains, stakeholder networks, public infrastructure, and ecological systems (Van Valkengoed and Steg, 2019; Winn et al., 2011). These effects should help mobilize country-level political and socio-cultural discourse about innovative CCA actions that the IPCC and prominent consulting groups have championed (Fredström et al., 2021). By extension, they should also motivate national governments to prioritize CCA policy to induce private sector action (Smith and Lenhart, 1996; Lee et al., 2022).

Higher levels of national climate impact should also strengthen demand conditions for CCA IP protection. In particular, these impacts increase the likelihood that the public, private, and civil sectors are able to discern impacts from climate change from typical variations in weather, which should catalyze the demand for private-sector solutions to climate impact (Orderud and Naustdalslid, 2020). They should also drive stakeholder expectations, including market participants such as investors, banks, and potential business partners, for more novel CCA as the combined effects of climate impact, policy initiatives, and demand conditions reinforce shared perceptions on the urgency of CCA. Combined, this should create the country-level contextual conditions that direct private-sector attention to the issue and help make sense of it as an entrepreneurial opportunity that can be seized with innovative responses.

We expect these responses to take the form of CCA IP protection. As discussed above, while IP protection does not necessarily lead to effective innovation, it does allow corporate entrepreneurs to better position themselves to benefit from a political economy that is increasingly adapting to climate impact. IP protection helps corporate entrepreneurs secure exclusive rights to appropriate value from novel CCA technologies and confers legitimacy to them for their efforts (Fischer and Ringler, 2014; Fisher et al., 2017; Renko et al., 2022; Tumasjan et al., 2021). CCA IP protection could also lead to innovation that helps corporate entrepreneurs protect their assets and seize potential market opportunities that might emerge to address societal needs for CCA. Greater CCA-related corporate entrepreneurial activities due to more severe climate impacts should, in the aggregate, eventually be reflected in greater national IP protection rates. Based on these arguments, we predict:

Hypothesis 1. Climate impact is positively associated with national CCA IP protection rates.

2.3. Institutional context and climate impact

While we expect the contextual conditions that are created by national climate impact to act as the primary mechanism for situating attention on CCA IP protection, we further argue that a country's institutional system should moderate this mechanism. Generally, attention is partially situated in countries' institutions because those institutions determine the appropriability and legitimacy of innovation behavior (Nicolini and Mengis, 2023; North, 1990). Specifically, both formal and informal institutions "reduce uncertainty for different actors by conditioning the ruling norms of behaviors and defining the boundaries of what is legitimate. Actors, in turn, rationally pursue their interests and make choices within a given institutional framework" (Peng et al., 2009: 66; see also Peng et al., 2008).

2.3.1. Formal institutions, climate impact, and CCA IP protection: the role of IPR protection

Formal institutions refer to a country's regulatory, legal, and political structures, as well as the rules and standards enacted and enforced by those structures (Holmes Jr et al., 2013). Their purpose is to promote order and stability in socioeconomic activity through explicit rules, incentives, and enforcement mechanisms (North, 1990), which underpin orderly processes for conducting transactions, making investments, and protecting private property (Deeds and Hill, 1999). Absent such systems, opportunistic actors can exploit *ex ante* and *ex post* incomplete contracts (Williamson, 1988), which harm corporate entrepreneurs' ability to capture rents from their innovation activities, including developing and protecting IP (Granstrand, 2005). We consider formal institutions related to intellectual property rights (IPR) protections and argue that they amplify the effects of climate impact on CCA IP protection.

Stronger IPR regimes help condition corporate entrepreneurs to develop and protect IP that helps them adapt to challenging stimuli because they reduce leakage of potential rents due the non-excludability of CCA IP and mitigate expropriation risk (Boudreaux et al., 2019; Granstrand, 2005). The value of CCA IP, if commercialized and unprotected, may be non-excludable from other market and public actors and are therefore difficult to appropriate (Ostrom, 2010). As a result, "much of this social return will accrue as spillovers to competing firms, to downstream firms that purchase the innovator's products, or to consumers" (Jaffe et al., 2002: 44). Stronger IPR regimes can help entrepreneurs limit rent leakage by giving them legal bases for protecting their IP. In turn, they incentivize corporate entrepreneurs to pursue innovative responses like IP development and protection with higher risk and reward (Jaffe et al., 2002). Conversely, weaker IPR regimes may drive corporate entrepreneurs to rule out or deprioritize innovative responses to climate impact in favor of shorter-term responses that create private-adaptation goods, since those goods involve rents that do not necessarily require strong appropriability regimes (Cuerva et al., 2014).

Second, ineffective IPR regimes may allow governments to expropriate benefits from entrepreneurs if they can be made publicly available to curry political favor with their electorates or other important political stakeholders (Boudreaux et al., 2019). This risk is particularly salient for CCA IP because it aims to help the public-at-large cope with the disruptive potential of climate change. Such a risk may drive entrepreneurs to pursue shorter-term CCA responses that are less vulnerable to governmental expropriation instead of CCA IP development or protection. More effective IPR regimes, on the other hand, impose and enforce property rights protections on political authorities as well as non-governmental actors in their jurisdictions (Acemoglu et al., 2001; Khoury et al., 2014). These stronger regimes, in turn, should reduce corporate entrepreneurs' concerns when considering innovative responses to the disruptive potential of climate change and tilt the risk-reward ratio more in favor of CCA IP development and protection as a response to climate impact (Estrin et al., 2013). In light of these arguments, the effect of climate impact on national CCA IP protection rates should be stronger in countries with stronger formal institutions in the form of IPR protection. Formally:

Hypothesis 2. The quality of a country's Intellectual Property Rights Regimes positively moderates the relationship between national Climate Impact and CCA IP Protection.

2.3.2. *Informal institutions, climate impact, and CCA IP protection*

Informal institutions are "enduring systems of shared meanings and collective understandings that, while not codified into documented rules and standards, reflect a socially constructed reality that shapes cohesion and coordination among individuals in a society" (Holmes Jr et al., 2013: 533; see also North, 1990).

They are reflected in a society's culture, norms, standards, and beliefs and often espoused through civil society groups that promote public interests (Berrone et al., 2013; Mair and Marti, 2009). As with their formal counterparts, entrepreneurial attention can be situated in a country's informal institutions (Hoffman and Ocasio, 2001). Rather than working through explicit rules, incentives, and enforcement mechanisms, they take form in non-governmental social networks that promote shared understandings of actions and practices and their social acceptability and desirability among civil-society actors. Such understandings are reflected through explicitly espoused values or tacit cultural practices (Jennings et al., 2013; Scott, 1995). Informal institutions can focus on a variety of issues and manifest through different types of networks, including business groups, supply chains, and non-governmental networks (Abushaikha et al., 2021; Inoue et al., 2013; Kim et al., 2010; Sutter et al., 2017). We consider how the attention to CCA IP protection can be situated in a country's informal environmental institutions.

More specifically, we expect corporate entrepreneurs' attention to CCA IP protection to be further situated in the values systems and mental models associated with a country's environmental movements. Such movements can shape a country's social norms for corporate environmental behavior, which can then affect the salience of environmental issues like climate impact to the entrepreneur by driving it to encode such issues as central to their legitimacy (Meek et al., 2010; Ocasio, 1997; Hoffman and Jennings, 2021; Hoffman and Ocasio, 2001). This in turn should help them make sense of research on the disruptive potential of climate change and drive them to prioritize CCA IP protection as a response to it (Ocasio, 1997).

In addition, the salience of national environmental movements should also magnify demand conditions and shared perceptions of the need for CCA among economic stakeholders. Stronger environmental movements often lead to formation of environmental groups

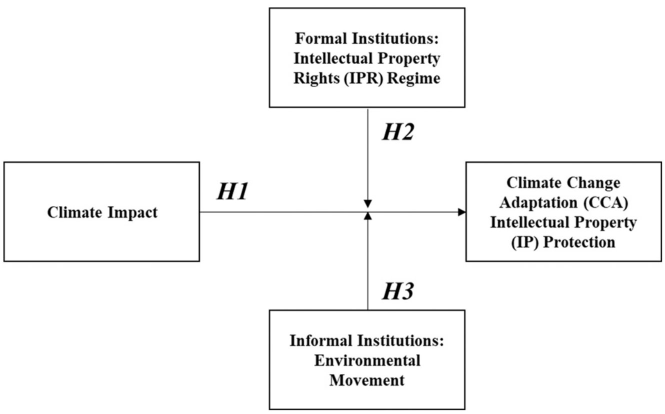

Fig. 1. Conceptual model.

