Afrifa, Godfred Adjapong, Tingbani, Ishmael, Yamoah, Fred A. and Appiah, Gloria (2020) *Innovation input, governance and climate change: Evidence from emerging countries.* Technological Forecasting and Social Change, 161 . ISSN 0040-1625.

INNOVATION INPUT, GOVERNANCE AND CLIMATE CHANGE: EVIDENCE FROM EMERGING COUNTRIES

Abstract

This study sheds light on the extent to which innovation input influences CO_2 emissions and how country-level governance factors may moderate this relationship. The sample for the study consists of CO_2 emissions per capita from 29 emerging countries and 725 country-year observations. We find a negative relationship between innovation input and CO_2 emissions, suggesting that countries that invest in innovation combat climate change by reducing CO_2 emissions. By separating the sample into low and high innovative countries, the results show that reduction of CO_2 emissions is more pronounced in countries with high innovation input. We further establish that country-level governance factors, including political stability, government effectiveness, regulation quality, rule of law and control of corruption all negatively moderate the effects of innovation input on CO_2 emissions. Our findings shed new light on the theoretical and practical implications of innovation and country-level governance on climate change initiatives.

Keywords: Innovation input, country-level governance, CO_2 emission, climate change, emerging countries

1. Introduction

The impact of climate change on the global economy remains the focus of many recent academic and policy discourse. Current evidence suggests that human-induced climate change poses a severe global threat to development and inclusive growth in the medium and long term (Abidoye and Odusola 2015; Du et al. 2017). Indeed, in its 2019 report on climate change, the Intergovernmental Panel on Climate Change (IPCC) established that there are both medium to long–term economic costs of increased temperatures that come with such changes in climate. These costs seem to be aggravated in the context of emerging and developing economies. For instance, anecdotal evidence from the August 2012 Massachusetts Institute of Technology report[1] on the economic cost of global warming suggested that rising temperatures had more adverse implications on the economic growth of developing countries compared to their developed counterparts. **The effects on emerging economies are dire because their economic strength relies heavily on sectors such as agriculture, forestry and tourism, which are highly sensitive to climatic conditions (Wade and Jennings, 2015).** The evidence suggests that for every one-degree centigrade increase in temperature, an emerging country can expect economic growth to drop by about 1.3 percentage points. Consequently, rapidly scaling up of low-carbon and climate-resilient infrastructure is not just key for meeting climate goals, but also for ensuring sustainable development and inclusive economic growth (Bak et al., 2017).

A promising step to reduce carbon emissions, according to researchers (e.g. Lin and Zhu, 2019), is the adoption of cutting-edge innovative technologies. These can mitigate climate change by conserving energy and reducing emissions. In response, governments and organisations across the globe, responding to various stakeholder pressures, have been prioritising investments into low-carbon and climate-resilient infrastructure in their innovation missions (Cimato and Mullan, 2010; Darnall and Carmin, 2005; Moratis, 2018). Specifically, they have been developing their innovative capabilities through higher expenditure on innovative technological strategies to power their economies **and business activities in ways that have minimal or no impact on the environment** (Aghion and Howitt, 1992; Pegkas et al., 2019). Prior studies, such as Hepburn (2006) and Cadez et al. (2019) affirm growing government legislation to minimise increasing greenhouse gas emissions globally. The fundamental assumptions driving this shift in policy is embedded in stakeholder and signalling theory (**Savage et al., 2010; Connelly et al., 2011**),

---

[1] http://news.mit.edu/2012/the-economic-cost-of-increased-temperatures-0807

where governments, in their attempt to respond to stakeholders' pressures, pursue low-carbon and climate-resilient policies to signal to the world that they care about the environment.

Moving further, research conversations have also considered ways in which progress in innovation can move from mere symbolic responses to actually benefit climate change efforts. Here, several studies have argued that governance quality matters in supporting long-term growth and development of countries, including those linked to climate goals (Kaufmann, Kraay and Mastruzzi, 2003; and 2007). Quality of governance - measured in terms of the capacity of governments to formulate appropriate policies, respect citizens and monitor the state of institutions (Kaufmann, Kraay and Mastruzzi, 2003; and 2007) - is likely to influence countries' innovative policies towards sustainable environments. These may be extremely valuable for the innovation input and climate change relationship. Specifically, countries with good quality governance may be able to pursue, formulate and invest in cutting-edge innovative technologies aimed at curbing environmental damage (see Gani, 2012).

In emerging countries, relevant technologies are being recognised for their prominent and transformational role in solving socio-economic, and environmental problems (Li and Wang 2017; Chen and Lei, 2018). This has led to a gradual, but progressive switch from out-dated technologies to innovative cutting-edge technologies in many facets of life (Binz, Truffer, Li, Shi & Lu, 2012). In fact, a general leapfrogging in innovative technologies are supervening at an augmented leap in recent decades (Mair and Marti, 2009; Amankwah-Amoah, 2015). In line with this, and coupled with the realisation that they stand to benefit most from eco-relevant innovations, innovation that specifically addresses environmental challenges have been observed across some emerging economies (Madichie, 2011; Findlay and Dimsdale, 2009). However, desired successes towards reaching climate change goals still seem distant. Most emerging markets are characterised by severe and sustained cases of institutional voids needed to pursue, formulate and invest in cutting-edge innovative technologies that can curb environmental damage (Amankwah-Amoah & Debrah, 2014; Mair and Marti, 2009; Tingbani et al., 2019). This makes government efforts to addressing climate change problems difficult for these economies.

There is potential value **in contributing to current climate improvement efforts by emerging economies through** research conversations relating to innovation, governance and climate change. **However**, not much progress has been achieved **in bridging knowledge gaps.** In fact, researchers seem to pay more attention to determinants (Tauringana and Chithambo,

2015) and impacts (Chithambo et al., 2020; Boakye et al., 2020) of climate change and GHG emissions, at the expense of questioning how investments in cutting edge innovative technologies impact on the environment. Less is also known about how the quality of governance may likely influence countries' investments in innovative technologies towards curbing environmental damage. **The dearth of research here is even more conspicuous in the context of emerging economies, which are also likely to struggle with appropriate levels of high-quality governance (Oman and Arndt, 2010). In relation to the later,** existing studies have mostly focused on developed or highly industrialised economies, **perhaps due to the fact that these economies are more likely to engage in activities that impact on the environment** (see Sprengel and Busch, 2011; Simaens and Koster, 2013; Su and Moaniba, 2017). **While useful insights have emerged from such studies, they have** undoubtedly placed emerging economies, **which suffer most from environmental misbehaviours, at a disadvantage of knowledge voids.** There is as yet, very little known on **what they can do themselves to mitigate the consequences of the negative environmental behaviours by more developed counterparts on their already struggling economies. In fact, as yet there is very little known about the** relationships that exist between **emerging countries' own** innovation activities, governance and climate change targets.

In order to contribute to filling these research gaps, we adopt a panel fixed effect model of a sample of 29 emerging countries and 725 country-year observations from the World Bank database over the period 1990 to 2018 to investigate the relationship between innovation input, governance and climate change. Evidence from this study suggests that investment in innovative, cutting-edge technologies reduces climate change problems. Specifically, the evidence reveals that emerging countries with high innovative competencies reduce climate change problems by approximately 26.8%, with a 10% increase investment in cutting edge technology. Our evidence also suggests that various governance indicators (political stability, rule of law, government effectiveness, regulatory quality and control of corruption) impose both direct and indirect impacts on the relationship between innovation input and climate change.

The study makes two broad contributions to literature. **First, it presents strong evidence from emerging economies to illuminate further the effect of investment in cutting-edge innovative technologies on climate change. Similar to most prior technology-climate change studies (Li and Wang, 2017; Chen and Lei 2018; Gani, 2012), our study highlights the implications of investment in cutting edge innovative technologies on climate change. However, beyond the findings from Li and Wang, (2017); Chen and Lei**

(2018) and Gani (2012), our study presents findings from the joint effects of governance and innovation input on climate change goals. Second, it documents the effect of governance on the relationship between innovation input and climate change. In particular, the current study sheds light on how quality of governance is likely to influence countries' investment into innovative technologies towards curbing environmental damage. To the best of our knowledge, there is no existing study that examines these relationships.

The rest of the paper is structured as follows: Section 2 presents the theoretical foundation and empirical literature for the study. Section 3 presents the methodology, followed by the empirical evidence in section 4. The discussion section is presented in section 5, and section 6 concludes with directions for future research.

2. Theoretical framework

2.1 Stakeholder Pressure on Climate Change

The climate change mitigation agenda is undoubtedly one of the key global imperatives of the 21st century (Cadez et al., 2019). This critical initiative is spearheaded by local, regional, national and international stakeholders who either signal for change, promote or sponsor action for transformation or undertake actions aimed at addressing the concerns of groups and individuals affected by **organisations** value creation operations (Freeman et al., 2010). **Together, these actions have been grouped under an umbrella theory, referred to as the Stakeholder Theory. It is underlain by an original ethos on how stakeholders cooperate for mutual benefits** (Savage et al., 2010, Freeman et al., 2010). **In addition, stakeholders, unlike shareholders who usually have a narrow/reductionist perspective, adopt a broad/holistic perspective on businesses (Freeman et al., 2020, pp. 217). These distinguishing characteristics** provide a firm basis to interrogate the climate change agenda as it is a phenomenon that requires **a broad altruistic view of businesses' activities, as well as** collective efforts of all **involved in mitigating any consequences** (Sprengel and Busch, 2011, Hoffman 2005; Chithambo et al., 2020, Talbot and Boiral, 2015). **An organisation's stakeholders could include** governments, international institutions and agencies, the business industry, non-governmental organisations and the general public.

