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Does national culture matter for environmental innovation? A study of emerging economies

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ABSTRACT

Environmental innovation is regarded as an essential tool to achieve the Paris Climate Conference agreement and Net Zero by 2050. Despite the extensive studies on the determinants of environmental innovation in developed countries, little attention has been paid to developing countries despite their dominance of emissions and different institutional characteristics. This paper fills the gap in the literature by investigating the determinants of environmental innovation in developing countries. In addition, the paper examines the role of national culture, an informal institutional factor, as a potential determinant of environmental innovation. Using 10,764 firm-year observations for a sample of 15 developing countries from 2015 to 2019, we find that environmental innovation is mainly driven by the demand-pull factor, rather than the technology-push factor, in developing countries. In addition, certain national cultural dimensions such as masculinity and long-term orientation enhance environmental innovation, while other dimensions such as power distance, individualism, uncertainty avoidance, and indulgence reduce it. The paper makes a theoretical contribution by extending the Porter Hypothesis towards institutional theory to include informal institutional factors (i.e. national culture) as a determinant of environmental innovation. The finding also suggests a rethink of policy in developing countries to focus more on demand-pull factors to promote environmental innovation.

1. Introduction

Considered one of the major challenges to human beings, climate change affects our societies on an unprecedented scale from food production to environmental disasters. In 2015, 193 parties, consisting of 192 countries and the European Union, agreed on the Paris Agreement at the Conference of the Parties (COP) 21 to limit the global temperature increase to 2 °C (aiming at 1.5 °C) in this century above the pre-industrial level (The Paris Agreement, 2015). The Agreement includes the parties setting up their Nationally Determined Contribution toward this goal and checking their progress every five years. At COP26 in 2021, the parties concluded that the aim toward a 1.5 °C increase in temperature was still alive but more efforts need to be made in terms of mitigation, adaptation, finance, and collaboration (COP26 The Glasgow Climate Pact, 2021). One of the key strategies of the mitigation effort is the Net Zero by 2050 commitment, in which more than 130 countries pledged to reach net-zero emissions before 2050 via natural carbon sinks (e.g. planting more trees) and environmental innovation (e.g. low-carbon technology and carbon-capture technology).

Due to the importance of environmental innovation on climate change, several studies investigated the determinants of environmental innovation. Early studies mainly tested the Porter hypothesis, which argues that a well-designed regulation can facilitate environmental innovation and subsequently improve firms' competitiveness (Brunnermeier and Cohen, 2003; Jaffe and Palmer, 1997; Porter and van der Linde, 1995; Rennings et al., 2006). Horbach (2008) and Horbach et al. (2012) extend this literature by examining the role of technology-push, demand-pull, and firm-specific factors as well as regulations on environmental innovation. Using German panel datasets, they argue that technology-push factors and regulations play a major role in promoting environmental innovation. Most of the literature, however, examined developed countries such as the USA and the European countries, leaving a gap in the literature regarding developing countries.

The study of developing countries is also practically important because developing countries exhibit different characteristics from developed countries in terms of regulations, technology-push, demand-pull, and firm-specific factors. For example, developing countries often lack a strong institutional environment that can enforce regulations

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effectively and efficiently (Agyei-Boapeah and Machokoto, 2018; Iyer et al., 2006). In addition, developing countries tend to lack skilled labour and technological knowledge, which are essential for technology-push factors. Customers in developing countries are often poorer than those in developed countries, so environmentally friendly but highly-priced products have limited affordability for them (Sheth, 2011). These institutional differences raise the question of whether we can apply the findings of developed countries to developing countries. Given that developing countries account for more than 63% of the world's CO_2 emissions ("Developing Countries Carbon Emissions", 2015) and are expected to suffer more from environmental disasters caused by climate change (Eckstein et al., 2021), it is essential to understand the determinants of environmental innovation in developing countries.

In addition to studying developing countries, this paper aims to make a theoretical contribution by extending Horbach (2008) and Horbach et al. (2012) to include an informal institutional factor (i.e. national culture) as a potential determinant of environmental innovation. Based on institutional theory (Oliver, 1997), culture exerts normative pressure on societal actors to guide certain social behaviour as informal regulations (DiMaggio and Powell, 1983; Scott, 2013). We, therefore, believe that informal regulations are as important as formal regulations in environmental innovation, which the current literature yet identified. Empirical studies have found that culture affects managerial decisions and corporate behaviour (Peng and Zhang, 2022), environmental disclosure (Gallego-Álvarez and Pucheta-Martínez, 2020), environmental performance (Wang et al., 2022), and national environmental practices (Roy and Goll, 2014). As far as the authors are aware, this is the first study to examine the role of national culture on environmental innovation. Therefore, we extend the Porter hypothesis, which focuses on formal regulations, to include informal regulations as an additional determinant of environmental innovation.

This paper aims to answer two research questions: (i) are the determinants of environmental innovation in developed countries also the determinants in developing countries? and (ii) does national culture affect environmental innovation?

Based on a large dataset of almost 11,000 firm-year observations across 15 developing countries over the period 2015–2019, we find that environmental innovation in developing countries is mainly driven by the demand-pull factors. Companies engage more in environmental innovation when there is a demand for corporate social responsibility and a partnership with environmental non-governmental organisations (NGOs). The results, on the other hand, show that the technology-push factor does not increase environmental innovation in developing countries. We also find that national culture has a significant impact on environmental innovation. Specifically, masculinity and long-term orientation increase environmental innovation, while power distance, individualism, uncertainty avoidance, and indulgence decrease it. To mitigate the endogeneity issues, we use a fixed-effects model in the firm-specific determinants model and include institutional governance factors as control variables in the national culture model. We also estimate the model with lagged control variables in the robustness test.

This paper makes several contributions to the literature and theory. First, the paper extends the current literature to developing countries where there are academic and practical needs for research (Holtbrügge and Dögl, 2012). The study of developing countries with different institutional characteristics from developed countries provides a boundary condition of the previous findings based on developed countries. Second, the paper extends the Porter hypothesis to institutional theory, which emphasises the importance of both formal and informal institutional factors on firms' behaviour.

The paper also makes several practical contributions. First, developing countries should devise their own strategies to promote environmental innovation. Given the lack of technological capability, developing countries should focus more on the demand-pull factors, rather than the technology-push factors, to promote environmental innovation. In addition, developing countries should review the strengths and weaknesses of their national culture on environmental innovation. As certain national cultural dimensions promote environmental innovation, countries can encourage those dimensions while discouraging the other dimensions. Due to the long-term nature of culture, changing culture is difficult, especially in the short term. However, culture can have a profound impact on environmental innovation as it applies to all members of society.

The remainder of the paper is organised as follows. Section 2 reviews the relevant literature and develops hypotheses, while Section 3 discusses the data and methodology. The results are presented and discussed in Section 4, followed by the analysis of the robustness test in Section 5. The paper concludes in Section 6.

2. Literature review and hypotheses development

2.1. Environmental innovation and its determinants

Environmental innovation is broadly defined as innovations in new processes, techniques, practices, systems, and products to avoid or reduce environmental harm (Beise and Rennings, 2005). Environmental innovations are a subset of a broader concept of eco-innovation (Konara et al., 2021). Eco-innovation, often used interchangeably with environmental innovation, can be viewed as the production, application, or exploitation of a product, service, production process, organisational structure, or management or business method that is novel to the firm or user, and which results in a reduction of environmental risk, pollution, and the negative impact of resource use (Horbach et al., 2012; Kemp and Pearson, 2007). These definitions suggest that environmental innovations can have a real impact on climate change. Empirical evidence suggests that environmental innovation reduces energy intensity and environmental pollution (Álvarez-Herránz et al., 2017) and carbon dioxide emissions (Balsalobre-Lorente et al., 2021). Therefore, environmental innovation is a matter of concern for firms and their stakeholders including governments, investors, customers, and society at large.