(NGOs) that mobilize civil society interests in issues like climate impact in their countries (Meek et al., 2010). Heightened civil society and NGO interest in this issue should translate into increased demand for solutions to it, which should enhance its legitimacy as an entrepreneurial opportunity (York et al., 2018). This, in turn, should prime them to incorporate CCA IP development and protection efforts in their cognitive repertoires of action (Ahmad and Erçek, 2020; Muñoz and Dimov, 2015). Taken together, these arguments suggest that the strength of an environmental movement in a country should positively moderate the impact of climate impact on CCA IP protection (Fig. 1):

Hypothesis 3. The strength of a country's Environmental Movement positively moderates the relationship between national Climate Impact and CCA IP Protection.

3. Methodology

3.1. Data and variables

We collected data from several sources. First, to measure CCA IP protection, we collected country-level patent data from PatentsView from the Office of the Chief Economist in the USPTO (Eagle, 2016; Choudhury and Kim, 2019). The PatentsView database classifies disambiguated assignees into several types; *US Company or Corporation*, *Foreign Company or Corporation*, *US Individual*, *Foreign Individual*, *US Government*, *Foreign Government*, and *Country Government*, *State Government (US)*. Since our focus is on corporate entrepreneurs, we only sample corporate patents whose assignee is classified as *US Company (or Corporation)* or *Foreign Company (or Corporation)*. We used the Y02A (technologies for adaptation to climate change) which was introduced in 2018 with the joint launch of the Cooperative Patent Classification (CPC) by the European Patent Office (EPO) and the U.S. Patent and Trademark Office (USPTO), replacing the European Patent Classification (ECLA) and other codes that were used in the search algorithms to identify climate change-related technologies (Dechezleprêtre et al., 2020; EPO, 2022; Angelucci et al., 2018). As a result, firms or inventors filing their patents to the USPTO before 2018 could not strategically choose Y02A. By implication, the patents filed before 2018 are substantive efforts at adapting to climate change rather than symbolic actions to categorize their patents and manage their legitimacy. For this reason, our sample includes patents that were filed before this period.

To measure climate impact, we relied on the Global Climate Risk Index (CRI) by Germanwatch. Data measuring intellectual property rights (IPR) regimes were collected from Ginarte and Park's patent-rights index (Ginarte and Park, 1997; Park, 2008), the Heritage Foundation's Economic Freedom Index (McMullen et al., 2008), and the Economic Freedom of the World by the Fraser Institute (Gwartney et al., 2019). We collected data to measure environmental movements from the UNEP (United Nations Environmental Program). Data for control variables were collected from the World Development Indicators provided by the World Bank and the educational attainment data from Barro and Lee (2013). As we draw from multiple data sources, our sample is constrained by countries and years within them. For instance, CRI values were available from 2005 onward. After merging the longitudinal data from the above sources with different coverage years and countries, an unbalanced panel data was employed for our analysis with 689 country-year observations consisting of 95 countries over the period 2005 to 2015.

3.1.1. Dependent variable

We measure CCA IP protection as the number of Y02A patents applications made by corporations in a country in a given year (Chirico et al., 2020; Taylor and Wilson, 2012). As shown in Appendix I, this subclass covers "technologies that allow adapting to the adverse effects of climate change in human, industrial (including agriculture and livestock) and economic activities" (USPTO, 2021). For our main analysis, the dependent variable was normalized on a natural logarithm scale. For robustness checks, we developed alternative dependent variables based on the multiple ownership of patents (i.e., dividing the ownership of patents with the number of assignees) and the grant year of patents instead of their application year.

3.1.2. Independent variable

To measure *climate impact*, we rely on the CRI by Germanwatch, which captures the extent to which countries have suffered direct loss associated with extreme weather-related events such as storms, floods, and heat waves (Eckstein et al., 2019; Kreft and Eckstein, 2014). The CRI is based on four indicators: the number of deaths, number of deaths per 100,000 inhabitants, total losses in US$ at purchasing-power parity, and losses per gross domestic product that are caused by the extreme weather-related events. Since lower index scores indicate higher climate impact, we multiply the index scores by negative one so that higher scores indicate greater impact (Huang et al., 2018).

3.1.3. Moderating variables

We measure the strength of a country's *IPR regime* using a composite index of Ginarte and Park's patent-rights index (Ginarte and Park, 1997) and the impartial courts score in the Economic Freedom of the World by the Fraser Institute (Belderbos et al., 2021). The Ginarte and Park patent-rights index has been used widely to capture patent rights in a country. However, a number of scholars have criticized it because it does not capture the extent to which those rights are enforced. To address this concern, several scholars have adjusted the index by multiplying it by the impartial courts score in the Economic Freedom of the World by the Fraser Institute, which addresses the missing enforcement element by capturing a country's perceived impartiality and quality of the legal system (e.g., Belderbos et al., 2021; Hu and Png, 2013; Maskus and Yang, 2013). We also follow Belderbos et al. (2021) and normalize the composite index by the annual maximum value of each index. The value of this variable ranges from 0 to 1, where the higher value implies stronger IPR protection and vice versa. As a robustness check, we used the property-rights score in the Heritage Foundation's Economic Freedom Index (e.g., Duanmu, 2014).

Following prior studies (Binder and Neumayer, 2005; Li et al., 2021), we measure the strength of a country's environmental movement using the number of UNEP accredited environmental NGOs per country (UNEP, 2022a). Essentially, environmental NGOs are the primary driving force for vigilance and advocacy of the environmental policy not only as organizers of (and advocates for) environmental movements but also as key players in environmental litigation and governance (Li et al., 2021; Selden and Song, 1994). We rely on the UNEP data to construct this measure because that organization has a track record of accrediting legitimate environmental NGOs who have carried out national or international environmental activities for at least two years (UNEP, 2022b).

3.1.4. Control variables

To account for any idiosyncratic differences, we included year and regional dummies throughout all of our models. We identified regions using World Bank classifications. We also incorporated a number of country-specific control variables in the regression specifications using data from the World Development Indicators provided by the World Bank and the educational-attainment data from Barro and Lee (2013). We controlled for gross domestic product (GDP) per capita because it reflects a country's resources to create CCA IP (Dau and Cuervo-Cazurra, 2014; Furman et al., 2002). We controlled for GDP growth because growing countries may offer more opportunities to create markets for CCA IP (Dau and Cuervo-Cazurra, 2014; Furman et al., 2002). As R&D is one of the driving forces behind CCA patenting activities, we controlled for the percentage of R&D expenditure to GDP (De Rassenfosse and de la Potterie, 2009). We controlled for CO_2 emission per capita and energy consumption per capita (Su and Moaniba, 2017), as it reflects national dependence on fossil fuels and energy demands incentivizing private-sector actors to engage in CCA. We controlled for trade openness (Taylor and Wilson, 2012), as it determines firms' access to technology and knowledge from other countries to create CCA IP. Finally, we controlled for education attainment (Barro and Lee, 2013), as education enables members of society to be aware of climate impact and pressures firms to engage in CCA (Striessnig et al., 2013).

3.2. Econometric model

We adopted a feasible generalized least squares (FGLS) regression method by following several longitudinal studies on analyzing country-level determinants of national innovation and entrepreneurship (Anokhin and Schulze, 2009; Bettencourt et al., 2007; Dau and Cuervo-Cazurra, 2014; Martinez et al., 2015). This method is asymptotically efficient over OLS in the presence of panel-specific heteroskedasticity, and/or serial correlation problems that are typical (Anokhin and Schulze, 2009). Since we have country-year panel data, FGLS mitigates those issues (Anokhin and Schulze, 2009; Audretsch and Thurik, 2001). In our main analysis, we specified the independent form of autocorrelation and heteroskedastic error structures since the number of countries outweighs the number of years in our data (Beck and Katz, 1995). As a robustness test, we also specified the AR1 autocorrelation structure, which did not affect the significance of our results.

We also conduct analysis using Generalized Estimating Equations (GEE) and between-effects models as a robustness check. Following the suggestion of Certo et al. (2017), we calculated intraclass correlation coefficients (ICCs)[2] that represent the relative influence of between-variance versus within-variance. This value was 0.805, meaning the overall variance of our dependent variable is mostly driven by the between-variance. This finding is consistent with our theory, which focuses on explaining how differences in climate impact between countries influence CCA IP protection. For this reason, GEE and between-effects models were further employed to ensure the robustness of our findings.

