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

**Abstract**

This study sheds light on the extent to which innovation input influences CO2 emissions, and how country-level governance factors may moderate this relationship. The sample for the study consists of CO2 emissions per capita from 29 emerging countries and 725 country-year observations. We find a negative relationship between innovation input and CO2 emissions, suggesting that countries that invest in innovation combat climate change by reducing CO2 emissions. By separating the sample into low and high innovative countries, the results show that the reduction of CO2 emission 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 CO2 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, CO2 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]](#footnote-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 evidence suggests that for every one-degree centigrade increase in temperature, a poor 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).

Indeed there is growing evidence that governments across the globe are now positioning themselves to respond to various stakeholder pressures to prioritise investments into low–carbon and climate-resilient infrastructure in their innovation missions (Cimato and Mullan, 2010; Darnall and Carmin, 2005; Moratis, 2018). Countries around the world have been developing their innovative capabilities through higher expenditure on research and development (R&D) (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 the increasing greenhouse gas emissions globally. The fundamental assumptions driving this shift in policy is embedded in stakeholder and signalling theory, 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.

It is evident that cutting-edge innovative technologies will continue to be popular in the fast-paced global marketplace of the 21st century. The bottom line, therefore, appears to be that investments in these technologies are also a way forward in addressing environmental challenges that climate change induces (Diaz Garcia, 2015; Lin and Zhu, 2019; Abdelzaher et al., 2020). An important argument by Lin and Zhu (2019) suggests that the adoption of cutting-edge innovative technologies can mitigate climate change by conserving energy and reducing emissions.

Several studies have also 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). The quality of governance is likely to influence countries’ innovative policies towards contributing to sustainable environments. The quality of governance is measured in terms of the capacity of government to formulate appropriate policies, respect citizens and monitor the state of the institutions (Kaufmann, Kraay and Mastruzzi, 2003; and 2007). These may be extremely valuable for the innovation input and climate change relationship. Specifically, countries with good quality of governance may be able to pursue, formulate and invest in cutting-edge innovative technologies aimed at curbing environmental damage (see Gani, 2012).

Despite the potential value of research conversations relating to innovation, governance and climate change, not much progress has been achieved, leading to key knowledge voids within this research area. In fact, researchers seem to pay more attention to determinants (Tauringana and Chithambo, 2015) and impacts (Depoers et.al 2016, Chithambo et al., 2020) of climate change and GHG emissions, which while useful, seem to have been at the expense of questioning how investments in cutting edge innovative technologies impacts on the environment. Less is also known about how quality of governance may likely influence countries’ investment in innovative technologies towards curbing environmental damage. Quite importantly, existing studies have mostly focused on developed or highly industrialised economies, perhaps, based on the understanding that such economies are more likely to engage in activities that impact on the environment. This focus has undoubtedly placed emerging economies at a disadvantage, as there is as yet, very little known on the relationships that exist between their 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 to further illuminate the effect of investment in cutting edge innovative technologies on climate change. Second, it documents the effect of governance on the relationship between innovation input and climate change. Unlike Gani (2012), who investigated the relationship between good governance and CO2 emissions, our study focuses on the joint effect of governance, 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 their value creation operations (Freeman et al., 2010). The prime ethos of the stakeholder theory is for stakeholders to cooperate for mutual benefits (Savage et al., 2010, Freeman et al., 2010). This understanding of stakeholder theory provides a firm basis to interrogate the climate change challenge as it is a phenomenon that requires collective efforts of all stakeholders (Sprengel and Busch, 2011, Hoffman 2005; Okereke 2007, Talbot and Boiral, 2015), including governments, international institutions and agencies, the business industry, non-governmental organisations and the general public at large.

 Indeed, Freeman et al. (2020, pp. 217) suggest that the point of departure between the shareholder and stakeholder debate is not so much about the dichotomy between them, but ‘a narrow/reductionist versus broad/holistic perspective on businesses’. The dual themes of collaboration and proactivity have been highlighted alongside suggestions that primary and secondary stakeholders exert different degrees of pressure (Goodman et al., 2017). Whereas Donaldson and Preston (1995) articulate the differences in scope and types of stakeholders captured by the traditional versus contemporary stakeholder models, Jones et al., (2018) underscores the triad interrelated descriptive, normative and instrumental values of the 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 organizations (NGOs), investors, employees, financial institutions the media, local authority, national governments, regional bodies among others (Cadez et al., 2019).

 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 product production (Cadez et al., 2019 and Czerny and Letmathe, 2017). It is commonly agreed among stakeholder theorists that, by virtue of the power vested in the regulatory stakeholders to exact sanctions, they are more influential than market–actor stakeholders (Okereke and Russel, 2010).