The dual themes of collaboration and proactivity have been highlighted alongside suggestions that **there are two different levels of stakeholders**; primary and secondary, **each of which** exerts different degrees of pressure **on organisations** (Goodman et al., 2017). Primary stakeholders mainly include those who are directly affected by a company's activities

such as shareholders, creditors, customers, suppliers, managers and employees, and state and local communities. Secondary stakeholders are those who are not directly and obviously influenced by a company's success or failure (see, Gibson, 2000). Whereas Donaldson and Preston (1995) articulate differences **among stakeholders in terms of** scope, captured by the traditional versus contemporary stakeholder models, **while** Jones et al., (2018) **identify** the triad interrelated descriptive, normative and instrumental values in a stakeholder model.

Stakeholder pressure on climate change manifests in a myriad of ways (Sprengel and Busch, 2011; Talbot and Boiral, 2015), and emerges from both external and internal sources (Cadez et al., 2019; Okereke and Russel, 2010). The extant literature identifies multiple external stakeholders who are either market actors or regulatory authorities (Okereke and Russel, 2010). These include customers, suppliers, competitors, non-governmental organisations (NGOs), investors, employees, financial institutions the media, local authority, national governments, regional bodies among others (Cadez et al., 2019). Examples of internal stakeholders who are directly affected by a given organisation's operations include shareholders, creditors, customers, suppliers, managers and employees, and state and local communities (Gibson, 2000).

Another strand of environmental management literature attests to an internal motivation by corporate stakeholders to address climate change challenges to avoid emission penalties and carbon taxes, and also take advantage of superior eco-friendly production methods (Cadez et al., 2019 and Czerny and Letmathe, 2017). Chithambo et al. (2020) found that stakeholders' pressure in the form of regulatory, mimetic, and shareholders pressure positively influenced the disclosure of GHG information. It is commonly agreed among stakeholder theorists that, by the power vested in the regulatory stakeholders to exact sanctions, they are more influential than market-actor stakeholders (Chithambo et al., 2020; Okereke and Russel, 2010).

2.2 Signalling theory and the Climate Change Agenda

Stakeholder pressure on climate change has escalated to the point where some major stakeholders, including governments across the globe, are signalling the need for action through policies that support green innovations by corporate actors (Cimato and Mullan, 2010, Darnall and Carmin, 2005, and Moratis, 2018). Studies such as Hepburn (2006) and Cadez et al. (2019) affirm growing government legislations to minimise the increasing greenhouse gas emissions globally. While genuine intentions to enact change may be present, these actions are also increasingly being recognised as a tacit signal to the rest of the world that these

governments do care about the environment. Tingbani et al. (2020) suggest that being diverse and open, countries are able to serve the demands of stakeholders better and legitimise their green credentials.

As a baseline, signalling theory serves to minimise information asymmetry between two parties (Spence, 2002). Signalling theory is fundamentally concerned with 'problems of social selection under conditions of imperfect information, and it has been applied to elucidate information asymmetry in management contexts; including entrepreneurship and human resource management (Connelly et al., 2011, p. 63). Within the context of environmental management literature, signalling theory has been applied to the ISO 26000 standards. For instance, Moratis (2018) suggested that businesses following ISO 26000 standards may send signals that impede, rather than facilitate stakeholders' capabilities to find and translate the quality of a company's underlying corporate social responsibilities.

A significant signalling agenda on the global stage is the Paris Agreement. A comprehensive review on this agreement by Calmfors and Hassler (2019), indicated that in itself, the agreement will not stop climate change but can potentially 'contribute to changing behaviour among states and non–state actors by providing infrastructure, signal and a direction for ramping up climate action and political commitments to decarbonisation' (Calmfors and Hassler, 2019, p. 23). It is also considered as potentially signalling a 'new phase of international climate diplomacy' with legally binding regulations for industrialised countries in particular (Calmfors and Hassler, 2019, p. 31).

Despite the intensified stakeholder pressure alongside signals from governments and international agencies, corporate responses across the globe via innovation do not seem to have had a significant influence on reducing climate change (Jeswani et al., 2008 and Weinhofer and Hoffmann, 2010). Climate change, like many other global challenges, requires a concerted effort to make a difference, as the challenge cannot be resolved by an individual stakeholder. The rather slow progress notwithstanding, the extant literature overwhelmingly confirms that corporate commitment towards climate change mitigation is significantly driven by stakeholder pressure (Reid and Toffel, 2009; Sangle, 2011; Sprengel and Busch, 2011, Hoffman 2005; Chithambo et al. 2020; Talbot and Boiral, 2015).

Of particular interest to this study is the underlying principles of the instrumental stakeholder theory that posits that pursuing stakeholder collaborations guarded by 'the norms and elements of traditional ethics' such as 'fairness, trustworthiness, loyalty, care, and respect' (Hendry, 2004, pp. 223–232) – will bring about improved performance in the long term (Barnett and Salomon, 2012; Harrison and Freeman, 1999). Equally important to this study is

the use of signalling theory in resolving information asymmetry among parties. Indeed, Sheng et al., (2016) confirmed that information asymmetry accentuates CO2 emissions in 75 emerging countries in Africa, Latin America and the Caribbean, and Asia and Oceania. Thus, for context, this study draws on the stakeholder theory and signalling theory as foundational concepts to examine the impact of innovation on climate change from emerging countries perspective.

2.3 The role of Innovation in Managing Climate Change

Current research suggests that there is a lot that relevant innovation can do to help achieve positive targets in tackling climate change problems (Diaz Garcia, 2015; Rutkauskas et al., 2014). In the agricultural sector, where a mostly deterministic approach appears to be the norm, agriculturist to adapt to the environmental challenges that climate change induces has used innovative technologies. For instance, based on empirical findings from the African Sahel regions, Elawad & Hall (2002), found that scientists had successfully developed early maturing cowpea cultivars to avoid the effects of late-season droughts. Similarly, Henry (2019) highlighted various ways in which genetic technologies could be used to develop new crop varieties, which will be able to withstand the harsh realities of climate change affecting the agricultural sector. In the Upper West region of Ghana Nyantakyi-Frimpong (2019) studied 619 plots of farmlands and identified a number of innovative agroecological techniques, collectively called Zai, that smallholder farmers are using to persevere in the face of harsh conditions induced by climate variability and change. Specifically, Zai helps improve soil fertility, enhance seed germination, and improve vegetation cover. This study points to the impactful relevance of indigenous innovations in making farmers in developing countries resilient to climate change problems.

In other sectors, scientists and organisations seem to be taking a more agentic approach and have suggested that innovation, particularly technologically driven ones, can mitigate climate change by conserving energy and reducing emissions (Lin and Zhu, 2019). A number of empirical researches have lent support to this more proactive view. For instance, Lin and Zhu (2019), using panel data from China between 2000 to 2015, found that Renewable Energy Technological Innovations, RETI – made up of low carbon technologies – while incredibly expensive, had a negative effect on CO_2 emissions. In a similar study, Li and Wang (2017), used a new combined approach (the effects of technological innovation during production processes on both CO_2 emissions and economic growth), to analyse panel data from 1996 to 2007 and found that technological innovations developed did indeed have a significantly

reductive effect on CO_2 emissions. Chen and Lei (2018), offered some nuance to the relationship between innovations and climate change. The authors, based on their panel data of a study of 30 countries between 1980–2014 found that technological innovations had higher reductive effects on carbon emissions in countries with higher levels of emissions, compared to counterparts with lower emissions. As the authors explain, this observation could be because higher emission countries recognise the high impact of their technological progress on the environment, and are thus, more likely to invest more into innovations that tackle significant problems. Further, Abdelzaher et al. (2020) relying on a longitudinal study of 73 countries between 1998 and 2013, found that R&D expenditure of innovative input directly reduced countries' vulnerability to climate change.

Focusing specifically on emerging countries categorised under the MSCI, positive progress has been demonstrated on the effect of innovation on climate change. In the UAE, for example, there have been high-level innovative efforts to complement International Renewable Energy Agency (IRENA) initiatives. This has seen the development of an entire city, Masdar City, operating as the world's first zero-carbon, zero-waste city, entirely powered by renewable energy (Madichi, 2011). In line with the stakeholder theory, an outcome that is expected to emerge from this city of climate change innovation is an encouragement, and perhaps a subtle source of pressure to other emerging markets on how comprehensive innovation efforts could be applied (Madichi, 2011). In Brazil, efforts have been made towards innovations that rely on the use of biofuels in place of other carbon-emitting fuels. Brazil is, in fact, one of the top countries globally noted for the use of biofuels, which has led to about 10% reduction in its carbon emissions for some time now (Findlay and Dimsdale, 2020).

In other MSCI countries, such as India, innovation towards promoting climate change efforts has been approached by explicitly including different stakeholders. For instance, the WWF India (World-Wide Fund for Nature, India) brings actors in the clean energy innovation ecosystem, including investors, incubators/accelerators, companies and policymakers, together to channel efforts towards building eco-friendly technologies. This has successfully led to the Climate Solver Initiative led, where small businesses are supported to come up with green technologies to help reduce climate emissions (WWF, 2017).

2.4 Governance, Innovation input and Climate change

According to researchers taking a Stakeholder theory perspective of climate change efforts, governments and international governing bodies, such as the EU in Europe or ECOWAS in sub-Saharan Africa, are among the most critical stakeholders with the capacity to support climate change goals (Sprengel and Busch, 2011). Aside having the regulatory powers to ensure best practices (Chithambo et al., 2020), governments' unique importance also stems from the fact that they are more inclined to take a long-term view of the consequences of environmental behaviours and are hence expected to take urgent steps to guide and guard behaviours that limit the achievement of positive outcomes. This is key, considering that the non-immediate effects of poor environmental practices on climate goals do not motivate consumers and individual companies to treat environmental concerns as a matter of urgency by themselves. Aside from these altruistic motivations, governments and other governing bodies may also intervene in innovation and climate change efforts to 'signal' positive responses to their various stakeholder audience (Simaens and Koster, 2013).