All predictor, moderating, and control variables were lagged by a year to deal with possible simultaneity issues. Furthermore, we mean-centered moderating variables to avoid potential multicollinearity issues and enhance the interpretability of the results. We used the following model to predict the CCA IP protection (*CCA IPP*):

$$\text{CCA IPP}_{it+1} = \beta_1\text{ClimateImpact}_{it} + \beta_2\text{Formal Inst}_{it} + \beta_3\text{Informal Inst}_{it} + \beta_4\text{ClimateImpact}_{it} \times \text{Formal Inst}_{it} + \beta_5\text{ClimateImpact}_{it} \times \text{Informal Inst}_{it} + \beta_6\text{ControlVar}_{it} + \text{Year} + \text{Region}_i + \varepsilon_{it}$$

where i is the country and t is the year.

4. Results

Table 1 shows the top 25 countries in terms of CCA IP protection across all years in our sample (i.e., number of CCA patents) along with their levels of climate impact. Table 2 presents the descriptive statistics and correlation matrix of the variables used in our analysis. In order to ensure that multicollinearity is not an issue in our models, we checked the variance inflation factors (VIF). The average VIF score of the main regression model was 2.75, which is well below the acceptable threshold of 10.

4.1. Tests of hypotheses

Table 3 presents the main results examining the relationship between climate impact and CCA IP protection and the moderating

[2] Results are available upon request.

Table 1
Top 25 countries in sample by patents.

Rank	Total number of CCA patents	Average value of climate impact	Countries
1	8676	−0.245	United States
2	1243	−0.49	Japan
3	836	−0.503	Germany
4	448	−0.539	United Kingdom
5	442	−0.519	France
6	343	−0.69	South Korea
7	319	−0.544	Canada
8	233	−0.256	China
9	198	−0.697	Belgium
10	197	−0.793	Israel
11	152	−0.85	Netherlands
12	129	−0.771	Sweden
13	122	−0.696	Switzerland
14	114	−0.802	Denmark
15	84	−0.536	Italy
16	83	−0.806	Norway
17	80	−0.33	Australia
18	75	−0.569	Spain
19	66	−0.739	Ireland
20	66	−0.581	Saudi Arabia
21	66	−1.02	Singapore
22	60	−0.23	India
23	40	−0.53	Austria
24	36	−0.461	Brazil
25	35	−0.953	Finland

Table 2
Correlation matrix and descriptive statistics.

	1	2	3	4	5	6	7	8	9	10	11
Dependent variable											
1 CCA IP protection[a]	1										
Independent variable											
2 Climate impact	0.20	1									
Control variables											
3 GDP per capita (1000)	0.66	−0.10	1								
4 GDP growth rate	−0.18	0.02	−0.30	1							
5 R&D/GDP	0.75	−0.01	0.70	−0.24	1						
6 Co2 emission per capita	0.43	−0.10	0.56	−0.17	0.42	1					
7 Trade openness	−0.06	−0.31	0.23	0.07	0.13	0.23	1				
8 Energy consumption per capita (1000)	0.49	−0.13	0.71	−0.21	0.52	0.92	0.27	1			
9 Education attainment	0.44	−0.11	0.55	−0.24	0.57	0.47	0.28	0.48	1		
Formal institutions											
10 IPR regime	0.61	−0.05	0.71	−0.08	0.63	0.53	0.23	0.63	0.44	1	
Informal institutions											
11 Environmental movement[a]	0.71	0.16	0.42	−0.13	0.39	0.28	−0.12	0.34	0.18	0.38	1
Number of observations	689	689	689	689	689	689	689	689	689	583	689
Mean	1.13	−0.65	21.39	3.46	1.14	6.42	43.23	2.86	10.18	0.44	0.72
S.D.	1.53	0.29	19.87	3.78	1.03	4.85	27.10	2.12	2.16	0.20	0.90
Min	0.00	−1.26	0.30	−14.76	0.02	0.04	9.17	0.26	1.48	0.04	0.00
Max	6.92	−0.02	91.57	25.16	4.43	39.40	228.04	19.99	13.28	0.96	4.01

Note: For our main analysis, we mean-centered the moderating variables.
[a] Logarithm transformed.

effects of formal and informal institutions on that relationship. We observe consistent estimates of the control variables across all the models.

Hypothesis 1 predicts a positive relationship between climate impact and CCA IP protection. Model 1 of Table 3 shows that *climate impact* has a positive and significant effect on CCA IP protection ($\beta = 0.299$, $p \approx 0.000$, CI = [0.187, 0.411]), as predicted in Hypothesis 1. The coefficient indicates that one unit increase in climate impact increases CCA IP protection by 7.72 %. This positive relationship holds across the different models of Table 3. We, therefore, conclude that Hypothesis 1 is supported.

Hypothesis 2 states that the effect of climate impact on CCA IP protection is stronger in countries with higher levels of formal regulatory institutions. In order to test this hypothesis, Model 2 of Table 3 estimates the moderating effect of IPR regime on the relationship between climate impact and CCA IP protection. The coefficient of the interaction term is positive and statistically

Table 3
Predicting CCA IP protection using FGLS.

	Model (1)	Model (2)	Model (3)	Model (4)
H1: Climate impact	0.299	0.601	0.574	0.589
	(0.06)	(0.09)	(0.06)	(0.08)
GDP per capita	0.032	0.026	0.019	0.017
	(0.00)	(0.00)	(0.00)	(0.00)
GDP growth rate	0.015	0.010	0.005	0.005
	(0.01)	(0.01)	(0.00)	(0.01)
R&D/GDP	0.751	0.840	0.588	0.659
	(0.04)	(0.04)	(0.03)	(0.03)
Co2 emission per capita	0.045	0.047	0.016	0.042
	(0.01)	(0.02)	(0.01)	(0.01)
Trade openness	−0.006	−0.004	−0.003	−0.002
	(0.00)	(0.00)	(0.00)	(0.00)
Energy consumption per capita	−0.190	−0.183	−0.098	−0.123
	(0.03)	(0.04)	(0.03)	(0.03)
Education attainment	0.008	0.001	0.039	0.019
	(0.01)	(0.01)	(0.01)	(0.01)
IPR regime		2.029		1.100
		(0.32)		(0.30)
H2: Climate impact × IPR regime		2.399		1.162
		(0.42)		(0.40)
Environmental movement			1.140	1.017
			(0.05)	(0.06)
H3: Climate impact × Environmental movement			0.716	0.598
			(0.08)	(0.09)
Constant	0.541	0.699	0.771	0.895
	(0.12)	(0.15)	(0.12)	(0.13)
Year fixed	Yes	Yes	Yes	Yes
Region fixed	Yes	Yes	Yes	Yes
Wald χ^2	4787.287	4381.009	7776.121	7114.293
Number of countries	95	78	95	78
Number of observations	689	583	689	583

Note: Standard errors are in parentheses.

significant (β = 2.399, p ≈ 0.000, CI = [1.571, 3.227]). We plot the estimates in Fig. 2 using one standard deviation above (high) and below (low) the mean value of IPR regime. When the level of IPR regime is high, one unit increase in climate impact increases CCA IP protection by 27.78 % from its mean value; by contrast, when the level of IPR regime is low, one unit increase in climate impact increases CCA IP protection only by 3.27 %. Therefore, we conclude that formal regulatory institutions in the form of IPR protection positively moderate the relationship between climate impact and CCA IP protection, as predicted in Hypothesis 2.

Hypothesis 3 suggests that in countries characterized by stronger environmental movements, climate impact will have a more positive effect on CCA IP protection. Model 3 of Table 3 estimates the moderating effect of environmental movement on the relationship between climate impact and CCA IP protection. The coefficient for the interaction term is positive and statistically significant (β = 0.716, p ≈ 0.000, CI = [0.567, 0.865]). We plot the estimates in Fig. 3 using one standard deviation above (high) and below (low) the mean value of environmental movement. When the level of environmental movement is high, one unit increase in climate impact increases CCA IP protection from its mean value by 31.47 %; by contrast, when the level of environmental movement Is low, one unit increase in climate impact decreases CCA IP protection by 1.82 % when other variables are at their mean value. Therefore, we conclude that environmental movement strength positively moderates the relationship between climate impact and CCA IP protection, thereby supporting Hypothesis 3.