Prior studies have mainly relied on the Porter hypothesis to explain environmental innovations by firms (see Horbach et al., 2012; Konara et al., 2021; Ren et al., 2021). The Porter hypothesis (Porter and van der Linde, 1995) posits that strict environmental regulations promote corporate environmental innovations in at least four ways: (i) focusing management attention on the potential resource efficiencies and technological improvements gained from minimising hazardous discharges, (ii) reducing corporate uncertainty about whether investments in environmental innovation will be value-enhancing, (iii) creating pressure to promote innovative thinking, and (iv) creating a level playing field and reducing opportunistic behaviour. Indeed, there is empirical evidence to suggest that in regions where environmental regulations have been stringent, the extent of environmental innovation by firms has been greater (Chen et al., 2018; Kesidou and Wu, 2020; Popp, 2006).

The extant literature has proposed a variety of determinants of environmental innovation (see del Río González, 2009; Horbach, 2008; Peñasco et al., 2017). Horbach (2008) suggests three sets of determinants of environmental innovations: (i) regulation and policy determinants, (ii) supply-side or push factors (e.g. technological capabilities, cost savings, and industrial relationships), and (iii) demand-side or pull factors (e.g. environmental consciousness and consumers' preferences). Among them, they argue that influence from regulation and cost-saving motivation are the main determinants. In a related study, Horbach et al. (2012) identify four categories of determinants of eco-innovation: (i) regulation (national and international), (ii) market-pull factors (e.g. consumer benefits), (iii) technology-push factors (e.g. knowledge and R&D capabilities), and (iv) firm-specific factors (e.g. management systems, organisational processes, and resources). In a similar vein, del Río González (2009) reports that both internal resources (e.g. financial resources and technological capabilities) and external institutional factors (e.g. partnerships, collaborations, and market pressures) influence firms to

undertake environmental innovations.

Another strand of the literature emphasises the role of international factors in driving corporate environmental innovation. For example, Peñasco et al. (2017) distinguish between the national and international drivers of eco-innovation among Spanish firms and show that some international factors (e.g. cooperation with international actors) promote eco-innovations, while other factors (e.g. international sales and foreign equity) do not. They further find that domestic factors play a more dominant role in eco-innovations than international pressures. Focusing on foreign subsidiaries of Japanese multinational firms, Kawai et al. (2018) suggest that both local and global stakeholder pressures encourage multinational firms to undertake green practices, which in turn motivate their subsidiaries to undertake environmental innovations. Similarly, Konara et al. (2021) argue that foreign subsidiaries vary in their engagement with environmental innovation depending on the strength of their multinational firms' home-ecological institutions (i.e. the environmental performance of the home nation). Based on a sample of foreign subsidiaries in Spain, the authors find that the home-ecological institutions of parent multinationals have a positive and significant impact on subsidiary-level environmental innovation.

Collectively, prior studies suggest that institutional pressures, both local regulations and international factors, as well as firm-level resources largely determine environmental innovation (Horbach, 2008; Kawai et al., 2018; Konara et al., 2021; Peñasco et al., 2017). However, a limitation of the prior environmental innovation research is that limited attention has been given to informal regulatory institutions, such as the socio-cultural norms of countries. To obtain a better understanding of environmental innovation, we suggest that it is important to include the potential impact of Hofstede's national cultural dimensions on a firm's environmental innovation.

2.2. Theory and hypotheses development

Institutional theory provides the theoretical perspective for our study. Institutional theory holds that organisations operating in similar environments tend to adopt similar strategic practices and approaches (DiMaggio and Powell, 1983; Kostova and Roth, 2002; Attah-Boakye et al., 2020; Kimani et al., 2021). Institutions consist of a set of rules and regulations and specific practices such as ideas, levels of bureaucracy, ways of understanding reality, and cultural frameworks that influence business activities (Cuervo-Cazurra, 2008), which help to accomplish a degree of social permanence in a particular context (Higgins and Larrinaga, 2014). The proponents of institutional theory suggest that a core element of the theory is the notion that institutions operate according to the formal and informal rules of society and the interactions between institutions and societal agents, such as individuals, firms, and governments (North, 1990; Scott, 2013). The formal rules comprise laws, regulations, governmental procedures, and organisational structures to guide human and organisational action (Peng et al., 2008; Ullah et al., 2019), whereas the informal rules include ideas, beliefs, attitudes, and values (i.e. culture) of a particular society. Informal institutions, therefore, exert normative and cultural pressures toward a certain social behaviour (DiMaggio and Powell, 1983; Scott, 2013). Empirical management literature often considers culture as an informal institutional factor that shapes managerial decisions and corporate behaviour (e.g. Peng and Zhang, 2022; Wang et al., 2022).

Combining institutional theory with the Porter hypothesis, we contend that certain types of cultural orientations can create pressures and incentives for firms to undertake environmental innovations. In particular, cultural institutions may substitute for or complement governmental regulations and organisational resources to achieve sound environmental behaviour, including environmental innovations. If certain cultural orientations value environmental sustainability, firms will respond to the demands of environmental innovations from stakeholders by imitating the practices of the leading companies to achieve environmental legitimacy (DiMaggio and Powell, 1983). This is because culture tends to set a collective programme related to mindset that affects the basic values held by citizens and establishes social standards/regulations for firms to follow (Vitell et al., 2003). Unlike governmental regulations that exert coercive pressures on firms (Campbell, 2006), socio-cultural regulations present normative pressures on firms to undertake environmental innovations (Roy and Goll, 2014).

Roy and Goll (2014) examine the impact of national culture on a country's sustainability performance. Based on their sample of 54 countries, they conclude that cultural practices influence the environmental practices of countries. Similarly, Gallego-Álvarez and Pucheta-Martínez (2020) find that certain cultural dimensions, such as individualism and a long-term orientation, are important determinants of environmental disclosures. It is important to highlight that, while both studies improve our understanding of the link between national culture and environmental practices, they do not specifically address the relationship between national culture and environmental innovation, which presents us with a significant void to fill.

The influence of cultural institutions is usually studied using the six cultural dimensions proposed by Hofstede (2001): power distance, individualism, masculinity, uncertainty avoidance, long-term orientation, and indulgence. These six dimensions provide us with the framework for analysing the relationship between national culture and environmental innovation. Therefore, we briefly discuss how each of the six cultural dimensions may relate to environmental innovation and formulate hypotheses therefrom.

2.2.1. Power distance

The power distance dimension reflects how less powerful members perceive the unequal distribution of power in a society (*National Culture*). In a high power distance culture, people accept a hierarchical order and do not need a justification for inequality. On the other hand, people in low power distance cultures strive to equalise the distribution of power and demand a justification for inequality. Empirical evidence shows that managers in a high power distance society experience less monitoring by the board of directors (Peng and Zhang, 2022), thereby pursuing short-term goals over long-term goals, such as environmental sustainability (Bai and Elyasiani, 2013). In addition, studies show that power distance has a negative relationship with corporate green ranking (Wang et al., 2022), economic prosperity, competitiveness, human development (Miska et al., 2018), corporate social performance (Ringov and Zollo, 2007), business ethics (Okpara, 2014; Scholtens and Dam, 2007; Zengin Karaibrahimoglu and Guneri Cangarli, 2016), and carbon disclosure (Luo and Tang, 2015). Therefore, people in high power distance countries may be less empowered to demand corporate environmental accountability from powerful corporations and their managers (Peng and Zhang, 2022). This could result in weaker cultural pressure and incentives for firms to undertake environmental innovations. Accordingly, we hypothesise as follows:

H1. Environmental innovations are negatively affected by power distance.