Against this background, governments, mainly of highly industrialised and technologically advanced nations, have been keen to intervene and contribute to efforts that reduce carbon emissions. **These could be in the form of directly pressurising individual companies to reduce carbon-based emissions, or even initiating mere political debates that prompt action among organisations (Sprengel and Busch, 2011). Some efforts have also been made by governance institutions in emerging economies, as observed in Brazil, Mexico and South Africa (Findlay and Dimsdale, 2009).**

A core and fruitful mandate that researchers have found relevant for public policymakers to undertake is putting in place policies that encourage demand for low–carbon energies (Anadon and Holdren, 2009). For example, adopting a general equilibrium analysis of the impact of relevant policies on the rate and focus of innovation, Gans (2011) found that policies that featured stringent emission caps could directly encourage organisations' quest for innovations that improve alternative energies, and reduce the rate at which they rely on fossil fuels. Guan et al. (2014) did a similar study of China, where the uptake of eco-technologies, compared to the country's carbon emissions, is low. They found that the government played an essential role in reducing climate change by setting up tax regimes that made it possible to price low-carbon alternatives lesser than fossil fuels. Gans (2011) found, in relation to these, that incentives to develop efficient eco-innovative technologies were only sustainable when carbon alternatives were readily available.

While these studies seem to point to a facilitative role by governments on innovation, and hence, climate change, there has been useful research that suggests that **the extent to which governance regulations on innovations affect climate change goals depend on contextual factors. First**, policies, depending on their nature and dynamic efficiency, can differ in the ways they induce eco-innovations. More often than not, the success of a policy to result in relevant innovations are linked to the anticipated reductions in emissions that can be achieved using the innovation (Newell, 2010).

Second, our theoretical lens, the signalling theory, helps shed light on reasons that may motivate organisations to respond to government pressures on adopting innovative efforts to reduce climate emissions. Specifically, organisations may undertake serious innovations for climate change purposes if they consider positive benefits these could bring their sustainability reporting, which are a strategic gain in dealing with various stakeholder audiences (Simaens and Koster, 2013). Specifically, they may respond positively to government pressures, if they consider that innovations undertaken to reduce carbon emissions will reduce any information asymmetries between themselves and stakeholders regarding their commitment to environmental concerns.

Third, there have been concerns that efforts in promoting eco-innovation and strict regulations on organisational processes can be detrimental to industrial productivity as industries are forced to bear what appears to be an additional cost in implementing or using eco–friendly innovations in their course of production (Dong et al., 2014). **This may be particularly the case for industries in emerging economies, which may have inherent financial struggles. In such scenarios,** government efforts towards managing climate problems may be seen as inhibitive to productivity and discourage organisations from pursuing innovative opportunities in mitigating climate change. This contrasts with the views that regulations are essential to innovation needed for mitigating and adapting to climate change (Cohen and Tubb, 2018). Abdelhazer et al.'s (2020) study of 73 countries between 1998 and 2013 may provide some answers to the discrepancies. In their study, the authors found that it was not enough for countries to have regulations, but that the quality of these regulations mattered. Thus, the quality of a country's regulatory controls, made up of its environmental regulations, intellectual property protection, and bureaucracies, as well as its freedom of trade, were effective in increasing the resilience of countries against climate change.

Finally, there have also been studies that have examined the general impact investments made in economic sectors by governments, have in encouraging these sectors' development and reliance on eco-technologies. Su and Moaniba's (2017) results, which were developed

based on their empirical study of a dataset of 70 countries concluded that government investments in areas such as transport, technology, water and sanitation did not necessarily lead to the development of eco-technologies in these sectors. It may appear, then, that governments will need to closely monitor investments in economic sectors to ensure that required quotas targeted at developing climate-friendly technologies are used for planned purposes.

While straightforward links are difficult to establish, these studies suggest that, there are at least, **possible successes** between eco-innovations and the current war against climate change, and that government actions may influence these relationships. What is not yet fully understood is **the extent to which** these purported relationships exist similarly in emerging countries, where governments **and large industries** are already preoccupied with other competing demands. In addition, it is still not clear the nature of government involvement **in these economies** that is needed for achieving climate goals. Accordingly, the guiding questions we ask in our paper are 1) whether investments in cutting-edge innovative technologies can help address climate change problems in emerging countries, and 2) the extent to which governance plays a role in this relationship.

3. Research Methodology

3.1 Data and sample

Data used for this study is country level information from 1990 to 2018 relating to CO_2 emission, innovation input and governance factors collected from the World Bank Development Indicators (WBDI). The sample consists of all emerging economies around the world, based on The Morgan Stanley Capital International Emerging Market Index (MSCI Index). The countries included are as follows: (1) three countries in Africa including Egypt, Morocco and South Africa; (2) five countries in the Middle East including Jordan, Kuwait, Qatar, Saudi Arabia and the United Arab Emirates; (3) six countries in Europe including Czech Republic, Greece, Hungary, Poland, Russian Federation and Turkey; (4) nine countries in Asia including China, Hong Kong, India, Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam; (5) five countries in South America including Argentina, Brazil, Chile, Colombia, Peru; (6) one country in North America, which is Mexico. Therefore, the sample consists of 29 emerging countries and 725 country-year observations. The sample of countries employed in the data is shown in Appendix 1.

3.2 Variable definitions

The main outcome variable used in this paper is the CO_2 emissions of metric tons per capita. This is appropriate for our study because CO_2 measures the influence of both natural and human activities on the environment (Le et al., 2020). Several studies have similarly used CO_2 emissions as a measure of the effects of natural and human activities on the environment (Li and Wang, 2017; Lin and Zhu, 2019).

The main independent variable used in this paper is innovation input, which is proxied by the percentage of R&D to GDP. Several studies have used R&D expenditure as a critical measure of innovation input (Godin, 2002; Arundel and Smith, 2013; Cirera et al., 2016). For example, Taques et al. (2020) used R&D in their study to measure innovation efforts. According to Cirera and Muzi (2020), R&D expenditure provides evidence of scientific and technological efforts of firms and countries. The advantage of using R&D expenditure as a measure of innovation input is that it is easily quantifiable (Cirera et al., 2016).

To control for factors that may affect the relationship between innovation input and CO_2 emission, we controlled for specific country-level characteristics including domestic credit to the private sector (DCTPS), market capitalisation (MarketCap), inflation and net domestic credit (NDC). The DCTPS is measured as the domestic credit to the private sector (% of GDP). Studies, including that of Lee et al. (2019) have shown that financial sector development may increase CO_2 emissions. This is because of improved access to financial services aids and boosts manufacturing and industrial activities, which may lead to higher levels of CO_2 emissions. MarketCap is measured as the market capitalisation of listed domestic companies (% of GDP). Larger firms may also consume more energy and emit Greenhouse Gasses (GHG), aggravating environmental concerns (Chithambo et al., 2020). Inflation is measured as a percentage of GDP. Lower inflation may increase CO_2 emission because it increases output and consumption (Daniel and Steege, 2020). NDC is the sum of net claims on the central government and other sectors of the domestic economy. Increased government spending may increase CO_2 emission because of its effect on production and consumption.

Given the impact of governance on human activities within a country, we further examine the moderating influence of country-level governance factors, including political stability, government effectiveness, regulatory quality, rule of law and control of corruption on the relationship between innovation input and CO_2 emission.

3.3 *Econometric model*

In this paper, the unbalanced panel data methodology approach is used because of the longitudinal nature of our data. To examine the influence of innovation input on CO_2 emissions, the following regression equation was estimated:

$$CO2_{it} = \beta_0 + \beta_1 R\&D_{it-1} + \beta_2 DCTPS_{it-1} + \beta_3 MarketCap_{it-1} + \beta_4 Inflation_{it-1} + \beta_5 NDC_{it-1} + Year\ effects + Country\ effects + \varepsilon_{it} \tag{1}$$

To examine the interaction influences of political stability, government effectiveness, regulatory quality, rule of law and control of corruption, we estimated the following econometric equation:

$$CO2_{it} = \beta_0 + \beta_1 R\&D_{it} + \beta_2 Governance_{it} + \beta_3 R\&D * Governance_{it} + \beta_4 DCTPS_{it} + \beta_5 MarketCap_{it} + \beta_6 Inflation_{it} + \beta_7 NDC_{it} + Year\ effects + Country\ effects + \varepsilon_{it}$$

(2)

Where the variable *Governance* represents the four moderation factors including political stability, government effectiveness, regulatory quality, rule of law and control of corruption. The estimations are performed separately for two groups: countries with innovation input values below the mean (low innovation input countries) and those with values above the mean (high innovation input countries). This set-up provides two sets of key results. Table 1 below defines all the variables used in this study.

[INSERT TABLE 1]

4. Empirical Analyses

4.1 *Descriptive statistics*

Table 2 presents the descriptive statistics for the study. **We winsorised all the continuous variables at 1% to reduce the problem of outliers.** Evidence from Table 2 suggests an average, countries from emerging markets emit on average of **8.0037** (metric tons per capita) CO_2 emission into the atmosphere with a median and standard deviation of 4.2224 (metric tons per capita) and **10.7892** (metric tons per capita) CO_2 emission respectively. The standard deviation figure shows a substantial variation in the climate change activities within the sample. The mean innovation input reported in Table 2 is about **68.55%** with standard deviation and median values of **32.49%** and 69.90%, respectively. In terms of the control variables, the average DCTPS is approximately **68.48**%; the mean MarketCap is £**318** billion; inflation is on average **16.05**%; the mean NDC is £**85,000** billion. For the moderating variables, the average

country has **–0.1177** points for politics; **0.3243** for GovEffect; **0.3411** for RegQuality; **0.1651** for ROL and **0.1064** for COC.

[INSERT TABLE 2]

4.2 *Pearson correlation matrix*

Table 3 presents the Pearson correlation matrix for the study. The findings presented in the Table suggest a positive but insignificant correlation between innovation input and climate change. The correlations between all the control variables are below 50% and therefore indicate no multicollinearity concerns.