4.2. Analytical extension I: investigation of potential mediating effect of environmental movement

In light of adversity created by climate change, there has been a surge in environmental movement and protests (Hall et al., 2010; Hoffman and Jennings, 2015; Waldron et al., 2015). This suggests climate impact can give rise to environmental movements, which in turn can place pressure on firms to engage in innovative CCA behavior. To test for the presence of a mediated relationship, we augmented our models to include environmental movement as a mediator.[3]

We employ the widely used mediation models suggested by Baron and Kenny (1986) and a bootstrapping method (MacKinnon et al., 2004). Models 1 and 2 of Table 4 show that climate impact is positively and significantly related to CCA IP protection (β = 0.728, p ≈ 0.000, CI = [0.499, 0.957]) and environmental movement (β = 0.403, p ≈ 0.000, CI = [0.207, 0.699]). Model 3 reports that environmental movement has a positive and significant effect on CCA IP protection (β = 0.653, p ≈ 0.000, CI = [0.575, 0.732]). When the moderating effect of IPR regime on the relationship between environmental movement and CCA IP protection is included in the

[3] We thank our review team for this great suggestion.

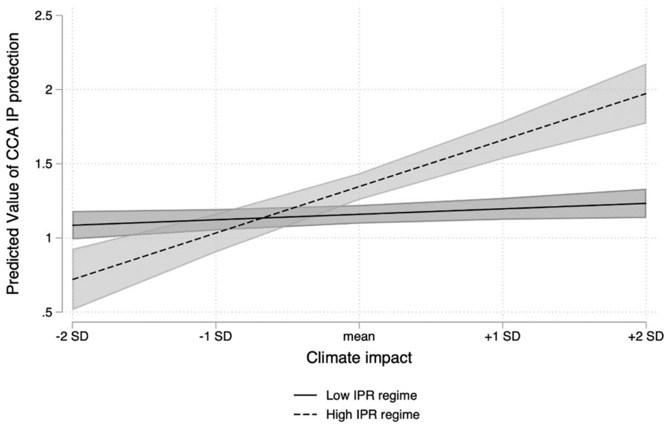

Fig. 2. The moderating effect of IPR regime on the relationship between climate impact and CCA IP protection.

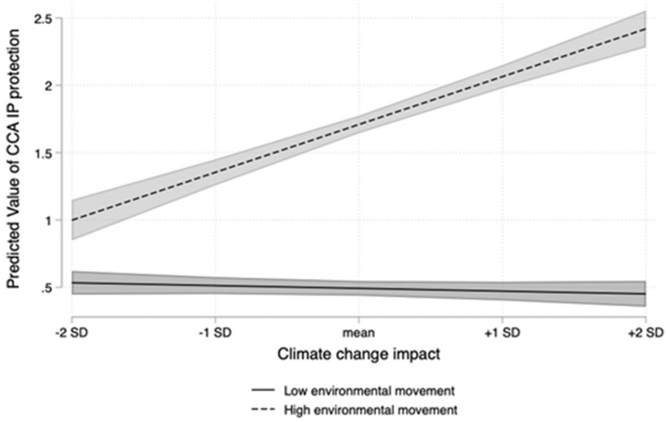

Fig. 3. The moderating effect of environmental movement on the relationship between climate impact and CCA IP protection.

model, the moderating effect is positive and significant (β = 2.031, p ≈ 0.000, CI = [0.991, 3.070]) along with the positive and statistically significant relationship between environment movement and CCA IP protection (β = 0.616, p ≈ 0.000, CI = [0.533, 0.698]) as shown in Model 4 of Table 4. To accurately estimate the indirect effects of environmental movement on CCA IP protection, we follow the bootstrap procedure (Shrout and Bolger, 2002) using 5000 bootstrap samples. As shown in Table 5, the indirect effect of climate impact on CCA IP protection via environmental movement is positive and statistically significant (β = 0.203, CI = [0.052, 0.304]). This indirect effect is also more pronounced when the level of the IPR regime exceeds one standard deviation above the mean (β = 0.329, CI = [0.081, 0.482]), compared to the effect observed at one standard deviation below the mean, where the relationship is weaker (β = 0.078, CI = [0.018, 0.147]).

4.3. *Analytical extension II: further exploration of triple-situated climate attention*

To further analyze the nature of "triple-situated" attention in country-level climate impact, appropriability regimes, and activism regime environments,[4] we re-estimated our models using subsamples of countries with high vs. low IPR regime and high vs. low environmental movement strength, respectively.

Comparing coefficients for models with high and low (above and below the median) IPR regime, the difference in coefficients between *climate impact* × *environmental movement* is statistically significant (β = 0.274, p = 0.043, CI = [0.009, 0.539]) as shown in Models 4 (β = 0.438) and 8 (β = 0.165) of Table 6. Comparing coefficients for models with high and low environmental movement, the difference in coefficients between *climate impact* × *IPR regime* is not statistically significant (β = −0.016, p = 0.983, CI = [−1.463, 1.431]) as shown in Models 4 (β = 0.101) and 8 (β = 0.117) of Table 7.

[4] We thank our review team for this great suggestion.

Table 4
Predicting CCA IP protection with environmental movement as mediator (A).

	Model (1)	Model (2)	Model (3)	Model (4)
	CCA IP protection	Environmental movement	CCA IP protection	CCA IP protection
Climate impact	0.728	0.403	0.465	0.550
	(0.12)	(0.10)	(0.10)	(0.12)
GDP per capita	0.034	0.016	0.024	0.021
	(0.00)	(0.00)	(0.00)	(0.00)
GDP growth rate	0.024	0.009	0.018	0.017
	(0.01)	(0.01)	(0.01)	(0.01)
R&D/GDP	0.732	0.143	0.638	0.699
	(0.05)	(0.04)	(0.04)	(0.05)
Co2 emission per capita	0.057	0.006	0.053	0.064
	(0.02)	(0.02)	(0.01)	(0.02)
Trade openness	−0.007	−0.003	−0.005	−0.003
	(0.00)	(0.00)	(0.00)	(0.00)
Energy consumption per capita	−0.200	−0.033	−0.178	−0.186
	(0.05)	(0.05)	(0.04)	(0.05)
Education attainment	0.016	−0.016	0.026	0.006
	(0.02)	(0.02)	(0.02)	(0.02)
Environmental movement			0.653	0.616
			(0.04)	(0.04)
IPR regime				1.617
				(0.43)
Environmental movement × IPR regime				2.031
				(0.53)
Constant	0.587	−0.310	0.790	0.800
	(0.22)	(0.21)	(0.18)	(0.20)
Year fixed	Yes	Yes	Yes	Yes
Region fixed	Yes	Yes	Yes	Yes
R^2	0.762	0.422	0.847	0.858
Number of countries	95	95	95	78
Number of observations	689	689	689	583

Note: Robust standard errors are in parentheses. Results are based on Baron and Kenny's method.

Table 5
Predicting CCA IP protection with environmental movement as mediator (B).

	Coef.	Bias	Bootstrap		
			s.e.	[95 % CI]	
IPR regime − 1 SD	0.078	0.015	0.038	[0.018	0.147]
IPR regime mean	0.203	0.036	0.067	[0.052	0.304]
IPR regime + 1 SD	0.329	0.058	0.106	[0.081	0.482]

Note: Results based on 5000 bias corrected bootstrap samples. Mean value of IPR regime is zero.

5. Robustness tests

We ran several additional tests to ensure the robustness of our findings. First, we employ an alternative measure for our moderating variable on formal institutions. For formal institutions, our arguments are also based on (general) property rights. To this end, we use the sub-index on property rights from the Heritage Foundation's Economic Freedom Index (McMullen et al., 2008). The result considering alternative IPR regime is shown in Appendix Table 2. We report that our main results are not affected by alternative choices of our moderating variable.

Second, we seek to rule out the possibility that our results are driven by the assumptions behind the specific estimation model (i.e., FGLS). To address this concern, we employ the generalized estimating equation (GEE) developed by Liang and Zeger (1986), which is a pooled estimator that considers both between and within variation in the data (Cameron and Trivedi, 2010). This estimation technique has been used in numerous entrepreneurship studies utilizing panel data (e.g., Dau and Cuervo-Cazurra, 2014; Lee et al., 2011). As reported in Appendix Table 2, we observe similar results to our main results. In addition, it shows results using between-effects models, as our primary focus is estimating between-variances among countries. These analyses produce similar results. Further, we re-estimated FGLS with AR1 autocorrelation structure or panel-specific AR1 autocorrelation structure and GEE with AR1 autocorrelation structure in case autocorrelation could have biased our results. Even with the autocorrelation assumptions, we continue to observe consistent results.