2.2.2. Individualism

The individualism dimension describes the importance of individuals in a society and the extent to which personal rights have an influence (Hofstede, 2001). In individualistic societies, people tend to prefer a loose social framework and care for only themselves and their immediate families. On the other hand, collective societies demand stronger cooperation among the members of a particular group to look after each other. Therefore, it is likely that people in individualistic societies may show weaker concerns for environmental matters since they care more about themselves than the other members of society. Empirical evidence supports this view that collective societies encourage teamwork and value sharing (Griffith et al., 2006) and organisational collaboration and communication (Dimitratos et al., 2011; Newburry and Yakova, 2006). Buhr and Freedman (2001) find that environmental issues are discussed

more by the corporate board in collective societies. Managers also tend to show high moral values (Okpara, 2014; Westerman et al., 2007), environmental performance (Thanetsunthorn, 2015), and corporate social responsibility (CSR) disclosure in collective societies (Gallén and Peraita, 2018).

Despite this, it is also possible to expect that individualism may encourage environmental innovation if people in individualistic societies come to view environmental concerns as a matter of individual interest. However, we believe this possibility may be more of a case for developed countries where the citizens have more awareness of climate change and disposable incomes. In developing countries, however, people worry more about basic utilities, such as food and clothing, than environmental matters due to their low disposable incomes (Sheth, 2011). Therefore, we believe individualism hinders environmental innovation in developing countries.

H2. Environmental innovations are negatively affected by individualism.

2.2.3. Masculinity

The masculinity dimension reflects a preference for achievement instead of harmony (*National Culture*). In masculine societies, importance is placed on competitiveness, ambition, and success (Hofstede et al., 2010; Li and Harrison, 2008). Therefore, masculine societies value economic benefits and financial performance (Li and Harrison, 2008) and career development and business success (Santema et al., 2005). Low-masculinity societies, however, emphasise cooperation and caring for the weak (Hofstede et al., 2010) and societal harmony, including environmental harmony (Gray, 1988). Empirical evidence shows that low-masculinity culture is positively related to corporate environmental reporting (Gallego-Álvarez and Ortas, 2017), environmental protection (Luo and Tang, 2015), and CSR disclosure (Gallén and Peraita, 2018). Despite the positive relationship between low masculinity and environmental reporting, we believe masculinity is positively related to environmental innovation because innovation requires entrepreneurship, ambition, competitiveness, and success, followed by financial rewards (Porter and van der Linde, 1995; Yan et al., 2016). We, therefore, propose the following hypothesis:

H3. Environmental innovations are positively affected by masculinity.

2.2.4. Uncertainty avoidance

The dimension of uncertainty avoidance refers to the degree to which people feel uncomfortable with uncertainty and ambiguity. Societies with high uncertainty avoidance try to control the uncertainty by formalising the interactions between people through rigid codes and rules of behaviour (Hofstede et al., 2010). Therefore, companies tend to adopt a rigid structure (Joiner, 2001) with detailed management styles (Li and Harrison, 2008), and employees tend to follow those rules in a high uncertainty avoidance culture (Hofstede et al., 2010). On the other hand, a low uncertainty avoidance culture encourages high-risk tolerance with a tendency toward exploration of novel solutions (Hofstede et al., 2010). Empirical evidence shows that a low uncertainty avoidance culture exhibits high CSR disclosure (Garcia-Sanchez et al., 2016), corporate environmental proactivity (Calza et al., 2016), and environmental innovation (Vachon, 2010). As innovations are inherently entrepreneurial and uncertain, we believe uncertainty avoidance is negatively related to environmental innovation.

H4. Environmental innovations are negatively affected by uncertainty avoidance.

2.2.5. Long-term orientation

The dimension of long-term orientation refers to the orientation toward the future versus the present and the past (*National Culture*). People in a long-term orientation culture understand that environments are dynamic, and success requires adjustments and change (Geletkanycz, 1997). Therefore, they set long-term objectives and encourage entrepreneurial activities and innovation (Hofstede et al., 2010). On the other hand, in a short-term orientation culture, people consider the most important events in life to be occurring now or having already occurred in the past. Therefore, they tend to maintain tradition and regard societal change with suspicion (*National Culture*).

Empirically, Cheng et al. (2014) find that stakeholders in long-term orientation societies provide more social and environmental reporting, which contains information about the future. Similarly, Hackert et al. (2012) find that companies invest more in pollution prevention, recycling, and waste reduction in a long-term orientation culture. Therefore, we formulate our fifth hypothesis as follows:

H5. Environmental innovations are positively affected by long-term orientation.

2.2.6. Indulgence

Lastly, the indulgence dimension refers to the degree to which a society allows free gratification of basic and natural human drives (*National Culture*). People in indulgent societies tend to satisfy their immediate needs and personal desires, while those in restraint societies suppress gratification and regulate it through strict social norms (Hofstede et al., 2010). We believe that it is likely that people and firms in indulgent societies are concerned less about climate change, a future issue, and devote fewer resources to environmental innovations. In a similar vein, Gallego-Álvarez and Ortas (2017) find that indulgence culture is negatively related to environmental reporting. Therefore, we propose our final hypothesis as follows:

H6. Environmental innovations are negatively affected by indulgence.

3. Data and methodology

We collected data for 15 developing countries for the years 2015 to 2019, resulting in 10,764 firm-year observations. Table 1 explains a list of firm-level and country-level variables used in the analysis, including their definitions, data sources, and data codes. Firm-specific data are downloaded from Thomson Eikon, and Hofstede's cultural dimensions are collected from Hofstede Insights. Institutional governance data on government effectiveness, rule of law, and political stability are collected from the World Bank. Table 2 reports the number of observations by countries across the years. Most environmental innovation data of developing countries start from 2015. Although some countries have small representations in the sample, most countries show a sufficient number of observations. Fig. 1 displays the average environmental innovations across the countries. Countries scoring higher on environmental innovation are Colombia, Turkey, India, Thailand, and the Philippines. Morocco, Pakistan, and Peru demonstrate low environmental innovation levels, but this might be due to their small sample sizes.

Despite the extensive studies of developed countries on the determinants of environmental innovation, we find that there are no comprehensive studies of the determinants for developing countries. Therefore, we first begin with the firm-level investigation of the determinants before studying the cultural impact on environmental innovation.

Using panel data, we implement a fixed-effects logistic regression and a fixed-effects linear regression to control for unobserved time-invariant factors. The use of panel data offers significant advantages over cross-sectional and time-series data, including controls for various sources of endogeneity such as unobserved heterogeneity, simultaneity, and dynamic endogeneity (for the details of the sources of endogeneity and how to control it, refer to Ullah et al., 2018, 2021). For an environmental innovation study, Horbach (2008) argues that panel data are more desirable than cross-sectional data due to the path dependency of environmental innovation. We use fixed-effects, rather than random-effects, because we suspect that some unobserved time-invariant

Table 1
Definition of variables.

Category	Variable	Definition	Source (item code)
Dependent variable	ENV_INN	A binary variable for environmental product	Thomson Eikon (ENPIDP019)
Culture	PDI	Power distance index	Hofstede Insight
	IDV	Individualism vs collectivism	Hofstede Insight
	MAS	Masculinity vs femininity	Hofstede Insight
	UAI	Uncertainty avoidance index	Hofstede Insight
	LTO	Long-term orientation vs short-term normative orientation	Hofstede Insight
	IVR	Indulgence vs restraint	Hofstede Insight
Technology-push	RNDASSET	R&D expenditure divided by total assets	Thomson Eikon (WC01201/ WC02999)
Demand-pull	CSR	A binary variable for corporate social responsibility reporting	Thomson Eikon (CGVSDP026)
	PARTNER	A binary variable for environmental partnership	Thomson Eikon (ENERDP070)
	CSRCOM	A binary variable for the corporate social responsibility committee	Thomson Eikon (CGVSDP005)
Firm-specific	LNEMPLOYEE	Natural logarithm of the number of employees	Thomson Eikon (WC07011)
	LEVERAGE	Total debt divided by total capital (%)	Thomson Eikon (WC08221)
	ROE	Return on equity (%)	Thomson Eikon (WC08301)
	BOARD	Total number of board members	Thomson Eikon (CGBSDP060)
	INDEPENDENCE	The proportion of independent directors (%)	Thomson Eikon (CGBSO07V)
	FEMALE	The proportion of female directors (%)	Thomson Eikon (CGBSO03V)
	LNCO2	Natural logarithm of total estimated CO_2 equivalents emission	Thomson Eikon (ENERDP123)
Institutional governance	GOV_EFF	Government effectiveness	Worldbank Worldwide Governance Indicators
	LAW	Rule of law	Worldbank Worldwide Governance Indicators
	POL_STA	Political stability and absence of violence or terrorism	Worldbank Worldwide Governance Indicators