[INSERT TABLE 3]

4.3 *Baseline regression: Innovation Input and Climate Change*

We present the baseline regression results on the impact of innovation input on climate change in Table 4. Columns (1)-(2) contain the results of the whole sample. Columns (3)-(4) contain the results of low and high innovative countries, respectively. The overall evidence presented in Table 4 suggests a significantly negative relationship between innovation input and climate change. The findings in column (1) of Table 4 reveals that the coefficient of the innovation input are negative and statistically significant at the **1%** level **(β = –1.6212, t–statistic = –3.09)**. This suggests that investments in innovative, cutting-edge technologies reduce climate change problems. The results show that for emerging markets, a 10% increase in innovative, cutting-edge technologies reduces climate change problems by **16.212%**.

Given the influence of country macroeconomic factors on country-level data, we suspect that the evidence presented in column 1 might be driven by the macroeconomic climate of countries and not only cutting-edge innovative technologies. Against this backdrop, we test the possibility of this in column (2) of Table 4 by introducing a number of country-level controls for macroeconomic factors and countries' commitment to investing in these technologies to tackling climate change problems. In these regressions, the signs and significance are maintained, but the coefficients have increased in magnitude. The results indicate that innovation input has a negative relationship with CO_2 **(β = –2.6184, t-statistic = –5.92)**, and the relationship is statistically significant at the **1%** level. Specifically, the findings show that a 10% increase investment in cutting edge technologies reduces climate change problems by **26.184%**.

The findings in columns (3 & 4) are similar to columns (1 & 2), but in this case, we introduce the level of innovation input to control for the level of innovation of countries.

15

Countries with high innovation input are categorised as high innovative countries that invest in cutting-edge technologies. Those with low innovation input are categorised as low innovative countries in accordance with the mean value of innovation input[2]. In comparison to columns (1 & 2), the results shown in column (4) indicate that highly innovative countries reduce climate change problems by approximately **21.408%** with a 10% increase in investment in cutting-edge technologies. However, we did not find any significant results for low innovative countries in column 3. The overall evidence from columns (1, 2 & 4) suggests that investment in innovative, cutting-edge technologies reduces climate change problems (Birdsall and Wheeler, 1993; Frankel and Romer, 1999; Frankel and Rose, 2002; Tamazian et al., 2009, 2010).

In terms of the control variables, the study finds their estimated coefficients to be broadly consistent with theoretical and empirical literature (Abbasi and Riaz, 2016; Shahbaz et al., 2016). For instance, we find a significantly positive relation between marketCap and CO_2 emissions in all columns, indicating that highly capitalised markets produce high CO_2 emissions. However, we find inflation and NDC to be insignificant in columns (2 & 3) and significant in column (4). The coefficient of DCTPS is also negative and statistically significant in columns (2 & 3).

[INSERT TABLE 4]

4.4 *Governance, innovation input and climate change*

We extend our analysis by exploring the potential impact of governance on the innovation-climate change relationship. As argued in the literature, countries with good governance can pursue, formulate and invest in cutting-edge innovative technologies aimed at curbing environmental damage (see Gani, 2012). Against this backdrop, we adopt a number of governance indicators, found relevant to emerging economies, to estimate their impact on innovation input climate change relationship.

Our first governance indicator is political stability. The theoretical and empirical evidence presented in the literature review suggests that political instability creates vulnerability among institutions and government to develop innovative policies towards maintaining a sustainable environment (see Gani, 2012). Given, such evidence, we argue that

---

[2]. The results from using the median innovation input to categorise countries into high and low innovation input produce qualitatively similar results.

political stability is most likely to influence the relationship between innovation input and climate change.

Table 5 presents the empirical evidence on the relationship between political, innovation input and climate change. The overall evidence suggests that political stability significantly moderates the relationship between innovation input and climate change throughout columns (1-4). In particular, we find the coefficient of the interaction variables *Innovation input X Politics* is negative and statistically significant at the **1%** level **(β= −1.2327, t-statistics = −3.75)** for column (2). The results show that, within a stable political system, governments become more effective in curbing climate change problems through innovative technologies. The evidence suggests that a 10% increase in investment in innovative technologies within politically stable countries accounts for a **12.327%** decrease in climate change problems. Interestingly, the evidence is even more sensitive for highly innovative countries. The evidence from column (4) reveals that a 10% increase in investment in innovative technology within politically stable, highly innovative countries, decreases climate change problems by **39.333%**. However, we did not find any significant evidence in model (3).

[INSERT TABLE 5]

Several prior evidences suggest that government effectiveness matters in countries' efforts towards tackling climate change problems (Fischer et al., 2001; Pushak et al., 2007; Gani, 2008). The overall evidence from these studies suggests that countries that maintain effective governments become more successful in pursuing effective, innovative policies towards curbing climate change problems. Gani (2008) argues that countries that maintain effective governments are able to gain confidence from producers and equally enforce governmental rules and regulations relating to CO_2 emissions with greater strength. Building on this evidence, we argue that effective governance may significantly moderate the relationship between innovation input and climate change problems.

Table 6 presents evidence on the relationship between government effectiveness, innovation input and climate change. Evidence from Table 6 shows that government effectiveness negatively and statistically significantly moderates the relationship between innovation input and climate change problems in columns (1, 2 & 4). This is consistent with previous estimations. Consistent with our expectations, we find the coefficient of the interaction variables *Innovation input* X *Governance is* negative and statistically significant at

the **1%** level **(β= −2.3544, t-statistics = −5.45)** for column (2). The results show that good governance contributes to a **23.544%** reduction in climate change problems with a 10% investment in innovative technologies. Similar to the results presented in Table 5, we find the evidence to be more pronounced among countries with high investments in innovation. The evidence from column (4) reveals that a 10% increase in investment in innovative technology of highly innovative countries, within effective governance, decreases climate change problems by **31.287%**. However, we did not find any significant evidence in model (3).

[INSERT TABLE 6]

Regulatory quality is another important governance indicator, which we argue, could significantly impact on the relationship between innovation input and climate change. Several studies have argued that regulatory quality affects environmental outcomes (Djankov et al. 2002; Est and Porters 2005). Countries with clear regulatory guidelines in terms of issuance of permits, fees charged and taxation on cutting-edge innovative technologies, can expect firms to adhere to efforts to curbing climate change. We, therefore, expect the regulatory quality to significantly moderate the relationship between innovation input and climate change problems.

The empirical results on the role of regulatory quality on innovation input and climate change relationships are presented in Table 7. Evidence from Table 7 suggests regulatory quality significantly moderates the relationship between innovation input and climate change problems in columns (1, 2 & 4). We find the coefficient of the interactive term of innovation input and regulatory quality (*Innovation input X Regulation*) to be negative and statistically significant at the **1%** level **(β= −2.0745, t-statistics = −4.29)** for column (2). The results show that regulatory quality contributes to **20.745%** reduction in climate change problem with a 10% investment in innovative technologies. The results from separating the sample into low and high innovative countries find the evidence to be more pronounced among countries with high investments in innovation. The evidence from column (4) reveals that a 10% increase in investment in innovative technology of highly innovative countries, with good regulatory quality, decreases climate change problems by **38.451%**. However, we did not find any significant evidence in model (3).

[INSERT TABLE 7]

Another essential element to environmental compliance is rule of law. Gani (2008) argues that in countries where rules exist and are well articulated, CO_2 emission control

procedures may be easily enforced, and firms would not feel hesitant to comply. Rule of law also provides legal enforcement mechanisms for compliance. According to Solakoglu (2007), secure property rights create incentives for using resources for efficient production when businesses earn entitlement for legal protection through registration. Thus, we expect rule of law to contribute to the reduction in climate change problems with the investment in innovative technologies.

Table 8 presents the empirical results of the moderating impact of rule of law on the relationship between innovation input and climate change. Evidence from Table 8 suggests that rule of law significantly moderates the relationship between innovation input and climate change problems in columns (1, 2 & 4). We find the coefficient of the interactive term of innovation input and rule of law (*Innovation input X ROL*) to be negative and statistically significant at the **1%** level **(β= −2.5180, t-statistics = −7.05)** for column (2). The results reveal that rule of law contributes to **25.180%** reduction in climate change problems with a 10% investment in innovative technologies. Consistently, we find the evidence to be much stronger high innovative countries. The evidence from column (4) reveals that a 10% increase in investment in innovative technology of highly innovative countries, with better rule of law, decreases climate change problems by **45.882%.** However, we did not find any significant evidence in model (3).

[INSERT TABLE 8]

We also establish empirical evidence on the impact of corruption on innovation input and climate change problems. Our argument is built on the premise that corruption has implications on the pace and extent to which climate change matters to countries (Fredriksson and Neumayer, 2016). For instance, corrupt governments may distort innovative environmental policies because corrupt politicians (or corrupt public officers) may be expected to use their authority on those activities on which it is easier to collect bribes (see Hwang, 2002). Also, public servants distort or are bribed on aspects of regulations relating to environmental policies to favour particular groups. Control of corruption plays a vital role in countries' effort in investing in cutting-edge technologies aimed at curbing climate change problems. Against this backdrop, we investigate the empirical link between control of corruption, innovation input and climate change.

Evidence of this relationship is presented in Table 9. Evidence from Table 9 shows that control of corruption significantly moderates the relationship between innovation input and climate change problems in columns (1, 2 & 4). We find the coefficient of the interactive term

of innovation input and control of corruption (*Innovation input X COC*) to be negative and statistically significant at the **1%** level **(β= −1.9665, t-statistics = −5.79)** for column (2). The results reveal that control of corruption contributes to approximately **19.665%** reduction in climate change problems with a 10% investment in innovative technologies. Consistently, we find the evidence to be much stronger in column (4), which suggests that control of corruption plays a critical role in countries' effort towards curbing climate change problems through investment in innovative technologies. The evidence suggests that through control of corruption, a 10% investment in innovation by highly innovative countries can reduce climate change problems by **34.969%.**

<div align="center">

[INSERT TABLE 9]

</div>

4.5 Governance index effect on the relationship between innovation input and climate change

Unreported results show that the correlation coefficients of the five different governance factors (political stability, governance effectiveness, regulatory quality, rule of law and control of corruption) are highly correlated. This stems from the fact that each of the five factors are effectively measuring a facet of the effectiveness of countries' governance. Thus, the five governance factors complement each other (Churchill Jr, 1979; Leuz, 2010). We therefore develop a governance index, incorporating all five governance factors to capture their multiple dimensions, using the principal component analysis (PCA). Similar to previous studies (Jellema and Roland, 2011), we retain eigenvalues greater than 1. We then conduct the varimax rotation is conducted, after the PCA (see, Gande and Kalpathy, 2017) by considering factor loadings that exceed 0.40 (Larcker et al., 2007). The results of the varimax rotation, which are presented in Appendix 2 show that all five governance factors have loadings greater than 0.4 and explain 85.57% of variance of the variables.