* 1. ***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.

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, pp. 63). Within the context of environmental management literature, signalling theory has been applied to the ISO 26000 standards. For instance, Moratis (2018) in his study, 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 major signalling agenda on the global stage is the Paris Agreement. However, a comprehensive review on the 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 an infrastructure, signal and a direction for ramping up climate action and political commitments to decarbonisation’ (Calmfors and Hassler, 2019, pp. 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, pp. 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, require 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; Okereke 2007, Talbot and Boiral, 2015).

 Of special 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 relevant to this study is the usefulness of signalling theory in resolving information asymmetry among parties. 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 largely deterministic approach has been taken, innovative technologies have been used to adapt to the environmental challenges that climate change induces. For instance, based on empirical findings from the African Sahel regions, [Elawad & Hall (2002](https://www.sciencedirect.com/science/article/pii/S0143622811001834%22%20%5Cl%20%22bib13)), 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 agroecological innovative 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 helped 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.

 However, 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 CO2 emissions. In a similar study, Li and Wang (2017), used a new combined approach (the effects of technological innovation during production processes on both CO2 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 CO2 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 due to the fact that 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 consequential 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.

**2.4 Governance, Innovation input and Climate change**

For some time now, governments of highly industrialised and technologically advanced nations have been keen to intervene and contribute to efforts that reduce carbon emissions. In line with this, a core and fruitful mandate that researchers have found relevant for public policy makers 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 emissions cap could directly encourage organisations’ quest for innovations that improve alternative energies, and reduce the rate at which they rely on fossil fuels. Zhang 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 government played an important 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 policies, depending on their nature and dynamic efficiency, can differ in the ways they induce eco-innovations. Most 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).

 In other studies, there have been concerns that efforts in promoting eco-innovations 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](https://www.sciencedirect.com/science/article/pii/S0040162516302542%22%20%5Cl%20%22bb0130)). In this sense, 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). Here, 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 impact general investments made in economic sectors by governments, has in encouraging these sectors development and reliance on eco-technologies. Su and Moaniba’s (2017) results, which they 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 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.

 These studies suggest that, there are at least, some links 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 whether these purported relationships exist similarly in emerging countries, where governments are already preoccupied with other competing demands. In addition, it is still not clear the nature of government involvement 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 CO2 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](https://www.thebalance.com/msci-index-what-is-it-and-what-does-it-measure-3305948)). 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 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 CO2 emission of metric tons per capita. This is appropriate for our study because CO2 measures the influence of both natural and human activities on the environment (Le et al., 2020). Several studies have similarly used CO2 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 CO2 emission, we controlled for certain country level characteristics including domestic credit to private sector (DCTPS), market capitalisation (MarketCap), inflation and net domestic credit (NDC). The DCTPS is measured as the domestic credit to private sector (% of GDP). Studies including that of Lee et al. (2019) have shown that financial sector development may increase CO2 emissions. This is because improved access to financial services aids and boosts manufacturing and industrial activities, which may lead to higher levels of CO2 emissions. MarketCap is measured as market capitalization 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 CO2 emission because it increases output and consumption (Daniel and Steege, 2020). NDC is the sum of net claims on the central government and on other sectors of the domestic economy. Increased government spending may increase CO2 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 CO2 emission.

## 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 CO2 emission, the following regression equation was estimated:

$CO2\_{it}=β\_{0}+β\_{1}R\&D\_{it-1}+ β\_{2}DCTPS\_{it-1}+β\_{3}MarketCap\_{it-1}+ β\_{4}Inflation\_{it-1}+β\_{5}NDC\_{it-1}+Year effects+Country effects+ε\_{it}$ (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:

$CO2\_{it}=β\_{0}+β\_{1}R\&D\_{it}+β\_{2}Governance\_{it}+ β\_{3}R\&D\*Governance\_{it}+ β\_{4}DCTPS\_{it}+β\_{5}MarketCap\_{it}+ β\_{6}Inflation\_{it}+β\_{7}NDC\_{it}+Year effects+Country effects+ε\_{it}$ (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 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 the 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) CO2 emission into the atmosphere with a median and standard deviation of 4.2224 (metric tons per capita) and 10.7892 (metric tons per capita) CO2 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 percent with standard deviation and median values of 32.49 and 69.90 percent 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 is 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 CO2 ($β$ = –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 level of innovation of countries. 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]](#footnote-2). In comparison to columns (1 & 2), the results shown in column (4) indicate that high 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 CO2 emissions in all columns, indicating that highly capitalised markets produce high CO2 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 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 CO2 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 5% 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. Consistent with our previous estimates, we find the evidence to be more pronounced among countries with high investments in innovation. The evidence presented in column (4) of Table 6 suggests that good governance contributes to a 31.287% reduction in climate change problems with a 10% investment in innovative technologies.