factors might be related to the determinants. For example, top management's attitude toward climate change may affect a firm's environmental innovation (Curwen et al., 2013; Huang and Jim Wu, 2010) as well as research and development (R&D) expenditures and CSR reporting. In addition, we empirically examined the model choice between fixed-effects and random-effects using the Hausman specification test. The null hypothesis was rejected, supporting the use of a fixed-effects model in the analysis. Several recent papers on environmental innovation also used a fixed-effects regression to mitigate the endogeneity issues (Hassan and Rousselière, 2022; Huseynov, 2021; Khan et al., 2022).

The firm-specific determinants model examines the relationship between environmental innovation and technology-push, demand-pull, and firm-specific factors as follows:

Table 2
Number of observations by country and year.

	2015	2016	2017	2018	2019	Total
Argentina	4	34	43	65	40	186
Brazil	310	308	308	323	299	1548
China	155	158	455	517	870	2155
Colombia	24	26	26	28	25	129
India	184	195	203	215	279	1076
Indonesia	193	193	205	214	218	1023
Malaysia	98	103	122	123	136	582
Mexico	235	266	282	289	260	1332
Morocco	8	8	8	6	7	37
Pakistan			5	5	5	15
Peru		16	13	14	13	56
Philippines	65	56	63	67	67	318
Russia	124	126	118	142	130	640
Thailand	169	186	192	213	237	997
Turkey	110	109	109	169	173	670
Total	1679	1784	2152	2390	2759	10,764

$$\begin{aligned} ENV\_INN_{i,t} = {} & \beta_0 + \beta_1 RNDASSET_{i,t} + \beta_2 CSR_{i,t} + \beta_3 PARTNER_{i,t} \\ & + \beta_4 CSRCOM_{i,t} + \beta_5 LNEMPLOYEE_{i,t} + \beta_6 LEVERAGE_{i,t} \\ & + \beta_7 ROE_{i,t} + \beta_8 BOARD_{i,t} + \beta_9 INDEPENDENCE_{i,t} \\ & + \beta_{10} FEMALE_{i,t} + \beta_{11} LNCO2_{i,t} + \sum_{i=12}^{15} \beta_i Year\ dummies + \varepsilon_{i,t} \end{aligned} \quad (1)$$

where $ENV\_INN_{i,t}$ is a binary variable for environmental innovation, and equals 1 if firm i at time t has an environmental product and 0 otherwise; $RNDASSET_{i,t}$ is R&D expenditure divided by total assets; $CSR_{i,t}$ is 1 if a firm issues a corporate social responsibility report and 0 otherwise; $PARTNER_{i,t}$ is 1 if a firm has a partnership with environmental NGOs and 0 otherwise; $CSRCOM_{i,t}$ is 1 if a firm has a corporate social responsibility committee and 0 otherwise; $LNEMPLOYEE_{i,t}$ is the natural logarithm of the number of employees; $LEVERAGE_{i,t}$ is total debt divided by total capital in percentage; $ROE_{i,t}$ is the return on equity in percentage; $BOARD_{i,t}$ is the size of the board of directors; $INDEPENDENCE_{i,t}$ is the proportion of independent directors in the board in percentage; $FEMALE_{i,t}$ is the proportion of female directors in percentage; and $LNCO2_{i,t}$ is the natural logarithm of CO_2 equivalents emission.

After examining the firm-level determinants, we expand the model to incorporate cultural dimensions as well as institutional governance factors as follows:

$$\begin{aligned} ENV\_INN_{i,j,t} = {} & \gamma_0 + \gamma_1 PDI_j + \gamma_2 IDV_j + \gamma_3 MAS_j + \gamma_4 UAI_j + \gamma_5 LTO_j \\ & + \gamma_6 IVR_j + \gamma_7 RNDASSET_{i,j,t} + \gamma_8 CSR_{i,j,t} + \gamma_9 PARTNER_{i,j,t} \\ & + \gamma_{10} CSRCOM_{i,j,t} + \gamma_{11} LNEMPLOYEE_{i,j,t} + \gamma_{12} LEVERAGE_{i,j,t} \\ & + \gamma_{13} ROE_{i,j,t} + \gamma_{14} BOARD_{i,j,t} + \gamma_{15} INDEPENDENCE_{i,j,t} \\ & + \gamma_{16} FEMALE_{i,j,t} + \gamma_{17} LNCO2_{i,j,t} + \gamma_{18} GOV\_EFF_{j,t} + \gamma_{19} LAW_{j,t} \\ & + \gamma_{20} POL\_STA_{j,t} + \sum_{i=21}^{24} \beta_i Year\ dummies + \varepsilon_{i,j,t} \end{aligned} \quad (2)$$

where PDI_j is power distance index score in country j; IDV_j is individualism score; MAS_j is masculinity score; UAI_j is uncertainty avoidance index score; LTO_j is long-term orientation score; IVR_j is indulgence score; $GOV\_EFF_{j,t}$ is government effectiveness score; $LAW_{j,t}$ is the rule of law score; and $POL\_STA_{j,t}$ is political stability score. Because national culture tends to be time-invariant, Eq. (2) is measured by logistic regression.

We considered possible endogeneity concerns. First, regarding an omitted variable bias, it is unlikely that any firm-level factors (micro-level factors) will affect national culture (a macro-level factor). However, it is possible that other macro-level factors, such as institutional factors, can affect both environmental innovation and national culture.

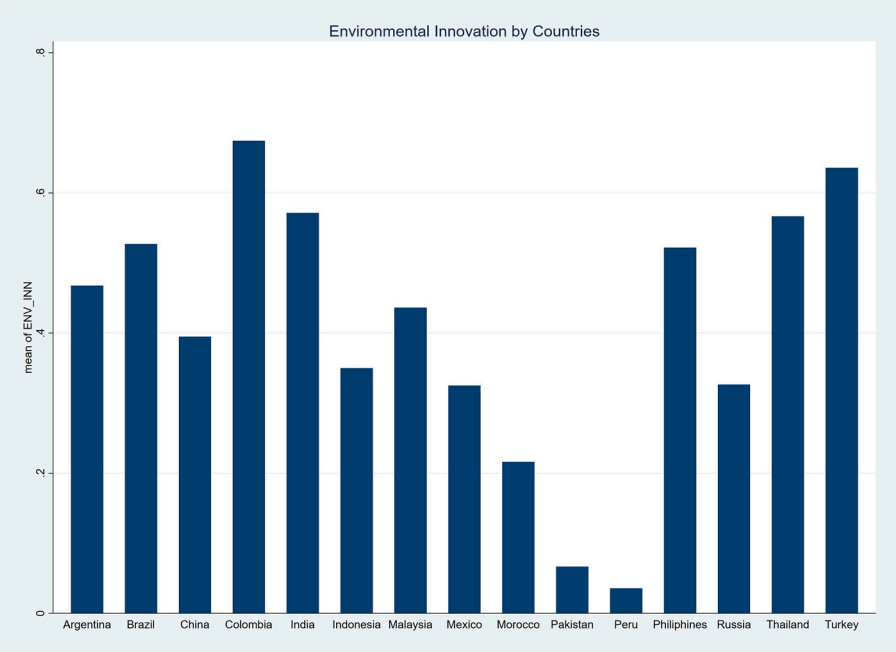

Fig. 1. Environmental innovation by countries.