The governance index is then used as the moderating variables in regression Equation (2). The results are presented in Table 10 and show that the governance index negatively moderates the relationship between innovation input and climate change problems in columns (1, 2 & 4). The coefficient of the interactive term of innovation input and governance index (*Innovation input X Index*) is negative and statistically significant at the 1% level (β= − 0.7850, t-statistics = −6.71) for column (2). Specifically, the results show that the five governance factors collectively contribute about 7.850% reduction in climate change problems with a 10% investment in innovative technologies. We also find

the results to be much stronger in column (4), which indicates that the five governance factors collectively plays a critical role in countries' effort towards curbing climate change problems through investment in innovative technologies. Overall, the evidence suggests that through high governance index, a 10% investment in innovation by highly innovative countries can reduce climate change problems by 10.628%.

[INSERT TABLE 10]

5. Discussions

This paper has attempted to address some of the gaps in our understanding of links between innovation, quality of governance and the environment by investigating how innovation input affects CO_2 emissions. The focus is on 29 emerging countries around the world for the period from 1990-2018. **The combination of the stakeholder theory and signalling theory offer an explanation of the negative relationship between innovation input and climate change, and the possible negative moderation of the governance factors.** The following core findings have been established. **Consistent with the stakeholder theory and signalling theory,** we found that innovation input negatively influences CO_2 emission. Given the overwhelming evidence of a negative relationship between innovation input and CO_2 emissions, an extended analysis was performed by including specific important country-level governance mechanisms to further expand research understanding on the role of innovation input on CO_2 emissions. The results **support the stakeholder theory and signalling theory by** showing that political stability, government effectiveness, regulatory quality, rule of law and control of corruption, all negatively moderate the innovation input and CO_2 relationship. **Thus, stakeholder pressures (Talbot and Boiral, 2015; Freeman et al., 2010) and signals for the need to take climate change actions (Darnall and Carmin, 2005, and Moratis, 2018) help curb CO2 emissions through investments in innovative technologies.**

First, the evidence that an increase in innovation input helps curtail CO_2 emission is congruent with many established studies that suggest investment in innovation input reduces climate change (Chen and Lei, 2018; Lin and Zhu, 2019; Abdelzaher et al., 2020). This also support theAlthough high-level innovation input leads to higher economic production and outputs (Gumus and Celikay, 2015), our results suggest innovation input increases productivity, but reduces CO_2 emissions. Many studies have suggested that cutting-edge innovations, while leading to high productivity, should also be relevant for reducing CO_2 emissions (Frankel and Rose, 2002; Tamazian et al., 2010). This is particularly due to the increased awareness of the harmful effects of human activities on the environment (Du et al.

2017; Le et al., 2020). This increased awareness has caused corporations to employ efficient methods of productivity (Moratis, 2018). Governments around the world have also committed to treaties that bind them to CO_2 emission reduction. Thus, although emerging countries are trying to catch up with the developed world through increased productivity, they do so with the full knowledge of their commitment to reducing CO_2 emissions. Another motivation that has caused countries to produce more efficiently and less CO_2 emission is pressure groups from various stakeholder background (Fredriksson and Neumayer, 2016). Although worldwide productivity is on the rise, the effects of pressure groups' actions on corporations and countries have led to better ways of achieving productivity, which emit less CO_2 into the atmosphere (Chuang and Qianfei, 2013; Chithambo et al., 2020).

Second, our results show that the negative effect of innovation input on CO_2 emission is more pronounced in emerging countries with better governance in the areas of political stability, government effectiveness, regulatory quality, rule of law and control of corruption. These findings confirm previous studies, including Pellegrini and Gerlagh (2006), Persson and Tabellini (2009), Fredriksson and Neumayer (2013). With better governance, rules and regulations that ensure the reduction of CO_2 emission is expected to be adhered to (Fredriksson and Neumayer, 2016). Moreover, in a better-governed country, violators of climate change laws are expected to be punished appropriately (Chithambo et al., 2020). Thus, corporations in better governed countries are expected to be deterred from engaging in harmful activities that increase CO_2 emission.

6. Conclusion, Theoretical and Practical Implications

The adoption of cutting-edge innovative technologies has been suggested as a promising approach to mitigate climate change by conserving energy and reducing emissions. This study adds to the limited body of research on this topic by examining the relationship between innovation input, governance and climate change in emerging economies. Of particular interest to our study was how quality of governance influence countries' investment in innovative technologies towards curbing environmental damage. We adopted a panel fixed effect model of a sample of 29 emerging countries and 725 country-year observations from the World Bank database over the period 1990 to 2018 to investigate the relationship between innovation, governance and climate change.

The data suggest that investment in innovative cutting-edge technologies reduces climate change problems in the countries studied. Specifically, the evidence established that highly innovative emerging economies reduce climate change problems by approximately

22

26.184% with a 10% increase investment in cutting edge technology. Further, the evidence gleaned also suggests that various governance indicators (political stability, rule of law, government effectiveness, regulatory quality and control of corruption) impose both direct and indirect impacts on the relationship between innovation input and climate change. The findings provide novel insights into the roles and interrelationships between governance, innovation input and climate change. We establish a negative relationship between innovation input and CO_2 emission; show that a reduction of CO_2 emission is more pronounced in countries with high innovation input and also indicate that country-level governance factors negatively moderate the effect of innovation input on CO_2 emissions.

Our findings have implications for governance, innovation input and climate change theory and practice. Theoretically, unlike earlier studies, our research is the first to investigate the joint effect of governance on innovation input and climate change. The study makes two broad contributions to literature by presenting novel insights that highlight the inverse relationship between innovative technologies and climate change, as well as governance factors that negatively moderate the relationship between innovation input and carbon dioxide emissions.

In terms of practice, the findings have direct implications for the quality of governance at the country-level as we found that this is likely to influence countries' investment in innovative technologies towards curbing environmental damage. In addition, whereas previous studies have predominantly focused on the climate-saving efforts of developed economies, our results suggest that emerging economies' innovative efforts also represents a significant contribution towards national and global successes. Beyond policy, the findings also have indirect implications for macro-environmental factors, such as political stability, general government institutional effectiveness, quality of the regulatory framework, rule of law and control of corruption. By inference, any green-oriented cutting-edge innovation will require an effective and efficient infrastructure of governance factors to stand a chance of succeeding to mitigate climate change.

While we have developed very useful insights, our study is not without limitations. Firstly, by focusing on emerging countries, our findings may not be applicable to other, more developed economies. However, our results provide a starting platform to indicate areas of possible interest for future research. Secondly, the aggregated nature of the innovation data employed in this study provides further research scope to investigate the role and impact of specific types of innovations on climate change in emerging economies to extend research understanding of this critical research area.

References

Abbasi, F., & Riaz, K. (2016). CO2 emissions and financial development in an emerging economy: an augmented VAR approach. *Energy Policy*, 90, 102-114.

Abdelzaher, D. M., Martynov, A., & Zaher, A. M. A. (2020). Vulnerability to climate change: Are innovative countries in a better position? *Research in International Business and Finance*, *51*, 101098.

Abidoye BO and F. Odusola (2015). Climate Change and Economic Growth in Africa: An Econometric Analysis, Journal of African Economies, Volume 24, Issue 2, Pages 277-301.

Aghion, P and Howitt P., (1992). A Model of Growth through Creative Destruction, Econometrica, Vol. 60, No. 2, pp. 323-351.

Amankwah-Amoah (2015). Solar energy in sub-Saharan Africa: the challenges and opportunities of technological leapfrogging. Thunderbird Int. Bus. Rev., 57 (1) (2015), pp. 15-31.

Amankwah-Amoah, J. and Debrah, Y. (2014) Emerging global firms: Insights of Chinese multinationals in Africa. In: The Routledge Companion to Business in Africa. Routledge Companions in Business, Management and Accounting. Routledge, Oxon. UK, pp. 315-331.

Anadon, L. D., & Holdren, J. P. (2009). Policy for Energy-Technology Innovation. *Acting in time on energy policy*, 89–127.

Arundel, A., Smith, K., 2013. History of the community innovation survey (2013) In: Gault, F. (Ed.), Handbook of Innovation Indicators and Measurement. Edward Elgar, pp. 60-87

Bak, C., A. Bhattacharya, O. Edenhofer, B. Knopf (2017). Towards a Comprehensive Approach to Climate Policy, Sustainable Infrastructure, and Finance, G20 Task Force on Climate Policy and Finance, Berlin.

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

Binz, B. Truffer, L. Li, Y. Shi, Y. Lu (2012). Conceptualising leapfrogging with spatially coupled innovation systems: the case of onsite wastewater treatment in China. Technol. Forecasting Social Change, 79 (2012), pp. 155-171.

Birdsall, N., & Wheeler, D. (1993). Trade policy and industrial pollution in Latin America: where are the pollution havens?. The Journal of Environment & Development, 2(1), 137-149.

Boakye J.D., Tingbani I., Ahinful G., Damoah I, and Tauringana V., (2020). Sustainable environmental practices and financial performance: Evidence from listed small and medium-sized enterprise in the United Kingdom. Business Strategy and the Environment.1, pp1-22.