Third, we employed alternative measures of our dependent variable in case our main measure was biased, as presented in Appendix Table 3. We consider the fractional ownership of patents, which accounts for when patents have multiple assignees. Overlooking patents with multiple assignees may bias the patent measure upward because it would not account for the fractional

Table 6
Sub-sample analysis based on high and low IPR regime.

	High IPR regime				Low IPR regime			
	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)	Model (7)	Model (8)
H1: Climate impact	0.709	0.581	0.279	0.204	0.207	0.215	0.247	0.248
	(0.16)	(0.16)	(0.12)	(0.13)	(0.06)	(0.15)	(0.07)	(0.16)
GDP per capita	0.030	0.023	0.016	0.017	0.044	0.043	0.043	0.042
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
GDP growth rate	0.036	0.036	0.024	0.022	−0.005	−0.006	−0.006	−0.007
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
R&D/GDP	0.771	0.833	0.655	0.716	0.744	0.735	0.713	0.708
	(0.06)	(0.05)	(0.04)	(0.04)	(0.08)	(0.09)	(0.09)	(0.09)
Co2 emission per capita	0.105	0.081	0.060	0.046	−0.114	−0.114	−0.111	−0.110
	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)
Trade openness	−0.006	−0.007	−0.006	−0.006	−0.004	−0.004	−0.004	−0.004
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Energy consumption per capita	−0.235	−0.298	−0.139	−0.199	0.128	0.147	0.112	0.133
	(0.05)	(0.05)	(0.04)	(0.04)	(0.08)	(0.08)	(0.08)	(0.08)
Education attainment	−0.063	−0.051	−0.009	0.009	0.033	0.031	0.036	0.034
	(0.03)	(0.03)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
IPR regime		2.887		0.181		0.233		0.280
		(0.74)		(0.48)		(0.55)		(0.57)
H2: Climate impact × IPR regime		1.677		0.101		0.026		−0.064
		(0.98)		(0.64)		(0.78)		(0.84)
Environmental movement			1.211	1.175			0.119	0.130
			(0.07)	(0.07)			(0.06)	(0.06)
H3: Climate impact × Environmental movement			0.498	0.438			0.140	0.165
			(0.10)	(0.10)			(0.08)	(0.09)
Constant	1.233	1.261	1.204	1.183	−0.053	−0.003	−0.006	0.055
	(0.29)	(0.28)	(0.22)	(0.22)	(0.11)	(0.15)	(0.12)	(0.16)
Year fixed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region fixed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wald χ^2	2437.400	2656.736	7182.856	7073.225	394.227	398.711	394.959	397.977
Number of countries	39	39	39	39	39	39	39	39
Number of observations	336	332	336	332	251	251	251	251

Note: Standard errors are in parentheses.

contribution of multiple assignees. For this reason, we constructed an alternative dependent variable by evenly dividing the ownership of the patents with the number of assignees (Hall et al., 2001). Further, we utilized grant year of a patent instead of its application year. We also consider that some private-sector actors might require more time to respond to climate impact that can subsequently be translated into CCA IP protection. As such, we use a three-year time lag. The results show that our main results are not sensitive to alternative operationalization of our dependent variable.

Fourth, we checked to see if our main results are sensitive to alternative operationalization of our independent variable.[5] As shown in Appendix Table 4, we conducted several analyses using data on fatalities and absolute losses (in million US$) sourced from Germanwatch. Although the coverage of this data set is smaller than that of the CRI score, it substantiates our main findings. Fifth, given that the U.S. accounts for a disproportionate number of Y02A patents, we conducted a test that excluded the U.S. from our sample to rule out the possibility that our results are driven by this highly productive country in terms of patenting. Sixth, since IPR regime is highly correlated with the Economic Freedom Indices, we did not include the aggregate score of economic freedom in our main analysis. Yet, it is crucial to consider economic freedom because a large body of literature has shown that economic freedom enhances entrepreneurial and innovative activity (Bennett and Nikolaev, 2021; Boudreaux et al., 2019; Gohmann et al., 2008). As a robustness check, we tested whether our results are sensitive to the inclusion of economic freedom as a control variable. Seventh, we conducted the same set of analysis excluding control variables to ensure that our main findings are not driven by such contextual variables (Breaugh, 2006). Finally, we ran our models after excluding patents that were jointly classified as Y02A and other mitigations patents (e.g., Y02B, Y02D, etc.) as reported in the Appendix Table 5. In all cases, the main findings hold by yielding qualitatively similar results, supporting our hypotheses. These results are all available upon request.

6. Discussion

We studied how country-level climate impact, IPR regimes, and environmental movements contribute to CCA IP protection because CCA-related innovation is at an early stage and it varies significantly across countries (e.g., Doh et al., 2019). Further, while some research has considered businesses' adaptive responses to climate change, scholars have yet to tackle the antecedents to entrepreneurial CCA activities. Using a sample of 689 country-year observations consisting of 95 countries over the period 2005 to 2015, we

[5] We thank our review team for this great suggestion.

Table 7
Sub-sample analysis based on high and low environmental movement.

	High environmental movement				Low environmental movement			
	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)	Model (7)	Model (8)
H1: Climate impact	0.730	0.679	−0.087	0.025	0.046	0.094	0.045	0.599
	(0.13)	(0.16)	(0.12)	(0.15)	(0.04)	(0.09)	(0.20)	(0.31)
GDP per capita	0.026	0.017	0.017	0.014	0.024	0.022	0.024	0.022
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
GDP growth rate	−0.006	−0.005	0.005	−0.004	0.001	−0.003	0.001	−0.003
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)
R&D/GDP	0.865	0.871	0.728	0.837	0.180	0.291	0.178	0.316
	(0.05)	(0.05)	(0.04)	(0.04)	(0.05)	(0.06)	(0.05)	(0.06)
Co2 emission per capita	0.118	0.150	0.022	0.052	−0.005	−0.009	−0.008	−0.004
	(0.02)	(0.03)	(0.02)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)
Trade openness	−0.004	−0.005	−0.008	−0.008	−0.002	−0.001	−0.002	−0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Energy consumption per capita	−0.314	−0.309	−0.055	−0.104	−0.053	−0.044	−0.050	−0.058
	(0.05)	(0.07)	(0.04)	(0.05)	(0.04)	(0.05)	(0.04)	(0.05)
Education attainment	−0.067	−0.158	0.001	−0.050	−0.009	−0.010	−0.007	−0.011
	(0.02)	(0.03)	(0.02)	(0.03)	(0.01)	(0.01)	(0.01)	(0.01)
IPR regime		4.029		1.181		0.150		0.153
		(0.48)		(0.44)		(0.33)		(0.32)
H2: Climate impact × IPR regime		2.623		0.101		0.109		0.117
		(0.72)		(0.61)		(0.42)		(0.42)
Environmental movement			1.394	1.318			0.098	0.230
			(0.08)	(0.09)			(0.22)	(0.27)
H3: Climate impact × Environmental movement			0.695	0.645			0.001	0.716
			(0.12)	(0.13)			(0.28)	(0.44)
Constant	1.840	2.198	1.290	1.357	0.206	0.155	0.277	0.329
	(0.30)	(0.34)	(0.25)	(0.28)	(0.08)	(0.12)	(0.17)	(0.21)
Year fixed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region fixed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wald χ^2	3178.846	3025.199	7847.764	6265.885	277.795	352.522	277.907	354.249
Number of countries	46	40	46	40	49	38	49	38
Number of observations	347	321	347	321	342	262	342	262

Note: Standard errors are in parentheses.

find country-level climate impact drives CCA IP protection, especially when there are strong IPR regimes and environmental movements. Our findings have implications for the literatures on sustainable entrepreneurship, the attention-based view of the firm, and corporate CCA.

6.1. Discussion and contributions

First, we contribute to the sustainable entrepreneurship literature by emphasizing the importance of how the geography of climate impact underpins innovative private-sector adaptive responses to climate change. Early research in sustainable entrepreneurship argued that increasing levels of ecological degradation offer an opportunity for sustainable entrepreneurship rooted in exploiting several market imperfections. These include inefficiencies in how natural resources are consumed, untapped markets for resolving environmental externalities, and information asymmetries that can be leveraged through knowledge generated by environmental innovation (Cohen and Winn, 2007). More recent research emphasizes how sustainable entrepreneurship faces significant institutional barriers because the evolution of economic regimes has often overlooked the economic value of the environment, which has allowed the private sector to freely degrade it (Vedula et al., 2022). Not surprisingly, these research contributions found that successful sustainable entrepreneurship may hinge on institutional entrepreneurship that legitimizes an ecological logic that values the environment (York et al., 2016). Nearly all of this research, however, has focused on sustainable entrepreneurship that emphasizes protecting and restoring the natural environment, as opposed to adapting to physical changes occurring as a result of environmental degradation (Tashman, 2021).