Therefore, in Eq. (2), we included institutional governance factors (e.g. government effectiveness, rule of law, political stability) as control variables. Second, regarding the reverse causality, it is also unlikely that environmental innovation (a micro-level factor) will affect national culture (a macro-level factor). However, environmental innovation may affect other firm-level variables used as control variables. Therefore, in the robustness test, we estimated Eq. (2) using the lagged control variables.

Across the models, we include year dummies to account for the time trend of environmental innovation. All continuous variables are winsorised at 1% and 99% to mitigate the impact of outliers, and robust standard errors are used to account for potential heteroskedasticity.

4. Results and discussions

Table 3 reports the descriptive statistics of the variables used. Environmental Innovation (ENV_INN) has a mean of 0.45, suggesting that nearly half of the firms report products that are designed or developed to be environmentally friendly. This is encouraging given that developing countries are often considered to have poor environmental regulations and practices. The high score might be because a large portion of the sample companies is large-listed companies, including some multinational companies also operating in developed countries. Multinational companies are subject to more stringent environmental regulations and scrutiny in the developed countries in which they are operating.

For the dimensions of national culture, the power distance index (PDI) has a mean of 77.34. Such a high score reflects the unequal distribution of power in developing countries (Ardanaz and Scartascini, 2013). On the other hand, the mean value of 29.35 in individualism (IDV) reflects the strong emphasis on collectivism in developing countries (King and Bu, 2005). The other national cultural factors have a

Table 3
Descriptive statistics.

Variable	N	Mean	SD	Min	p25	p50	p75	Max
ENV_INN	10,764	0.45	0.50	0.00	0.00	0.00	1.00	1.00
PDI	10,764	77.34	10.76	49.00	69.00	78.00	81.00	104.00
IDV	10,764	29.35	10.67	13.00	20.00	30.00	38.00	48.00
MAS	10,764	53.66	11.57	34.00	46.00	50.00	66.00	69.00
UAI	10,764	58.98	22.41	30.00	36.00	64.00	82.00	95.00
LTO	10,764	52.16	22.94	13.10	31.74	45.59	81.36	87.41
IVR	10,764	46.62	23.88	0.00	23.66	45.09	59.15	97.32
RNDASSET	3472	0.01	0.02	0.00	0.00	0.00	0.02	0.13
CSR	10,764	0.80	0.40	0.00	1.00	1.00	1.00	1.00
PARTNER	10,764	0.48	0.50	0.00	0.00	0.00	1.00	1.00
CSRCOM	10,764	0.62	0.49	0.00	0.00	1.00	1.00	1.00
LNEMPLOYEE	10,764	9.54	1.52	5.51	8.62	9.58	10.57	12.83
LEVERAGE	10,764	41.36	23.49	0.00	24.14	41.75	59.26	88.45
ROE	10,764	14.40	17.44	−44.51	7.24	12.81	19.10	102.07
BOARD	10,764	10.88	3.64	4.00	9.00	10.00	13.00	22.00
INDEPENDENCE	10,764	41.69	16.35	0.00	31.58	40.00	50.00	83.33
FEMALE	10,764	11.11	10.52	0.00	0.00	10.00	16.67	42.86
LNCO2	10,764	12.55	2.66	6.58	10.72	12.35	14.33	18.54
GOV_EFF	10,764	0.16	0.32	−0.68	−0.09	0.13	0.38	1.08
LAW	10,764	−0.25	0.28	−0.82	−0.39	−0.27	−0.15	0.62
POL_STA	10,764	−0.59	0.40	−2.41	−0.79	−0.54	−0.33	0.26

The definitions of variables are provided in Table 1.

mean of around 50, indicating that, on average, developing countries do not exhibit strong tendencies toward masculinity versus femininity, uncertainty avoidance, long-term orientation versus short-term orientation, and indulgence versus restraint. Each cultural variable, however, has a wide sample distribution.

For the technology-push factor, we use R&D intensity (RNDASSET) following Horbach (2008) and measure it as R&D expenditure divided by total assets. Due to the lack of R&D expenditure data, which is also common in developed countries, the number of observations is small (3472) for RNDASSET. Therefore, we only included RNDASSET in additional models. For the demand-pull factors, we include CSR reporting (CSR), a partnership with environmental NGOs (PARTNER), and the existence of the CSR committee on the board (CSRCOM). Our sample suggests that firms in developing countries actively report CSR. About half of the firms have a partnership with environmental NGOs and the CSR committee.

The firm-specific variables reflect the characteristics of firms in developing countries. Due to the requirement of non-missing information across the variables, our sample firms tend to be large. The mean natural logarithm of the number of employees (LNEMPLOYEE) is 9.54, equivalent to 14,000 employees. An average firm has a leverage of 41%, calculated as total debt divided by total capital. An average firm has 11 board members, of which 42% of them are independent. Furthermore, 11% of board members are female. The low mean values of institutional governance factors (e.g. government effectiveness of 0.16, rule of law of −0.25, and political stability of −0.59) demonstrate weak institutional governance in developing countries.

Table 4 reports the correlation matrix for the variables. Environmental innovation is not strongly correlated to other variables, although it is slightly correlated to the demand-pull factors (CSR, PARTNER, and CSRCOM). Although most variables are moderately correlated, we find that LTO and IVR are strongly negatively correlated (−0.78). This is understandable given that long-term orientation and indulgence are conceptually related in the opposite direction. However, due to this high correlation, we also test the model excluding each factor in the robustness test.

The first analysis explores the firm-specific determinants of environmental innovation. Therefore, this analysis extends the previous firm-specific determinants literature based on developed countries. Table 5 reports the results of fixed-effects linear regressions in Models 1 and 3 and fixed-effects logistic regressions in Models 2 and 4. In Models 3 and 4, we include RNDASSET, the technology-push factor, as a potential determinant. Due to the small number of RNDASSET observations, Models 3 and 4 have small sample sizes. Therefore, we interpret the results of Models 3 and 4 only as supplementary analysis to check the effect of the technology-push factor in developing countries.

The results of Models 1 and 2 show that environmental innovation is positively related to the demand-pull factors (CSR, PARTNER, and CSRCOM), consistent with the results found in Eiadat et al. (2008). Large firms and firms with female directors also tend to have more environmental innovations (He and Jiang, 2019; Liao et al., 2019). Leveraged firms, on the other hand, have fewer environmental innovations (Javeed et al., 2021). Surprisingly, we find that independent directors are negatively related to environmental innovation, which is in contrast to the finding of Garcia-Sanchez et al. (2021) in developed countries. Independent directors are generally believed to bring resources to an organisation including experience, knowledge, and skills. However, the negative relation to environmental innovation in our results might suggest that independent directors are not truly independent from management in developing countries (Meng et al., 2018), or they are conservative and risk-averse (Zaman et al., 2018), so they do not encourage environmental innovation, which is inherently uncertain. We find some evidence that large polluters (LNCO2) tend to engage less in environmental innovation (Zhang et al., 2017).

We extend the firm-specific determinants model to include national culture and institutional governance factors in the second analysis.