Cadez, S., Czerny, A., & Letmathe, P. (2019). Stakeholder pressures and corporate climate change mitigation strategies. Business Strategy and the Environment, 28(1), 1-14.

Calmfors, L. and Hassler, J. (2019), Climate Policies in the Nordics, Nordic Economic Policy Review 2019, pp. 23 and 33.

Chen, W., & Lei, Y. (2018). The impacts of renewable energy and technological innovation on the environment-energy-growth nexus: new evidence from a panel quantile regression. *Renewable energy*, *123*, 1-14.

Chithambo, L., I. Tingbani, G. A. Afrifa, E. Gyapong and I. S. Damoah (2020). "Corporate voluntary greenhouse gas reporting: Stakeholder pressure and the mediating role of the chief executive officer." Business Strategy and the Environment n/a(n/a).

Chuang, L., Qianfei, L. (2013). The motivation analysis of enterprises voluntarily implementing environmental management system. In: 25th Chinese Control and Decision Conference. CCDC), pp. 4855-4858

Churchill Jr, G. A. (1979). A paradigm for developing better measures of marketing constructs. Journal of Marketing Research, 16(1), 64-73.

Cimato, F., & Mullan, M. (2010). Adapting to climate change: analysing the role of government. Defra Evidence and Analysis Series, Paper, 1.

Cirera, X. and S. Muzi (2020). "Measuring innovation using firm-level surveys: Evidence from developing countries☆." Research Policy 49(3): 103912.

Cirera, X., Lopez-Bassols, V., Muzi, S., 2016. Measuring Firm Innovation. A Review of Existing Approaches. World Bank.

Cohen, M. A., & Tubb, A. (2018). The impact of environmental regulation on firm and country competitiveness: A meta-analysis of the Porter hypothesis. *Journal of the Association of Environmental and Resource Economists*, *5*(2), 371-399.

Connelly, B. L., Certo, S. T., Ireland, R. D., & Reutzel, C. R. (2011). Signalling theory: A review and assessment. Journal of Management, 37(1), 39-67.

Czerny, A., & Letmathe, P. (2017). Eco-efficiency: GHG reduction-related environmental and economic performance. The case of the companies participating in the EU Emissions Trading Scheme. Business Strategy and the Environment, 26(6), 791-806.

Daniel, V. and L. t. Steege (2020). "Inflation expectations and the recovery from the Great Depression in Germany." Explorations in Economic History 75: 101305.

Darnall N, and Carmin J. (2005). Greener and cleaner? The signalling accuracy of US voluntary environmental programs. Policy Sci-ences38: 71-90.

Díaz–García, C., González-Moreno, Á., & Sáez-Martínez, F. J. (2015). Eco-innovation: insights from a literature review. *Innovation*, *17*(1), 6-23.

Djankov, S., R. La Porta, F. Lopez-de-Silanes, and A. Shleider (2002), "The Regulation of Entry," Quarterly Journal of Economics, 117, 1-37.

Donaldson, T., & Preston, L. E. (1995). The stakeholder theory of the corporation: Concepts, evidence, and implications. Academy of Management Review, 20(1), 65-91.

Dong, L., Gu, F., Fujita, T., Hayashi, Y., & Gao, J. (2014). Uncovering opportunity of low-carbon city promotion with industrial system innovation: A case study on industrial symbiosis projects in China. *Energy Policy*, *65*, 388-397.

Du D., Zhao, X and Huang R. (2017). The Impact of Climate Change on Developed Economies, Economics Letters 153, 43-46.

Elawad, H. O. A., & Hall, A. E. (2002). Registration of Ein El Gazal'cowpea. (Registrations Of Cultivars). *Crop Science*, *42*(5), 1745-1747.

Esty, D.C., and M.E. Porter (2005), "National Environmental Performance: An Empirical Analysis of Policy Results and Determinants," Environment and Development Economics, 10, 391-434.

Findlay, M., & Dimsdale, T. (2008). Climate action in major emerging economies. Available at https://www.e3g.org/docs/Plus-Five-%28US%29-Updated-260109-TD.pdf

Fischer, S., P. Alonso-Gamo, and UE von Allmen (2001), "Economic Developments in the West Bank and Gaza since OSLO," The Economic Journal, 111, F254-F275

Frankel and Romer, 1999; Frankel, J. A., & Romer, D. H. (1999). Does trade cause growth?. American economic review, 89(3), 379-399.

Frankel and Rose, 2002; Frankel, J., & Rose, A. (2002). An estimate of the effect of common currencies on trade and income. The quarterly journal of economics, 117(2), 437-466.

Fredriksson, P. G. and E. Neumayer (2013). "Democracy and climate change policies: Is history important?" Ecological Economics 95: 11-19.

Fredriksson, P. G. and E. Neumayer (2016). "Corruption and Climate Change Policies: Do the Bad Old Days Matter?" Environmental and Resource Economics 63(2): 451-469.

Fredriksson, PG and E. Neumayer (2016). Corruption and climate change policies: do the bad old day's matter? Environ. Resour. Econ., 63 (2), pp. 451-469

Freeman R.E, Phillips R., and Rajendra S. (2020) Tensions in Stakeholder Theory, Business & Society, Vol. 59(2) 213-231.

Freeman, R.E., Harrison, J.S., Wicks, A.C., Parmar, B.L. and Colle, S (2010). *Stakeholder Theory: The State of the Art* Cambridge: Cambridge University Press.

Gande, A. and S. Kalpathy. 2017. "CEO compensation and risk-taking at financial firms: Evidence from U.S. federal loan assistance." Journal of Corporate Finance 47: 131-150.

Gani, A (2012). The relationship between good governance and carbon dioxide emissions: evidence from developing economies. Journal. Economics Development, 37 (2012), pp. 77-93.

Gans, J. S. (2012). Innovation and climate change policy. *American Economic Journal: Economic Policy*, 4(4), 125-45.

Godin, B. (2002), "The rise of innovation surveys: measuring a fuzzy concept", Project on the History and Sociology of STI Statistics, Paper no. 16, Communication presented at the International Conference in Honour of K. Pavitt "What We Know About Innovation", 13-15 November 2003, SPRU, University of Sussex, Brighton (UK).

Goodman, J., Korsunova, A., & Halme, M. (2017). Our collaborative future: Activities and roles of stakeholders in sustainability-oriented innovation. Business Strategy and the environment, 26(6), 731-753.

Gumus, E., & Celikay, F. (2015). R&D expenditure and economic growth: New empirical evidence. Margin: The Journal of Applied Economic Research, 9(3), 205-217.

Harrison, J. S., & Freeman, R. E. (1999). Stakeholders, social responsibility, and performance: Empirical evidence and theoretical perspectives. Academy of Management Journal, 42(5), 479-485.

Hendry, J., 2001. Economic contract versus social relationships as a foundation for normative stakeholder theory. Business Ethics: A European Review, 10: 223-232.

Henry, R. J. (2019). Innovations in plant genetics adapting agriculture to climate change. *Current Opinion in Plant Biology*.

Hepburn, C. (2006). Regulation by prices, quantities, or both: A review of instrument choice. Oxford Review of Economic Policy, 22(2), 226-247.

Hoffman, A. J. (2005). Climate Change Strategy: The business logic behind voluntary greenhouse gas reductions. California Management Review, 47(3), 21-46.

Hwang, J. (2002), "A Note on the Relationship between Corruption and Government Revenue," Journal of Economic Development, 27(2), 161-176.

IPCC Special Report on Climate Change and Land (2019). Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems (SRCCL), Geneva, Switzerland. 2-6 August 2019.

Jellema, J. and G. Roland. 2011. "Institutional clusters and economic performance." Journal of Economic Behavior & Organization 79(1): 108-132.

Jeswani, H. K., Wehrmeyer, W., and Mulugetta, Y. (2008). How warm is the corporate response to climate change? Evidence from Pakistan and the UK. Business Strategy and the Environment, 17(1), 46-60.

Jones, T. M., Harrison, J. S., & Felps, W. (2018). How applying instrumental stakeholder theory can provide a sustainable competitive advantage-Academy of Management Review, 43(3), 371-391.

Kaufmann, D., A. Kray, and M. Mastruzzi (2007). Governance Matters VI: Aggregate and Individual Governance Indicators, World Bank Policy Research Working Paper, 4280, Washington, DC.

Larcker, D. F., Richardson, S. A., & Tuna, I. (2007). Corporate governance, accounting outcomes, and organizational performance. The Accounting Review, 82(4), 963-1008.

Le, T.H., H.C. Le and F. Taghizadeh-Hesary (2020). "Does Financial Inclusion impact CO2 Emissions? Evidence from Asia." Finance Research Letters: 101451.

Leuz, C. (2010). Different approaches to corporate reporting regulation: How jurisdictions differ and why. Accounting and Business Research, 40(3), 229-256.

Li, M., & Wang, Q. (2017). Will technology advances alleviate climate change? Dual effects of technology change on aggregate carbon dioxide emissions. *Energy for Sustainable Development*, *41*, 61-68.

Lin, B., & Zhu, J. (2019). The role of renewable energy technological innovation on climate change: empirical evidence from China. *Science of the Total Environment*, *659*, 1505-1512.

Madichie, N.O. (2011), "IRENA – Masdar City (UAE)-exemplars of innovation into emerging markets", Foresight, Vol. 13 No. 6, pp. 34-47

Mair, J., & Marti, I. (2009). Entrepreneurship in and around Institutional Voids: A Case Study from Bangladesh, *Journal of Business Venturing*, 24, 419-435.

Moratis, L. (2018). Signalling responsibility? Applying signalling theory to the ISO 26000 standard for social responsibility. Sustainability, 10(11), 4172.

Newell, R. G. (2010). The role of markets and policies in delivering innovation for climate change mitigation. *Oxford Review of Economic Policy*, *26*(2), 253-269.

Nyantakyi-Frimpong, H. (2020). What lies beneath Climate change, land expropriation, and zaï agroecological innovations by smallholder farmers in Northern Ghana. *Land Use Policy*, *92*, 104469.