Our study addresses the latter question by exploring how the geography of climate impact can resituate private-sector attention on salient CCA innovation activities. It does so by highlighting how entrepreneurs' attentional biases can inhibit them from focusing on non-routine issues such as climate change and showing how climate events and institutional context can shift their focus to its disruptive potential. By implication, attention appears to affect whether entrepreneurs view such market failures as opportunities when it is situated primarily in geographies that experience higher climate impact. This suggests that entrepreneurs will increase their attention to innovative forms of CCA in the future as climate impact becomes more pervasive and severe around the globe. Taken together, we believe our findings can act as a platform for entrepreneurship scholars to study CCA innovation in environments impacted by climate change, especially in geographies with supportive institutions.

Findings from our analytical extensions provide additional insights into the mechanisms at play. First, they suggest that environmental movements may act as an intermediary mechanism that helps explain how climate impact drives CCA IP protection. Thus, environmental movements seem to play a role in shaping and interpreting climate impact, potentially magnifying perceptions of their severity via public outreach, media campaigns, and expert opinion. NGOs such as The Nature Conservancy and World Wildlife Fund frequently take out advertising in major publications, organize protests that receive widespread media attention, serve as expert witnesses in legislative hearings, and otherwise raise visibility of pressing ecological challenges. By amplifying the urgency of climate impact, they may capture the attention of entrepreneurs, direct it toward climate-impact cues, and prompt them to increase their CCA IP investments.

Second, results of models using subsamples of countries with high vs. low IPR regime and high vs. low environmental movements, respectively, yielded mixed results. Higher levels of IPR regime strength magnified the moderating effect of environmental movement on the climate impact-CCA IP protection relationship, implying that stronger appropriability regimes help condition corporate decision-makers to attend to CCA IP when climate impact and environmental movements are both salient. This suggests that attention to IP protection strength of formal property rights institutions can magnify the effect that climate impact has on situated attention to CCA IP protection by creating more fertile ground for risky undertakings. At the same time, higher levels of environmental movement strength did not magnify the moderating effect of IPR regime on the climate impact-CCA IP protection relationship, implying that environmental movements do not play the same underlying conditioning role in the tripartite situated attention to CCA IP protection.

Second, our study extends research on the ABV by considering how attention can be multiply-situated in different external continencies. Since Ocasio's (1997) seminal work on the topic, the ABV has become a central theoretical perspective on many topics related to strategy and entrepreneurship including how attention influences organizational learning, adaptation, governance, stakeholder management, technology development, and even institutional change processes and more (Nigam and Ocasio, 2010; Laureiro-Martinez, 2021). One topic receiving significant work is the role that attention plays in dictating how firms respond to and influence their external contexts, including events and logics in their institutional environments. Key findings in this area include the role that changing institutional logics play in structuring executive attention (Ocasio and Thornton, 1999); how missed external cues damage organizational performance and drive them to alter attentional structures (Rerup, 2009); how powerful actors can influence industry attention to climate events and drive their emergence as central industry issues (Hoffman and Ocasio, 2001); and how ongoing industry attention to public issues can create opportunities to change institutional logics (Nigam and Ocasio, 2010).

One topic that has been overlooked is how attention can be situated in multiple overlapping institutional fields simultaneously, including fields organized around environmental issues like climate change, which can affect how organizations allocate attention and respond to external events. Such research is warranted because corporations frequently face institutional multiplicity in their external environments with potentially incompatible institutional logics. Further, they are also embedded in their ecological environments, which are being disrupted by unsustainable industrial activity and are returning disruptive physical forces into many national political economies that contain multiplex institutions (Tashman, 2021). Therefore, to understand how attention is situated in contextual conditions, it is necessary to consider the role that multiply-situated attention plays in driving corporate behavior. Our study addresses this issue by showing how corporate attention to the issue of climate change and the need for CCA-related innovation depends on how climate impacts a country's political economy, and how its institutions support corporate efforts in this regard. In doing so, it shows how attention to CCA IP protection can be catalyzed by proximal climate impact and attenuated by the traditional appropriability and activist regimes that traditionally act as foundations for innovative behavior.

Third, our study advances research on corporate CCA by considering factors that drive the unexplored and potentially critical topic of CCA-related IP (Hall et al., 2010; Howard-Grenville et al., 2014). Scholars have explored several aspects of CCA, including the nature of firms' vulnerability to climate change (Tashman and Rivera, 2016) and how these firms manage their vulnerability by protecting their resources (Busch, 2011), diversifying into less-vulnerable revenue streams (Hoffmann et al., 2009), and building adaptive capacity and resilience (Linnenluecke and Griffiths, 2010), as well as what draws their attention to the phenomenon (Pinkse and Gasbarro, 2019). Still, research on CCA-related IP is nascent. One potential reason is that the practice is stagnating globally, meaning there is little for scholars to study at this point (Dechezleprêtre et al., 2020; Pörtner et al., 2022).

Our study considers an early stage of the CCA innovation lifecycle, namely IP protection efforts, and uncovers factors to explain why corporate CCA IP protection efforts are heterogeneously distributed across countries. Our findings suggest that the economic and human toll of the physical impacts of climate change and favorable institutions in a country motivate sociopolitical pressures and demand conditions for CCA innovation, which drives corporate attention to protecting IP related to CCA. This finding is consistent with prior research on CCA that has found that experience with the physical impacts of climate change drive corporate CCA efforts, especially when institutional conditions support such efforts (Tashman and Rivera, 2016). The results, however, do not imply that corporations will bring CCA innovation to markets. Thus, it will be important to revisit this topic as climate impacts worsen to see if they catalyze more attention to CCA innovation and its commercialization. Relatedly, our results suggest that policy makers, environmental activists, and corporations may need to work more closely to identify and lower barriers to CCA innovation that have stunted its development to date (Doh et al., 2019).

6.2. Policy and practice implications

Our study also suggests several policy implications. Predictions derived from climate models suggest that the regions that will experience the most significant physical impact of climate change are also those that are generally characterized by weaker IPR regimes and environmental movements such as Africa or South America (UNFCCC, 2007). This is concerning because countries in these regions often lack the resources to drive CCA initiatives themselves (UNEP, 2021; UNFCC, 2021). Our study adds another layer of complexity to this issue by demonstrating that relatively weaker institutional environments in terms of weak IP protection and the absence of environmental movements will likely dampen local CCA innovation activity. While such unfavorable institutional conditions may sometimes be viewed as a source of comparative advantage for firms that are adept at leveraging institutional voids and building internal markets (Martin, 2014; Peng et al., 2009), the political economy in countries with the most climate impact suggests that such advantages may not emerge in the CCA context. Hence, an important policy implication that emerges from our study is that local policymakers need to address institutional weaknesses in order to create more favorable environments for private-sector CCA innovation. Alternatively, global stakeholders such as international governmental agencies (e.g., the United Nations) need to work with local institutions (e.g., civil society organizations) to channel entrepreneurs' attention to the need to adapt to climate change and to address the voids that are most consequential when it comes to hampering CCA innovation activity. The Global Environmental Facility (GEF) and the Green Climate Fund are examples of two such agencies that seek to provide funding and guidance to support these investments.

6.3. Limitations and future research

In this study, we focus on national CCA IP protection rates. While these national CCA IP protection rates represent the aggregate CCA innovation activity by private-sector actors in a country, our study design does not allow us to speak to industry- or firm-level heterogeneity in CCA IP protection. Similarly, there could be variation in climate impact and institutions across a country's subnational regions. Now that our study has established climate impact as a driver of CCA IP protection across different countries, future research may build upon our findings and develop an even more fine-grained understanding of the different drivers of CCA IP protection within high (low) climate-impact countries.

Moreover, our study does not account for how many patent holders may be multinational corporations that have diversified country risk because of their overseas operations. Future research may therefore consider more closely how climate impact affects multinational enterprises with geographically dispersed operations (Pinkse and Kolk, 2012).

Finally, we acknowledge the potential limitation of the Y02A patent classification that includes other sub-classes for dual purposes (e.g., adaptation and mitigation). Our additional analysis alleviates this issue by excluding patents that were jointly classified as adaptation and mitigation patents. The Y02A patent classification might have some misclassified patents because the measure is relatively new. Future studies could use text-mining techniques to identify technologies and patents that provide solutions to climate change.