Table 4
Correlation matrix.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	ENV_INN																			
2	PDI	−0.10																		
3	IDV	0.09	−0.09																	
4	MAS	−0.07	0.25	−0.07																
5	UAI	0.01	−0.31	0.38	−0.37															
6	LTO	−0.06	0.28	−0.27	0.12	−0.53														
7	IVR	−0.02	−0.10	0.08	0.23	0.57	−0.78													
8	CSR	0.27	0.02	0.12	−0.17	0.13	−0.09	0.05												
9	PARTNER	0.22	−0.01	0.21	−0.27	0.32	−0.29	0.20	0.38											
10	CSRCOM	0.24	−0.07	0.28	−0.22	0.18	−0.30	0.16	0.42	0.37										
11	LNEMPLOYEE	0.10	0.14	0.08	0.01	0.14	0.14	−0.01	0.22	0.21	0.12									
12	LEVERAGE	0.18	−0.07	0.08	−0.01	0.10	−0.10	0.08	0.13	0.09	0.11	0.14								
13	ROE	−0.02	0.04	0.02	−0.07	0.05	0.00	−0.03	−0.01	0.01	0.03	−0.07	−0.08							
14	BOARD	0.13	−0.12	0.16	0.04	0.24	−0.27	0.26	0.17	0.15	0.20	0.24	0.16	−0.09						
15	INDEPENDENCE	−0.02	0.15	−0.05	0.13	−0.09	−0.15	0.18	−0.03	−0.06	0.08	−0.03	−0.02	0.06	−0.08					
16	FEMALE	0.06	0.08	−0.01	−0.03	−0.16	−0.01	−0.05	0.08	0.03	0.13	−0.02	−0.01	0.03	0.05	0.08				
17	LNCO2	0.11	0.05	0.11	−0.09	0.15	0.01	0.00	0.22	0.28	0.20	0.38	0.03	−0.07	0.18	−0.13	−0.07			
18	GOV_EFF	−0.01	0.40	−0.42	0.15	−0.67	0.30	−0.30	−0.05	−0.23	−0.07	−0.11	−0.07	−0.02	−0.01	0.12	0.22	−0.11		
19	LAW	0.11	0.02	0.00	−0.21	−0.48	−0.13	−0.15	0.08	0.01	0.21	−0.22	0.02	−0.06	−0.08	0.10	0.29	−0.13	0.60	
20	POL_STA	−0.09	0.30	−0.29	0.22	−0.40	0.26	−0.04	−0.08	−0.13	−0.13	−0.03	−0.10	−0.05	−0.16	0.05	0.06	−0.08	0.38	0.28

Pearson correlation coefficients. The definitions of variables are provided in Table 1.

Table 5
Firm-specific factors and environmental innovation.

	(1)	(2)	(3)	(4)
	Fixed-effects linear	Fixed-effects logistic	Fixed-effects linear	Fixed-effects logistic
	ENV_INN	ENV_INN	ENV_INN	ENV_INN
RNDASSET			0.638	−43.016
			1.056	−0.679
CSR	0.088***	2.480***	0.057***	24.805
	7.724	4.645	3.423	0.017
PARTNER	0.120***	1.999***	0.098***	2.894***
	10.767	4.889	5.110	2.674
CSRCOM	0.124***	1.172***	−0.030	−3.455***
	10.982	3.238	−1.477	−2.942
LNEMPLOYEE	0.047***	2.241***	0.016	−2.294
	3.840	5.508	0.720	−1.530
LEVERAGE	−0.002***	−0.046***	0.000	−0.084**
	−5.394	−3.884	0.768	−2.310
ROE	0.000	0.005	0.001	−0.012
	0.832	0.972	1.355	−0.339
BOARD	−0.002	0.214***	0.003	1.249***
	−1.147	3.582	1.304	4.644
INDEPENDENCE	−0.002***	−0.057***	−0.002***	−0.133***
	−6.865	−6.806	−3.726	−2.929
FEMALE	0.001***	0.038**	−0.001	0.002
	2.977	2.281	−0.928	0.045
LNCO2	−0.004	−0.272**	−0.021***	−0.505
	−0.943	−1.987	−3.485	−1.330
Intercept	−0.021		0.463**	
	−0.177		2.134	
Year dummies	Yes	Yes	Yes	Yes
Observations	10,764	1863	3472	366
Number of firms	3010	426	1201	86
R-sq	0.114		0.066	
Chi2		697		172
Prob > chi2		0		0

The firm-specific determinants of environmental innovation are estimated using fixed-effects linear regressions (Models 1 and 3) and fixed-effects logistic regressions (Models 2 and 4). The R&D intensity is included in Models 3 and 4. t-statistics are reported for the fixed-effects linear regressions (Models 1 and 3), and z-statistics are reported for the fixed-effects logistic regressions (Models 2 and 4). *, **, and *** represent significance at the 10%, 5%, and 1% levels, respectively. Robust standard errors are used across the models, and all continuous variables are winsorised at 1% and 99%.
ENV_INN is a binary variable for environmental innovation, equals 1 if a firm has an environmental product and 0 otherwise; RNDASSET is R&D expenditure divided by total assets; CSR is 1 if a firm issues a corporate social responsibility report and 0 otherwise; PARTNER is 1 if a firm has a partnership with environmental NGOs and 0 otherwise; CSRCOM is 1 if a firm has a corporate social responsibility committee and 0 otherwise; LNEMPLOYEE is the natural logarithm of the number of employees; LEVERAGE is total debt divided by total capital in percentage; ROE is the return on equity in percentage; BOARD is the size of the board of directors; INDEPENDENCE is the proportion of independent directors in percentage; FEMALE is the proportion of female directors in percentage; LNCO2 is the natural logarithm of CO_2 equivalents emission.

Table 6 reports the results of Eq. (2) when each national cultural dimension is added (Models 1–6) as well as all cultural dimensions are added together (Model 7). The results show that power distance index (PDI) is negatively related to environmental innovation when used alone (Model 1) and used together with other cultural variables (Model 7), supporting Hypothesis 1. In a high power distance society, managers hold extensive power over organisational resources and structure, making them less challenged and accountable to internal and external stakeholders (Miska et al., 2018; Peng and Lin, 2009). Similarly, Wang et al. (2022) find that power distance reduces the positive impact of human capital on the environment in the study of environmental degradation. In Model 2, we find that individualism is also negatively related to environmental innovation, supporting Hypothesis 2, although its effect disappears when it is used with other cultural factors in Model 7. As climate change is a collective matter, the result indicates that collectivism is more conducive to environmental innovation. Model 3 indicates that there are more environmental innovations in the masculinity culture. The coefficients on MAS are significantly positive in Models 3 and 7, supporting Hypothesis 3. As environmental innovation requires competitiveness, assertiveness, and success, masculine societies that encourage these values tend to have more environmental innovations. In Model 4, we find that uncertainty avoidance is negatively related to environmental innovation, supporting Hypothesis 4, although its effect is not present in Model 7. This is consistent with the results of Vachon (2010) and Wang et al. (2022). They argue that increased tolerance of risk-taking should be encouraged in society to improve the environment. In Model 5, we find that long-term orientation is positively related to environmental innovation, supporting Hypothesis 5. As people in long-term oriented societies understand that climate change is dynamic and requires behavioural change and adjustments (Geletkanycz, 1997), they tend to engage more in entrepreneurial activities and innovation (Hofstede et al., 2010). In Models 6 and 7, we find that indulgence is negatively related to environmental innovation, supporting Hypothesis 6. Because environmental innovation requires planning, behavioural adjustments, persistence, and the drive to succeed, people in the indulgence culture engage less in environmental innovation.

Across the models, the coefficients on the demand-pull factors (CSR, PARTNER, and CSRCOM) remain significantly positive, demonstrating the importance of the demand-pull factors on environmental innovation in developing countries. On the other hand, the impact of the institutional governance factors is less clear. Government effectiveness (GOV_EFF) has mixed signs across the models. Countries with a strong rule of law (LAW) tend to have more environmental innovations, while countries with high political stability (POL_STA) tend to have fewer environmental innovations.