Okereke, C., & Russel, D. (2010). Regulatory pressure and competitive dynamics: Carbon management strategies of UK energy-intensive companies. California Management Review, 52(4), 100-124.

Oman, C. P., & Arndt, C. (2010). Measuring governance. OECD Development Centre. Policy Brief. No 9. Available at http://www.oecd.org/dev/46123827.pdf

Pegas, P., Staikouras, Ch., & Tsamadias, C. (2019). Does research and development expenditure impact innovation? Evidence from the European Union countries. Journal of Policy Modeling, 41(5), 1005-1025.

Pellegrini, L. and R. Gerlagh (2006). "Corruption, Democracy, and Environmental Policy: An Empirical Contribution to the Debate." The Journal of Environment & Development 15(3): 332-354.

Persson T, Tabellini G (2009) Democratic capital: The nexus of political and economic change. Am Econ J Macroecon 1:88-126

Pushak, T., E.R. Tiongson, and A. Varoudakis (2007), "Public Finance, Governance and Growth in Transition Economies: Empirical Evidence from 1992-2004," World Bank Policy Research Working Paper, 4255, Washington, DC.

Reid, E. M., and Toffel, M. W. (2009). Responding to public and private politics: Corporate disclosure of climate change strategies. Strategic Management Journal, 30(11), 1157-1178.

Rutkauskas, A. V., Račinskaja, I., & Kvietkauskienė, A. (2014). The technology of complex adaptive systems as an adequate synergy tool of knowledge, innovation and technology features designing universal sustainable development of a country-*International Journal of Transitions and Innovation Systems 2*, *3*(2), 104-114.

Sangle, S. (2011). Adoption of cleaner technology for climate proactivity: A technology-firm-stakeholder framework. Business Strategy and the Environment, 20(6), 365-378.

Savage, G.T., Bunn, M.D, Gray, B., Xiao, Q., Wang, S., Wilson, E.J. and Williams, E.S (2010). 'Stakeholder Collaboration: Implications for Stakeholder Theory and Practice' Journal of Business Ethics, 96: 21-26.

Shahbaz et al., 2016, Shahbaz, M., Loganathan, N., Muzaffar, A. T., Ahmed, K., & Jabran, M. A. (2016). How urbanization affects CO2 emissions in Malaysia? The application of STIRPAT model. Renewable and Sustainable Energy Reviews, 57, 83-93.

Simaens, A., & Koster, M. (2013). Reporting on sustainable operations by third sector organisations: A signalling approach. Public Management Review, 15(7), 1040-1062.

Solakoglu, E.G. (2007), "The Effect of Property Rights on the Relationship between Economic Growth and Pollution for Transition Economies," Eastern European Economics, 45, 77-94.

Spence, M. (2002), Signalling in retrospect and the informational structure of markets. American Economic Review, 92: 434-459.

Sprengel, D. C., & Busch, T. (2011). Stakeholder engagement and environmental strategy-The case of climate change. Business Strategy and the Environment, 20(6), 351-364.

Su, H. N., & Moaniba, I. M. (2017). Does innovation respond to climate change? Empirical evidence from patents and greenhouse gas emissions. *Technological Forecasting and Social Change*, *122*, 49-62.

Talbot, D., & Boiral, O. (2015). Strategies for climate change and impression management: A case study among Canada's large industrial emitters. Journal of Business Ethics, 132(2), 329-346.

Tamazian, A., & Rao, B. B. (2010). Do economic, financial and institutional developments matter for environmental degradation? Evidence from transitional economies. Energy Economics, 32(1), 137-145.

Tamazian, A., Chousa, J. P., & Vadlamannati, K. C. (2009). Does higher economic and financial development lead to environmental degradation: evidence from BRIC countries. Energy policy, 37(1), 246-253.

Taques, F. H., M. G. López, L. F. Basso and N. Areal (2020). "Indicators used to measure service innovation and manufacturing innovation." Journal of Innovation & Knowledge.

Tauringana V, Chithambo L. (2015). The effect of DEFRA guidance on greenhouse gas disclosure. British Accounting Review 47(4): 425-444.

Tingbani I., Chithambo L., Tauringana V., Papanikolaou N. (2020). Board gender diversity, environmental committee and greenhouse gas voluntary disclosures. Business Strategy and the Environment. 2020. pp 1-17.

Tingbani I., Okafor G., and Tauringana V., Zalata A.M. (2019). Terrorism and country-level global business failure. Journal of Business Research, *98* (2019), pp. 430-44.

Wade, K., & Jennings, M. (2015). Climate change and the global economy: regional effects. Schroders. https://www. schroders. com/en/ch/asset-management/insights/economics/climate-change-and-the-global-economy-regional-effects.

Weinhofer, G., & Hoffmann, V. H. (2010). Mitigating climate change-How do corporate strategies differ? Business Strategy and the Environment, 19(2), 77-89.

WWF India (2017) Climate solver. WWF's Climate Innovation Platform. Available from https://d2391rlyg4hwoh.cloudfront.net/downloads/brochure__climate_solver_2017_final.pdf

Zhang, X., Karplus, V. J., Qi, T., Zhang, D., & He, J. (2016). Carbon emissions in China: How far can new efforts bend the curve? *Energy Economics*, *54*, 388-395

Table 1. Description of variables and data source.

Description	Abbreviation	Source
CO_2 emission	CO_2	https://info.worldbank.org/governance/wgi/
Research and development expenditure (% of GDP)	Innovation input	https://info.worldbank.org/governance/wgi/
The market capitalisation of listed domestic companies (current US$)	MarketCap	https://info.worldbank.org/governance/wgi/
Inflation, GDP deflator (annual %)	Inflation	https://info.worldbank.org/governance/wgi/
Net domestic credit (current LCU)	NDC	https://info.worldbank.org/governance/wgi/
Domestic credit to the private sector (% of GDP)	DCTPS	https://info.worldbank.org/governance/wgi/
Political Stability and Absence of Violence/Terrorism – Estimate of governance (ranges from approximately –2.5 (weak) to 2.5 (strong) governance performance)	Politics	https://info.worldbank.org/governance/wgi/
Governance effectiveness – Estimate of governance (ranges from approximately –2.5 (weak) to 2.5 (strong) governance performance)	GovEffect	https://info.worldbank.org/governance/wgi/
Regulatory quality – Estimate of governance (ranges from approximately –2.5 (weak) to 2.5 (strong) governance performance)	RegQuality	https://info.worldbank.org/governance/wgi/
Rule of law – Estimate of governance (ranges from approximately –2.5 (weak) to 2.5 (strong) governance performance)	ROL	https://info.worldbank.org/governance/wgi/
Control of corruption – Estimate of governance (ranges from approximately –2.5 (weak) to 2.5 (strong) governance performance)	COC	https://info.worldbank.org/governance/wgi/

Table 2. Descriptive statistics

This Table displays summary statistics for variables used in the regression tests. Definitions of the variables are provided in Table 1.

Variable	N	mean	p50	sd	p10	p25	p75	p90
CO_2 emission	725	8.0037	4.2224	10.7892	1.0790	1.8026	8.7427	18.0409
Innovation	725	0.6855	0.6990	0.3249	0.2346	0.5840	0.6990	1.0561
DCTPS	725	0.6848	0.6536	0.3585	0.2757	0.4058	0.8686	1.2234
MarketCap (billions)	457	318	117	601	21.6	44.7	285	771
Inflation	671	0.1605	0.0477	0.6378	0.0096	0.0262	0.0899	0.1946
NDC (billions)	695	85000	914	397000	19.6	138	6750	67300
Politics	667	−0.1177	−0.1300	0.8311	−1.2300	−0.7500	0.5800	0.9900
GovEffect	667	0.3243	0.1500	0.6409	−0.3400	−0.1300	0.7000	1.1500
RegQuality	667	0.3411	0.2500	0.6844	−0.4300	−0.1500	0.6900	1.3500
ROL	667	0.1651	0.0900	0.6617	−0.6400	−0.4000	0.6200	1.0500
COC	667	0.1064	−0.1100	0.7431	−0.6200	−0.4000	0.4600	1.3100

Table 3.

This Table presents the correlation coefficients among all variables used in regression tests. All variables are as defined in Table 1. *indicates statistical significance at the 5%.

Variables	1	2	3	4	5	6
CO_2	1					
Innovation	0.0193	1				
DCTPS	–0.0909*	0.1776*	1			
MarketCap (log)	–0.0182	0.3331*	0.3614*	1		
Inflation	–0.0624	–0.0052	–0.0094	–0.1918*	1	
NDC (log)	–0.3498*	0.0422	0.0840*	0.2998*	–0.2272*	1

Table 4.

Results of the influence of Innovation input on CO_2 emission. Columns (1)-(2) contain the results of the whole sample. Columns (3)-(4) contain the results of low and high Innovation input, respectively. All variables are defined in Table 1. P-values are shown in parentheses. ***, **, and * indicate statistical significance at 1%, 5% and 10% levels, respectively.

Variables	1	2	3	4
Innovation	–1.6212***	–2.6184***	–0.7093	–2.1408**
	(–3.09)	(–5.92)	(–1.00)	(–2.42)
DCTPS		–1.5250*	–1.5729	–2.1749*
		(–1.80)	(–1.40)	(–1.75)
MarketCap (log)		0.8022***	0.9654***	0.9487***
		(3.36)	(3.15)	(2.79)
Inflation		0.3302	0.7679	–14.5671***
		(0.21)	(0.39)	(–3.27)
NDC (log)		0.1001	–0.4855	3.3936***
		(0.33)	(–1.27)	(4.16)
Constant	7.6171***	–13.3572	–3.8578	–105.0846***
	(11.69)	(–1.40)	(–0.32)	(–5.19)
Year dummies	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes
R–sq	0.048	0.184	0.217	0.542
N	725	426	294	132

Table 5.