7. Conclusion

The objective of this study was to create a platform for entrepreneurship scholars interested in the interface between climate change adaptation and strategic innovation. We have developed a model that elucidates the channels through which climate impact can translate into higher national CCA IP protection rates. We have further identified institutional conditions that influence entrepreneurs' responsiveness to climate impact. The findings prompt important questions related to how entrepreneurs located in countries with low IP protection and weak environmental movements can be incentivized to innovate in response to heightened climate impact. Overall, our study draws attention to CCA IP protection as an important entrepreneurial response to climate change.

Data availability

Data will be made available on request.

Acknowledgements

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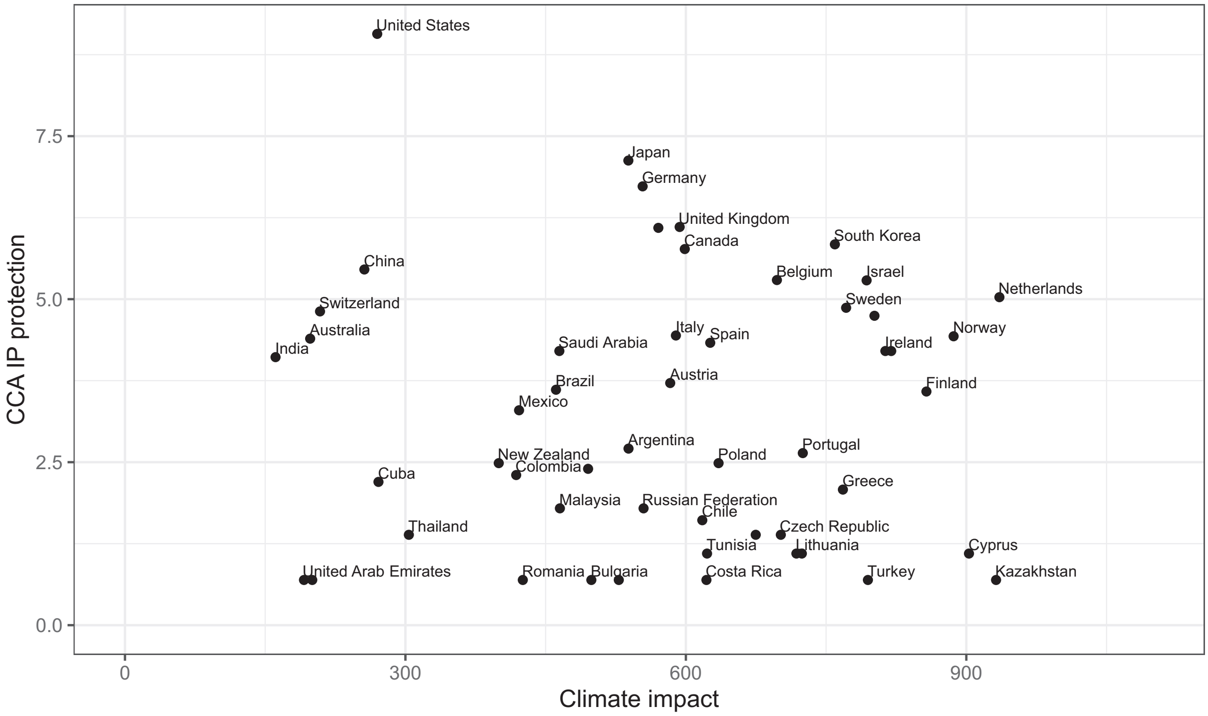
Appendix A



Appendix Fig. I. Different types of Y02A patents.
Note: While y-axis indicates the log value of the total sum of CCA patents, x-axis is the total sum of the climate impact.

Appendix Table 1
Different types of Y02A patents.

Subclass codes, descriptions, and examples	Percentage of patents
Y02A 10/00: Technologies for adaptation to climate change at coastal zones; at river basins (e.g. Artificial reefs or seaweed; Restoration or protection of coral reefs; Controlling or monitoring of flood or hurricane)	0.97 %
Y02A 20/00: Water conservation; Efficient water supply; Efficient water use (e.g. Rainwater harvesting; Saltwater intrusion barriers; Solar thermal; Photovoltaics; Wave energy)	7.26 %
Y02A 30/00: Adapting or protecting infrastructure or their operation (e.g. Strengthening power lines or underground power cables; Planning or developing urban green infrastructure)	6.22 %
Y02A 40/00: Adaptation technologies in agriculture, forestry, livestock or agroalimentary production (e.g. Genetically Modified [GMO] plants; Alternative feeds for fish; Cooking stoves using biomass)	16.04 %
Y02A 50/00: Technologies for adaptation to climate change in in human health protection, e.g. against extreme weather (e.g. Vehicle emission control or emission reduction by using catalytic converters; Solutions to mosquito-borne, fly-borne, tick-borne or waterborne diseases whose impact is exacerbated by climate change)	56.19 %
Y02A 90/00: Technologies having an indirect contribution to adaptation to climate change (e.g. Weather forecasting or climate simulation; Monitoring or fighting invasive species)	13.31 %

Source: https://www.uspto.gov/web/patents/classification/cpc/html/cpc-Y02A.html.

Appendix Table 2
Predicting CCA IP protection using alternative IPR regime variable and alternative estimation models.

	Alternative IPR regime				Between effects				GEE			
	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)	Model (7)	Model (8)	Model (9)	Model (10)	Model (11)	Model (12)
H1: Climate impact	0.299	0.467	0.574	0.593	1.615	2.297	1.291	1.854	0.728	0.863	0.595	0.600
	(0.06)	(0.08)	(0.06)	(0.07)	(0.46)	(0.59)	(0.37)	(0.51)	(0.20)	(0.26)	(0.17)	(0.18)
GDP per capita	0.032	0.032	0.019	0.019	0.039	0.032	0.029	0.024	0.034	0.028	0.025	0.022
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
GDP growth rate	0.015	0.012	0.005	0.002	0.044	0.007	0.023	−0.003	0.024	0.021	0.018	0.016
	(0.01)	(0.00)	(0.00)	(0.00)	(0.04)	(0.05)	(0.03)	(0.04)	(0.01)	(0.01)	(0.01)	(0.01)
R&D/GDP	0.751	0.763	0.588	0.602	0.797	0.803	0.619	0.652	0.732	0.782	0.615	0.676
	(0.04)	(0.04)	(0.03)	(0.03)	(0.12)	(0.14)	(0.10)	(0.13)	(0.14)	(0.15)	(0.08)	(0.10)
Co2 emission per capita	0.045	0.037	0.016	0.017	0.064	0.025	0.027	0.027	0.057	0.058	0.041	0.059
	(0.01)	(0.01)	(0.01)	(0.01)	(0.04)	(0.06)	(0.04)	(0.05)	(0.05)	(0.06)	(0.03)	(0.04)

(*continued on next page*)

Appendix Table 2 (*continued*)

	Alternative IPR regime				Between effects				GEE			
	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)	Model (7)	Model (8)	Model (9)	Model (10)	Model (11)	Model (12)
Trade openness	−0.006	−0.006	−0.003	−0.002	−0.005	0.002	−0.002	0.002	−0.007	−0.005	−0.004	−0.003
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Energy consumption per capita	−0.190	−0.155	−0.098	−0.091	−0.241	−0.040	−0.140	−0.017	−0.200	−0.204	−0.158	−0.175
	(0.03)	(0.03)	(0.03)	(0.03)	(0.11)	(0.14)	(0.09)	(0.12)	(0.12)	(0.14)	(0.07)	(0.09)
Education attainment	0.008	0.007	0.039	0.038	0.018	−0.048	0.023	−0.031	0.016	0.004	0.025	0.003
	(0.01)	(0.01)	(0.01)	(0.01)	(0.05)	(0.07)	(0.04)	(0.06)	(0.05)	(0.07)	(0.03)	(0.05)
IPR regime						6.414		3.738		2.717		1.206
						(1.83)		(1.66)		(1.15)		(0.73)
H2: Climate impact × IPR regime						8.601		4.719		2.914		1.423
						(2.68)		(2.44)		(1.39)		(0.87)
Environmental movement			1.140	1.118			1.240	0.962			1.022	0.932
			(0.05)	(0.06)			(0.24)	(0.30)			(0.12)	(0.14)
H3: Climate impact × Environmental movement			0.716	0.662			1.200	0.871			0.617	0.524
			(0.08)	(0.08)			(0.37)	(0.46)			(0.16)	(0.17)
Property rights		0.006		0.005								
		(0.00)		(0.00)								
H2: Climate impact × Property rights		0.012		0.006								
		(0.00)		(0.00)								
Constant	0.541	0.611	0.771	0.784	1.008	1.589	1.194	1.534	0.587	0.647	0.869	0.877
	(0.12)	(0.13)	(0.12)	(0.13)	(0.69)	(0.87)	(0.53)	(0.73)	(0.45)	(0.50)	(0.32)	(0.35)
Year fixed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region fixed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wald χ^2	4787.287	4135.462	7776.121	7902.337					333.704	498.392	1091.776	1162.772
Loglikelihood					−76.564	−58.676	−50.504	−43.256				
Number of countries	95	91	95	91	95	78	95	78	95	78	95	78
Number of observations	689	638	689	638	689	583	689	583	689	583	689	583

Note: Standard errors are in parentheses.