Overall, the results support institutional theory that the behaviour of a firm is influenced by the institutional macro-level structures, including the informal rules of a society (North, 1990; Scott, 2013). Our results

Table 6
Culture and environmental innovation.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	ENV_INN	ENV_INN	ENV_INN	ENV_INN	ENV_INN	ENV_INN	ENV_INN
PDI	−0.020***						−0.021***
	−7.709						−6.694
IDV		−0.005**					−0.005
		−2.042					−1.032
MAS			0.008***				0.016***
			4.060				2.773
UAI				−0.014***			−0.004
				−9.450			−0.854
LTO					0.009***		−0.001
					6.720		−0.564
IVR						−0.008***	−0.010***
						−7.439	−2.782
CSR	1.035***	1.009***	1.029***	1.029***	0.994***	1.008***	1.047***
	15.452	15.103	15.375	15.345	14.852	15.061	15.668
PARTNER	0.433***	0.365***	0.395***	0.467***	0.439***	0.423***	0.576***
	8.825	7.593	8.131	9.396	8.812	8.577	11.110
CSRCOM	0.328***	0.331***	0.326***	0.379***	0.355***	0.352***	0.414***
	6.438	6.441	6.381	7.378	6.926	6.878	7.842
LNEMPLOYEE	0.062***	0.053***	0.051***	0.044***	0.025	0.033**	0.050***
	3.860	3.307	3.247	2.815	1.499	2.070	2.978
LEVERAGE	0.012***	0.012***	0.011***	0.012***	0.012***	0.012***	0.012***
	12.549	12.544	12.308	12.906	12.713	12.853	12.500
ROE	0.000	0.000	0.000	0.000	0.000	−0.001	0.001
	0.125	−0.074	0.185	0.330	−0.132	−0.447	0.733
BOARD	0.021***	0.033***	0.029***	0.046***	0.048***	0.047***	0.039***
	3.270	5.273	4.655	7.122	7.200	7.115	5.279
INDEPENDENCE	−0.002	−0.003**	−0.004***	−0.003**	−0.001	0.000	0.000
	−1.238	−2.264	−2.825	−2.135	−0.468	−0.222	0.134
FEMALE	0.001	0.000	0.000	0.000	0.000	0.000	0.001
	0.709	0.079	−0.024	−0.151	−0.133	0.081	0.538
LNCO2	0.024***	0.022**	0.023**	0.021**	0.017**	0.016*	0.022**
	2.733	2.473	2.560	2.330	1.970	1.868	2.498
GOV_EFF	0.287***	−0.245**	−0.211**	−0.588***	−0.434***	−0.328***	−0.235
	2.703	−2.367	−2.259	−5.714	−4.318	−3.472	−1.434
LAW	0.674***	1.077***	1.143***	0.812***	1.288***	0.967***	0.880***
	6.018	9.614	10.224	7.608	11.511	9.197	3.609
POL_STA	−0.300***	−0.440***	−0.474***	−0.502***	−0.485***	−0.333***	−0.311***
	−4.922	−7.390	−7.915	−8.359	−8.017	−5.651	−4.212
Intercept	−1.800***	−3.019***	−3.565***	−2.552***	−3.539***	−2.794***	−1.791***
	−7.032	−15.878	−16.479	−13.208	−18.009	−14.645	−4.139
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	10,764	10,764	10,764	10,764	10,764	10,764	10,764
Pseudo R-sq	0.111	0.107	0.108	0.113	0.110	0.111	0.120

The relationship between environmental innovation and national culture is estimated using logistic regressions. Coefficients and z-statistics are reported. *, **, and *** represent significance at the 10%, 5%, and 1% levels, respectively. Robust standard errors are used across the models, and all continuous variables are winsorised at 1% and 99%.

ENV_INN is a binary variable for environmental innovation, equals 1 if a firm has an environmental product and 0 otherwise; PDI is power distance index score in country *j*; IDV is individualism score; MAS is masculinity score; UAI is uncertainty avoidance index score; LTO is long-term orientation score; IVR is indulgence score; RNDASSET is R&D expenditure divided by total assets; CSR is 1 if a firm issues corporate social responsibility report and 0 otherwise; PARTNER is 1 if a firm has a partnership with environmental NGOs and 0 otherwise; CSRCOM is 1 if a firm has a corporate social responsibility committee and 0 otherwise; LNEMPLOYEE is the natural logarithm of the number of employees; LEVERAGE is total debt divided by total capital in percentage; ROE is the return on equity in percentage; BOARD is the size of the board of directors; INDEPENDENCE is the proportion of independent directors in percentage; FEMALE is the proportion of female directors in percentage; LNCO2 is the natural logarithm of CO_2 equivalents emission; GOV_EFF is government effectiveness score; LAW is the rule of law score; POL_STA is political stability score.

provide the first evidence of the impact of national culture on firms' environmental innovation. Although the previous studies focused on the impact of formal regulations and firm-specific factors, according to the Porter hypothesis, we extend this literature and argue that informal regulations (i.e. national culture) also matter to environmental innovation.

5. Robustness tests

Although the results generally support the hypotheses, the correlation coefficients in Table 4 suggest that long-term orientation (LTO) and indulgence (IVR) variables might be highly correlated (−0.78). This is understandable because these two concepts share a commonality in the opposite direction. For example, indulgence inherently reflects short-term orientation, and long-term orientation inherently reflects restraint. Therefore, the use of both factors in one model, Model 7 in Table 6, may have a high collinearity problem. In untabulated results, we estimated Model 7 with LTO or IVR omitted. The results were qualitatively the same as Model 7: LTO was not significant, while IVR was significant at the 1% level.

To address the potential endogeneity issues, we first considered the case of omitted variable bias. As national culture is a macro-level factor, we believe it is unlikely that micro-level firm-specific factors could affect national culture. However, as other macro-level factors, such as institutional factors, could affect national culture, we include institutional governance factors in Eq. (2) as control variables. In addition, we considered the case of reverse causality. Similarly, it is unlikely that environmental innovation, which is a firm-specific factor, would affect

Table 7
Culture and environmental innovation with lagged control variables.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	ENV_INN	ENV_INN	ENV_INN	ENV_INN	ENV_INN	ENV_INN	ENV_INN
PDI	−0.018***						−0.019***
	−6.039						−5.224
IDV		−0.005*					−0.007
		−1.877					−1.398
MAS			0.005**				0.018***
			2.026				2.880
UAI				−0.012***			0.001
				−6.983			0.296
LTO					0.009***		−0.003
					5.783		−0.893
IVR						−0.008***	−0.014***
						−6.713	−3.254
L.CSR	0.964***	0.932***	0.951***	0.957***	0.919***	0.934***	0.983***
	13.130	12.724	12.952	12.969	12.494	12.699	13.307
L.PARTNER	0.303***	0.243***	0.260***	0.320***	0.313***	0.301***	0.421***
	5.252	4.295	4.541	5.508	5.345	5.182	6.973
L.CSRCOM	0.223***	0.232***	0.220***	0.270***	0.253***	0.257***	0.311***
	3.701	3.817	3.649	4.452	4.181	4.258	4.968
L.LNEMPLOYEE	0.059***	0.051***	0.048***	0.041**	0.020	0.028	0.042**
	3.104	2.738	2.628	2.228	1.029	1.464	2.113
L.LEVERAGE	0.013***	0.014***	0.013***	0.014***	0.014***	0.014***	0.013***
	12.329	12.361	12.179	12.514	12.440	12.569	12.026
L.ROE	0.000	0.000	0.000	0.000	−0.001	−0.001	0.000
	−0.214	−0.242	−0.149	−0.057	−0.334	−0.657	0.006
L.BOARD	0.031***	0.045***	0.041***	0.057***	0.060***	0.059***	0.050***
	4.149	6.106	5.641	7.602	7.755	7.829	5.944
L.INDEPEND~E	−0.002	−0.003*	−0.003**	−0.003*	−0.001	0.000	0.000
	−1.348	−1.949	−2.221	−1.858	−0.393	−0.167	0.241
L.FEMALE	0.000	−0.002	−0.002	−0.002	−0.002	−0.002	−0.001
	−0.079	−0.681	−0.676	−0.894	−0.816	−0.639	-0.202
L.LNCO2	0.018*	0.017	0.017	0.015	0.012	0.011	0.014
	1.750	1.644	1.602	1.406	1.194	1.050	1.336
L.GOV_EFF	0.242*	−0.273**	−0.203*	−0.513***	−0.409***	−0.304***	−0.195
	1.931	−2.230	−1.825	−4.303	−3.518	−2.755	−1.038
L.LAW	0.823***	1.234***	1.219***	0.941***	1.395***	1.069***	1.069***
	6.035	9.002	9.099	7.171	10.469	8.351	3.729
L.POL_STA	−0.235***	−0.369***	−0.377***	−0.401***	−0.398***	−0.246***	−0.178**
	−3.413	−5.452	−5.577	−5.971	−5.851	−3.676	−2.054
Intercept	−1.475***	−2.632***	−2.989***	−2.230***	−3.127***	−2.383***	−1.523***
	−4.861	−11.975	−12.026	−9.897	−13.785	−10.750	−3.053
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	7687	7687	7687	7687	7687	7687	7687
Pseudo R-sq	0.103	0.100	0.100	0.105	0.103	0.104	0.111