Results of the moderating influence of political stability on the relationship between Innovation input and CO_2 emission. The dependent variable in all columns is CO_2 emission. Columns (1)-(2) contain the results of the whole sample. Columns (3)-(4) contain the results of low and high Innovation input, respectively. All variables are defined in Table 1. P-values are shown in parentheses. ***, **, and * indicate statistical significance at 1%, 5% and 10% levels, respectively.

Variables	1	2	3	4
Innovation	−0.0091	−0.6112*	0.1541	−1.7468**
	(−0.02)	(−1.65)	(0.32)	(−2.12)
Politics	0.1722	0.4298	0.0051	4.1627***
	(0.40)	(1.63)	(0.02)	(3.41)
Innovation * politics	−1.6237***	−1.2327***	−0.0070	−3.9333***
	(−3.05)	(−3.75)	(−0.02)	(−4.24)
DCTPS		−2.0838***	−2.5154***	−0.6141
		(−3.54)	(−3.52)	(−0.51)
MarketCap (log)		0.3818**	0.1432	0.4448
		(2.20)	(0.74)	(1.28)
Inflation		1.2814	0.5374	−12.1084***
		(1.15)	(0.44)	(−2.88)
NDC (log)		0.7093**	0.2274	1.9526**
		(2.55)	(0.72)	(2.37)
Constant	8.1101***	−20.6213**	−2.0970	−55.7070**
	(14.95)	(−2.55)	(−0.22)	(−2.54)
Year dummies	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes
R–sq	0.042	0.168	0.189	0.618
N	551	375	243	132

Table 6.

Results of the moderating influence of governance effectiveness on the relationship between Innovation input and CO_2 emission. The dependent variable in all columns is CO_2 emission. Columns (1)-(2) contain the results of the whole sample. Columns (3)-(4) contain the results of low and high Innovation input, respectively. All variables are defined in Table 1. P-values are shown in parentheses. ***, **, and * indicate statistical significance at 1%, 5% and 10% levels, respectively.

Variables	1	2	3	4
Innovation	1.0171*	0.7828**	0.1473	0.5201
	(1.79)	(2.07)	(0.38)	(0.48)
GovEffect	0.2197	2.0403***	0.0003	4.3393***
	(0.28)	(3.84)	(0.00)	(3.45)
Innovation * GovEffect	–2.2429***	–2.3544***	–0.5805	–3.1287***
	(–3.11)	(–5.45)	(–0.75)	(–3.70)
DCTPS		–1.6640***	–2.7176***	–0.6103
		(–2.81)	(–3.56)	(–0.49)
MarketCap (log)		0.3063*	0.1415	0.5414
		(1.86)	(0.77)	(1.53)
Inflation		1.5592	0.4116	–9.9063**
		(1.42)	(0.34)	(–2.21)
NDC (log)		0.5781**	0.2519	2.3116***
		(2.12)	(0.78)	(2.83)
Constant	7.8373***	–16.5511**	–2.4818	–70.6430***
	(14.02)	(–2.15)	(–0.26)	(–3.35)
Year dummies	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes
R–sq	0.043	0.200	0.194	0.605
N	551	375	243	132

Table 7.

Results of the moderating influence of regulatory quality on the relationship between Innovation input and CO_2 emission. The dependent variable in all columns is CO_2 emission. Columns (1)-(2) contain the results of the whole sample. Columns (3)-(4) contain the results of low and high Innovation input, respectively. All variables are defined in Table 1. p-values are shown in parentheses. ***, **, and * indicate statistical significance at 1%, 5% and 10% levels, respectively.

Variables	1	2	3	4
Innovation	1.1574**	0.7431*	0.3656	0.0421
	(2.02)	(1.94)	(0.90)	(0.05)
RegQuality	1.0395	2.5960***	0.6706	6.0447***
	(1.51)	(4.97)	(1.15)	(5.20)
Innovation * RegQuality	–2.9565***	–2.0745***	–0.8494	–3.8451***
	(–3.85)	(–4.29)	(–1.24)	(–4.31)
DCTPS		–1.8694***	–2.4664***	–1.6919
		(–3.22)	(–3.49)	(–1.46)
MarketCap (log)		0.0970	0.1064	0.0074
		(0.55)	(0.54)	(0.02)
Inflation		1.0282	0.4014	–11.1801***
		(0.93)	(0.33)	(–2.78)
NDC (log)		0.6187**	0.1986	2.3797***
		(2.26)	(0.64)	(3.07)
Constant	7.7856***	–12.6383	–0.5778	–59.1536***
	(13.52)	(–1.61)	(–0.06)	(–2.90)
Year dummies	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes
R–sq	0.046	0.196	0.196	0.646
N	551	375	243	132

Table 8.

Results of the moderating influence of rule of law on the relationship between Innovation input and CO_2 emission. The dependent variable in all columns is CO_2 emission. Columns (1)-(2) contain the results of the whole sample. Columns (3)-(4) contain the results of low and high Innovation input, respectively. All variables are defined in Table 1. p-values are shown in parentheses. ***, **, and * indicate statistical significance at 1%, 5% and 10% levels, respectively.

Variables	1	2	3	4
Innovation	0.7614	0.1616	0.1744	0.1634
	(1.45)	(0.49)	(0.45)	(0.22)
ROL	−0.4461	1.4936***	0.1397	3.0136**
	(−0.65)	(3.25)	(0.27)	(2.18)
Innovation * ROL	−2.5908***	−2.5180***	0.0423	−4.5882***
	(−4.28)	(−7.05)	(0.07)	(−5.94)
DCTPS		−1.9786***	−2.5469***	−0.1295
		(−3.45)	(−3.52)	(−0.13)
MarketCap (log)		0.2895*	0.1344	0.5636*
		(1.76)	(0.71)	(1.72)
Inflation		1.4555	0.6175	−4.1465
		(1.37)	(0.50)	(−1.13)
NDC (log)		0.6464**	0.2282	1.5862**
		(2.48)	(0.73)	(2.33)
Constant	8.0695***	−17.1719**	−1.9283	−51.1110***
	(15.43)	(−2.32)	(−0.21)	(−2.72)
Year dummies	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes
R–sq	0.083	0.248	0.189	0.735
N	551	375	243	132

Table 9.

Results of the moderating influence of control of corruption on the relationship between Innovation input and CO_2 emission. The dependent variable in all columns is CO_2 emission. Columns (1)-(2) contain the results of the whole sample. Columns (3)-(4) contain the results of low and high Innovation input, respectively. All variables are defined in Table 1. p-values are shown in parentheses. ***, **, and * indicate statistical significance at 1%, 5% and 10% levels, respectively.

Variables	1	2	3	4
Innovation	0.2468	0.0706	0.2133	0.5823
	(0.48)	(0.21)	(0.54)	(0.61)
COC	–1.4361**	1.0169**	–0.6918	2.6753**
	(–2.35)	(2.21)	(–1.27)	(2.53)
Innovation * COC	–2.6186***	–1.9665***	–0.0213	–3.4969***
	(–4.23)	(–5.79)	(–0.04)	(–5.61)
DCTPS		–1.9155***	–2.6417***	–0.4183
		(–3.37)	(–3.71)	(–0.36)
MarketCap (log)		0.3612**	0.2000	0.5455*
		(2.13)	(1.06)	(1.67)
Inflation		1.2862	0.0958	–6.1146
		(1.15)	(0.08)	(–1.48)
NDC (log)		0.7070***	0.2049	2.3971***
		(2.65)	(0.66)	(3.29)
Constant	8.3745***	–20.4297***	–2.6768	–72.5408***
	(16.40)	(–2.71)	(–0.29)	(–3.90)
Year dummies	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes
R–sq	0.126	0.212	0.197	0.664
N	551	375	243	132

Table 10.

Results of the moderating influence of the index from political stability, governance effectiveness, regulatory quality, rule of law and control of corruption, using the principal component analysis (PCA), on the relationship between Innovation input and CO_2 emission. The dependent variable in all columns is CO_2 emission. Columns (1)-(2) contain the results of the whole sample. Columns (3)-(4) contain the results of low and high Innovation input, respectively. All variables are defined in Table 1. P-values are shown in parentheses. ***, **, and * indicate statistical significance at 1%, 5% and 10% levels, respectively.

Variables	1	2	3	4
Innovation	0.1019	–0.1945	0.0610	–0.6567
	(0.19)	(–0.58)	(0.14)	(–0.80)
Index	–0.4177*	0.5914***	–0.0063	1.2340***
	(–1.66)	(3.29)	(–0.03)	(2.74)
Innovation * Index	–0.8670***	–0.7850***	–0.0909	–1.0628***
	(–4.23)	(–6.71)	(–0.43)	(–5.50)
DCTPS		–1.8936***	–2.5603***	–0.7194
		(–3.37)	(–3.61)	(–0.64)
MarketCap (log)		0.2427	0.1550	0.3863
		(1.39)	(0.79)	(1.05)
Inflation		1.5053	0.4338	–7.5595*
		(1.39)	(0.36)	(–1.83)
NDC (log)		0.6039**	0.2342	2.1750***
		(2.28)	(0.74)	(2.91)
Constant	8.1340***	–14.7014*	–2.4655	–61.5988***
	(15.62)	(–1.90)	(–0.26)	(–3.13)
Year dummies	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes
R-sq	0.089	0.234	0.190	0.657
N	551	375	243	132

Appendix 1

List of countries
Argentina
Brazil
Chile
China
Colombia
Czech Republic
Egypt, Arab Rep.
Greece
Hong Kong SAR, China
Hungary
India
Indonesia
Jordan
Kuwait
Malaysia
Mexico
Morocco
Peru
Philippines
Poland
Qatar
Russian Federation
Saudi Arabia
Singapore
South Africa
Thailand
Turkey
United Arab Emirates
Vietnam

Appendix 2.

Countries governance index

Factor	Component loading
Political stability	0.4026
Government effectiveness	0.4591
Regulatory quality	0.4479
Rule of law	0.4603
Control of corruption	0.4632