Appendix Table 3
Predicting CCA IP protection using alternative dependent variables.

	Patent with fractional ownership				Patent with granted year				3 years lead in patent			
	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)	Model (7)	Model (8)	Model (9)	Model (10)	Model (11)	Model (12)
H1: Climate impact	0.274	0.569	0.527	0.564	0.289	0.534	0.509	0.506	0.228	0.565	0.440	0.507
	(0.05)	(0.08)	(0.06)	(0.08)	(0.06)	(0.09)	(0.05)	(0.08)	(0.06)	(0.10)	(0.07)	(0.09)
GDP per capita	0.031	0.025	0.018	0.016	0.025	0.024	0.018	0.020	0.027	0.020	0.017	0.014
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
GDP growth rate	0.014	0.011	0.006	0.006	0.010	0.004	0.005	0.002	0.006	−0.000	−0.001	−0.008
	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)
R&D/GDP	0.735	0.820	0.579	0.655	0.681	0.820	0.517	0.643	0.632	0.758	0.558	0.623
	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)	(0.04)	(0.04)	(0.04)	(0.03)	(0.03)
Co2 emission per capita	0.043	0.044	0.020	0.047	0.026	0.019	0.001	0.007	0.045	0.047	0.034	0.059
	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)
Trade openness	−0.006	−0.004	−0.003	−0.002	−0.005	−0.003	−0.003	−0.002	−0.005	−0.003	−0.002	−0.002
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Energy consumption per capita	−0.182	−0.174	−0.102	−0.126	−0.123	−0.156	−0.047	−0.106	−0.145	−0.185	−0.118	−0.190
	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)	(0.04)
Education attainment	0.004	0.001	0.039	0.017	0.003	0.005	0.045	0.048	0.012	0.012	0.031	0.019
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)
IPR regime		1.933		1.193		1.277		−0.077		2.702		1.622
		(0.30)		(0.29)		(0.32)		(0.30)		(0.36)		(0.32)
H2: Climate impact × IPR regime		2.270		1.299		1.935		0.491		2.850		1.467
		(0.39)		(0.39)		(0.43)		(0.40)		(0.47)		(0.44)
Environmental movement			1.071	0.932			1.036	0.985			1.081	0.928
			(0.05)	(0.06)			(0.05)	(0.06)			(0.06)	(0.07)
H3: Climate impact × Environmental movement			0.663	0.531			0.613	0.558			0.683	0.541
			(0.08)	(0.09)			(0.07)	(0.09)			(0.08)	(0.10)
Constant	0.479	0.615	0.647	0.760	0.376	0.467	0.464	0.346	0.573	0.801	0.865	1.078
	(0.11)	(0.13)	(0.11)	(0.12)	(0.12)	(0.14)	(0.11)	(0.13)	(0.11)	(0.15)	(0.13)	(0.15)
Year fixed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region fixed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wald χ^2	4538.336	4658.803	7030.584	6523.607	2853.431	2916.199	6620.061	6437.811	2337.162	2929.691	6661.199	5984.072
Number of countries	95	78	95	78	95	78	95	78	95	78	95	78
Number of observations	689	583	689	583	689	583	689	583	689	583	689	583

Note: Standard errors are in parentheses.

Appendix Table 4
Predicting CCA technology protection with fatal score and loss score.

	Fatal score				Loss score			
	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)	Model (7)	Model (8)
Fatal score	0.090	0.220	0.081	0.142				
	(0.01)	(0.02)	(0.01)	(0.02)				
Loss score					0.049	0.090	0.041	0.055
					(0.01)	(0.01)	(0.01)	(0.01)
GDP per capita	0.032	0.032	0.023	0.024	0.030	0.022	0.020	0.014
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
GDP growth rate	0.019	0.007	0.009	0.004	0.020	0.013	0.014	0.011
	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)
R&D/GDP	0.796	0.808	0.614	0.671	0.783	0.836	0.630	0.685
	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.05)	(0.03)	(0.04)
Co2 emission per capita	0.079	0.035	0.031	0.063	0.074	0.079	0.039	0.075
	(0.02)	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)	(0.01)	(0.02)
Trade openness	−0.006	−0.001	−0.002	−0.001	−0.006	−0.005	−0.003	−0.004
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Energy consumption per capita	−0.238	−0.139	−0.141	−0.144	−0.231	−0.227	−0.146	−0.165
	(0.04)	(0.05)	(0.03)	(0.04)	(0.04)	(0.05)	(0.03)	(0.04)
Education attainment	0.021	0.054	0.040	0.016	0.017	0.037	0.050	0.044
	(0.02)	(0.01)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)
IPR regime		−1.389		−0.589		0.266		0.338
		(0.30)		(0.27)		(0.26)		(0.22)
H2: Climate impact × IPR regime		0.832		0.487		0.256		0.149
		(0.07)		(0.08)		(0.06)		(0.05)
Environmental movement			0.428	0.396			0.478	0.444
			(0.05)	(0.05)			(0.04)	(0.05)
H3: Climate impact × Environmental movement			0.091	0.055			0.040	0.028
			(0.01)	(0.01)			(0.01)	(0.01)
Constant	−0.315	−1.195	−0.094	−0.300	0.024	−0.127	0.064	0.058
	(0.18)	(0.16)	(0.15)	(0.17)	(0.15)	(0.15)	(0.13)	(0.12)
Year fixed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region fixed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wald χ^2	3522.109	4479.549	8072.635	7368.743	7001.658	3622.262	4829.917	5493.175
Number of countries	90	75	90	75	90	75	90	75
Number of observations	423	364	423	364	423	364	423	364

Note: Standard errors are in parentheses.

Appendix Table 5
Predicting CCA IP protection after excluding patents that were jointly classified as Y02A and other mitigations patents (e.g. Y02B, Y02D, etc.).

	Model (1)	Model (2)	Model (3)	Model (4)
H1: Climate impact	0.302	0.609	0.560	0.601
	(0.05)	(0.08)	(0.06)	(0.07)
GDP per capita	0.033	0.027	0.017	0.017
	(0.00)	(0.00)	(0.00)	(0.00)
GDP growth rate	0.013	0.008	0.005	0.003
	(0.00)	(0.00)	(0.00)	(0.00)
R&D/GDP	0.650	0.756	0.550	0.604
	(0.03)	(0.03)	(0.02)	(0.03)
Co2 emission per capita	0.042	0.049	0.025	0.050
	(0.01)	(0.02)	(0.01)	(0.01)
Trade openness	−0.006	−0.003	−0.002	−0.001
	(0.00)	(0.00)	(0.00)	(0.00)
Energy consumption per capita	−0.188	−0.212	−0.116	−0.167
	(0.02)	(0.04)	(0.02)	(0.03)
Education attainment	0.004	0.001	0.032	0.016
	(0.01)	(0.01)	(0.01)	(0.01)
IPR regime		1.844		0.990
		(0.29)		(0.26)
H2: Climate impact × IPR regime		2.364		1.140
		(0.39)		(0.34)
Environmental movement			1.105	1.005
			(0.05)	(0.06)
H3: Climate impact × Environmental movement			0.717	0.621
			(0.07)	(0.09)
Constant	0.488	0.626	0.696	0.812
	(0.11)	(0.13)	(0.10)	(0.11)

(*continued on next page*)

Appendix Table 5 (*continued*)

	Model (1)	Model (2)	Model (3)	Model (4)
Year fixed	Yes	Yes	Yes	Yes
Region fixed	Yes	Yes	Yes	Yes
Wald χ^2	10,399.414	5229.163	7811.373	7557.303
Number of countries	95	78	95	78
Number of observations	689	583	689	583

Note: Standard errors are in parentheses.

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