The relationship between environmental innovation and national culture is estimated with lagged control variables using logistic regressions. Coefficients and z-statistics are reported. *, **, and *** represent significance at the 10%, 5%, and 1% levels, respectively. Robust standard errors are used across the models, and all continuous variables are winsorised at 1% and 99%.
ENV_INN is a binary variable for environmental innovation, equals 1 if a firm has an environmental product and 0 otherwise; PDI is power distance index score in country *j*; IDV is individualism score; MAS is masculinity score; UAI is uncertainty avoidance index score; LTO is long-term orientation score; IVR is indulgence score. L. denotes a lagged variable. RNDASSET is R&D expenditure divided by total assets; CSR is 1 if a firm issues a corporate social responsibility report and 0 otherwise; PARTNER is 1 if a firm has a partnership with environmental NGOs and 0 otherwise; CSRCOM is 1 if a firm has a corporate social responsibility committee and 0 otherwise; LNEMPLOYEE is the natural logarithm of the number of employees; LEVERAGE is total debt divided by total capital in percentage; ROE is the return on equity in percentage; BOARD is the size of the board of directors; INDEPENDENCE is the proportion of independent directors in percentage; FEMALE is the proportion of female directors in percentage; LNCO2 is the natural logarithm of CO_2 equivalents emission; GOV_EFF is government effectiveness score; LAW is the rule of law score; POL_STA is political stability score.

national culture. However, environmental innovation could affect other firm-level control variables in Eq. (2). Therefore, we estimate Eq. (2) using lagged control variables. Table 7 reports that the results are qualitatively the same as those in Table 6. The cultural dimensions, demand-pull factors, and institutional governance factors show the same signs, indicating that reverse causality is unlikely.

6. Conclusion

Five years after the Paris Climate conference in 2015 (and one year delay due to Covid-19), almost 200 countries attended the Conference of the Parties (COP) 26 in Glasgow in 2021 to check the progress toward the Paris Agreement (COP26 The Glasgow Climate Pact, 2021). Environmental innovation plays a key role to achieve the Net Zero by 2050 commitment, in which more than 130 countries pledged to it (What is net zero and how are the UK and other countries doing?, 2021). Although the Paris Agreement and Net Zero by 2050 are important for both developed and developing countries, the current literature mostly focuses on developed countries only. This lack of studies on developing countries is worrisome because (i) developing countries exhibit different institutional characteristics from developed countries, (ii) developing countries account for more CO_2 emissions than developed countries, and (iii) developing countries are more likely to suffer from environmental disasters.

This paper aims to fill in this gap by studying the determinants of environmental innovation in developing countries. The paper also extends the current literature to include informal regulations (i.e. national culture) as a potential determinant. Therefore, this paper extends the

Porter hypothesis, which emphasises the role of formal regulations on environmental innovation, toward institutional theory.

By examining the data of 15 developing countries from 2015 to 2019, totalling almost 11,000 observations, we find that environmental innovation in developing countries is largely driven by the demand-pull factor, rather than the technology-push factor. The three proxies of the demand-pull factor (CSR reporting, partnership with environmental NGOs, and CSR committee) all indicate a significantly positive relationship with environmental innovation at the 1% level, while the technology-push factor remains insignificant. This is understandable because developing countries tend to lack technological capability in terms of skilled labour, infrastructure, resources, the scale of economy, and knowledge (Sheth, 2011). Our results indicate that it would be unwise for developing countries to follow the strategies of developed countries, which focus on the technology-push factor to promote environmental innovation. Instead, developing countries would be more successful by designing their own strategies based on their relative strengths, such as the demand-pull factor. In addition, we find that national culture plays an important role in environmental innovation. While masculinity and long-term orientation increase environmental innovation, power distance, individualism, uncertainty avoidance, and indulgence tend to decrease environmental innovation. As tackling climate change requires a long-term endeavour, developing countries may want to review the strengths and weaknesses of their national culture and make an effort to direct them toward climate change. For example, countries can encourage more participative decision making (i.e. reducing power distance) to promote environmental innovation (Wang et al., 2022).

We checked potential endogeneity issues in this study. First, we use the fixed-effects model with a panel dataset in our first analysis of the firm-specific determinants to mitigate the potential issue caused by omitted time-invariant variables, such as management's attitude toward climate change and the path dependency of environmental innovation. Second, in the national culture model, we added the institutional governance factors as control variables to mitigate the omitted variable bias that might be related to environmental innovation and national culture. Finally, we checked the reverse causality by using the lagged control variables in the robustness test.

We make several contributions to the literature and theory. First, as far as the authors are aware, this is the first comprehensive study to examine the determinants of environmental innovation in developing countries. Therefore, the paper extends the current literature and examines the boundary condition of the previous findings. Second, the paper introduces national culture as a potential determinant of environmental innovation. Therefore, we extend the Porter hypothesis, which emphasises the role of formal regulations, toward institutional theory, which emphasises the role of both formal and informal regulations.

The paper also makes several practical contributions. First, given that developing countries have different characteristics and capabilities from developed countries, developing countries should devise their own strategies that utilise their relative strengths toward climate change. Despite the emphasis on the technology-push factor in developed countries, developing countries should rely more on the demand-pull factors to promote environmental innovation. Second, developing countries should review the strengths and weaknesses of their national culture toward climate change. Although national culture is difficult to change, especially in the short term, it can make a profound impact on climate change as it applies to all societal actors, according to institutional theory. Therefore, the right balance of national culture can promote environmental innovation for generations to come.

As the final remark, the authors would like to emphasise the importance of national culture on environmental innovation. As climate change is a global challenge that requires efforts from every citizen, we believe that the theoretical framework of the Porter hypothesis should be extended to institutional theory to accommodate the impact of both formal and informal institutional factors.

This paper has caveats. Although an international sample can provide more generalisability of the results than a single-country sample, it limits the ability to accommodate country-specific factors in the study. For example, our study does not examine the impact of climate regulations in each country, because they occurred at different times and had different focuses and impacts. In addition, although we examine 15 developing countries that have sufficient data on environmental innovation and culture, we do not claim that our results are representative of all 137 developing countries in the world (The World Bank, 2022). As shown in the descriptive statistics, developing countries exhibit vastly different characteristics in terms of culture, institutional governance, and firm-specific factors. Therefore, the results of this paper should be interpreted with these caveats.

We recommend that future research extends and complements this study. The main focus of this study is the impact of the informal institutional factor (i.e. national culture) on environmental innovation. As institutional theory refers to both formal and informal institutional factors, future research can investigate the impact of the formal institutional factor and complement this study. In addition, future research can increase the coverage of developing countries to increase the generalisability of the finding.

Declaration of competing interest

The authors do not have any conflict of interest.

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