**[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 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. Consistently, we find the evidence to be much stronger in column (4).

**[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, CO2 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 in column (4).

**[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 favor certain groups. Control of corruption plays an important 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 very important role in countries’ effort towards curbing climate change problems through investment in innovative technologies. The evidence suggests that through control of corruption, highly innovative countries can reduce climate change problems by 34.969% by investing in innovative technologies.

**[INSERT TABLE 9]**

**5.** **Discussions**

This paper has attempted to address some of the gaps in our understanding of links between innovation and the environment by investigating how innovation input affects CO2 emissions. The focus is on 29 emerging countries around the world for the period from 1990-2018. The following core findings have been established. We found that innovation input negatively influences CO2 emission. Given the overwhelming evidence of a negative relationship between innovation input and CO2 emissions, an extended analysis was performed by including certain important country-level governance mechanisms to further expand on the role of innovation input on CO2 emissions. The results show that political stability, government effectiveness, regulatory quality, rule of law and control of corruption all negatively moderate the innovation input and CO2 relationship.

 First, the evidence that an increase in innovation input helps curtail CO2 emission is congruent with many established studies that suggest investment in innovation input reduces climate change (Chen et al., 2018; Lin and Zhu, 2019; Abdelzaher et al., 2020). Although high-level innovation input leads to higher economic production and outputs (Gumus and Celikay, 2015), our results suggest innovation input not only increases productivity but also reduces CO2 emissions. Many studies have suggested that cutting-edge innovations while leading to high productivity, should also be relevant for reducing CO2 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 CO2 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 CO2 emissions. Another group that has caused countries to produce more efficiently and less CO2 emission is pressure group (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 productivity which emit less CO2 into the atmosphere (Chuang and Qianfei, 2013; Chithambo et al., 2020).

 Second, our results show that the negative effect of innovation input on CO2 emission is more pronounced in 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 CO2 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 CO2 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 aims to add to the limited body of research on this topic by examining the relationship between innovation input, governance and climate change in emerging economies. Of special interest to our study was how the quality of governance is likely to influence countries' investment in innovative technologies towards curbing environmental damage. 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, 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 high innovative emerging economies reduce climate change problems by approximately 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 impact 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 CO2 emission; show that a reduction of CO2 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 CO2 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. Beyond policy, the findings also have indirect implications for macro-environmental factors, such as political stability, general government institutional effectiveness, quality of regulation 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.

Like all research, this study is not without limitations. Firstly, this study is limited by its focus on emerging countries and hence findings may not be applicable to other economies. 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 important research area.

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**Table 1. Description of variables and data source.**

|  |  |  |
| --- | --- | --- |
| Description | Abbreviation  | Source |
| CO2 emission | CO2 | <https://info.worldbank.org/governance/wgi/> |
| Research and development expenditure (% of GDP) | Innovation input | <https://info.worldbank.org/governance/wgi/> |
| Market capitalization 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 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/> |

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| **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** |
| CO2 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 |

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| **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** |
| CO2 | 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 |

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| **Table 4.** Results of the influence of Innovation input on CO2 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 |
|  |  |  |  |  |

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| **Table 5.** |
| Results of the moderating influence of political stability on the relationship between Innovation input and CO2 emission. The dependent variable in all columns is CO2 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 |

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| **Table 6.** |
| Results of the moderating influence of governance effectiveness on the relationship between Innovation input and CO2 emission. The dependent variable in all columns is CO2 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 |

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| **Table 7.** |
| Results of the moderating influence of regulatory quality on the relationship between Innovation input and CO2 emission. The dependent variable in all columns is CO2 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 |
|  |  |  |  |  |

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| **Table 8.** |
| Results of the moderating influence of rule of law on the relationship between Innovation input and CO2 emission. The dependent variable in all columns is CO2 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 |
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| **Table 9.** |
| Results of the moderating influence of control of corruption on the relationship between Innovation input and CO2 emission. The dependent variable in all columns is CO2 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 |

**Appendix 1**

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| **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 |
|  |
|  |

1. http://news.mit.edu/2012/the-economic-cost-of-increased-temperatures-0807 [↑](#footnote-ref-1)
2. The results from using the median innovation input to categorise countries into high and low innovation input produce qualitative similar results. [↑](#footnote-ref-2)