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Working Paper

Governance, vulnerability to climate change, and green growth: International evidence

ADB Economics Working Paper Series, No. 500

Provided in Cooperation with:

Asian Development Bank (ADB), Manila

Suggested Citation: Le, Thai-ha; Chang, Youngho; Park, Donghyun (2016) : Governance, vulnerability to climate change, and green growth: International evidence, ADB Economics Working Paper Series, No. 500, Asian Development Bank (ADB), Manila

This Version is available at:

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GOVERNANCE, VULNERABILITY TO CLIMATE CHANGE, AND GREEN GROWTH: INTERNATIONAL EVIDENCE

Thai-Ha Le, Youngho Chang, and Donghyun Park

NO. 500

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November 2016

**ADB ECONOMICS
WORKING PAPER SERIES**

ADB Economics Working Paper Series

Governance, Vulnerability to Climate Change, and Green Growth: International Evidence

Thai-Ha Le, Youngho Chang,
and Donghyun Park

No. 500 | November 2016

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Printed in the Philippines.

ISSN 2313-6537 (Print), 2313-6545 (e-ISSN)
Publication Stock No. WPS168507-2

Cataloging-In-Publication Data

Asian Development Bank.
Governance, vulnerability to climate change, and green growth: International evidence.
Mandaluyong City, Philippines: Asian Development Bank, 2016.

1. Air quality. 2. Governance. 3. Green growth. 4. PM2.5 5. Vulnerability to climate change.
I. Asian Development Bank.

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ABSTRACT

We examine the role of governance and vulnerability to climate change in green growth using a global panel data set of 122 countries in 2000–2012. We find that, as expected, governance has a positive effect on environmental performance and vulnerability to climate change has a negative effect. This suggests that promoting good governance and reducing climate change vulnerability can contribute to a cleaner environment. We find qualitatively similar results for the subsample of high-income countries, but governance does not have a significant effect for the subsamples of upper-middle-income, lower-middle-income, and low-income countries. One possible interpretation is that high-income countries have environmental policies which are strong enough to protect the environment, whereas other countries have relatively weak environmental policies which need to be strengthened.

Keywords: air quality, governance, green growth, PM2.5, vulnerability to climate change

JEL code: Q56

I. INTRODUCTION

At initial stages of industrialization, countries prioritize economic growth and job creation rather than cleaning up air and water pollution. Furthermore, poor countries often do not have adequate resources for tackling environmental degradation and are saddled with relatively weak environmental regulations. Consequently, the pollution level of poor countries deteriorates rapidly as they industrialize. However, as a country grows richer, its citizens tend to value the environment more highly, and thus demand stronger regulatory institutions. As a result, it is possible that leading industrial sectors become cleaner and pollution peaks as a country reaches a certain threshold income level and then falls toward preindustrial levels as income rises even further (Dasgupta et al. 2005).

The scenario outlined above suggests that policy makers in many developing countries are explicitly or implicitly pursuing a policy of “grow first, clean up later.” The same scenario does not bode well for the environmental prospects of developing countries. Since it could take a long time for many low- to middle-income countries to reach the threshold income level at which their citizens begin to vocally demand a cleaner environment, they may have to suffer worsening pollution and environmental degradation for many decades. The so-called inverted U-shape relationship between income level and pollution level is known as the Environmental Kuznets Curve (EKC) but it has been challenged by many economists. In particular, several studies on the EKC do not support the existence of a simple, straightforward relationship between pollution and per capita income due to the presence of other structural factors. In this context, we go beyond the EKC by incorporating two structural factors, namely, governance and vulnerability to climate change.

Our results confirm that the simple link between income and environment suggested by the conventional EKC is misspecified. In particular, we find that governance has a significant effect on environmental quality for the full sample of countries. The other factor we incorporate is vulnerability to climate change, which is not due to climate alone but instead reflects a diverse constellation of underlying factors. These include the sociopolitical environment, economic structure, and institutional and political characteristics (Diaz and Ortega 2011). Environmental outcomes can be significantly affected by these factors. Using advanced econometric techniques and newly available data, we aim to contribute to the existing literature on the environment and sustainable growth by incorporating these two important variables into a more complete model of environmental change.

Air pollution has been a serious problem across the world. The cost for countries is enormous. Air pollution affects economies and quality of life, and it causes major chronic diseases and even death. The health impact of air pollution is much larger than the estimates of only a few years ago. Every year, 3 million people around the world die due to outdoor pollution. The World Health Organisation (WHO) estimates that in 2012 around 7 million premature deaths resulted from air pollution, more than double previous estimates. Of the 7 million, air pollution claimed 3.7 million lives and indoor air pollution caused 4.3 million lives. Based on the WHO Global Urban Ambient Air Pollution Database as of May 2016, which covers 3,000 cities in 103 countries, more than 80% of people living in urban areas are breathing air laden with pollutants far above WHO limits. The reality is even more disturbing since many countries have random monitoring systems or none at all (Gulf News Editorial 2016). As such, environmental issues in general and air pollution in particular are of interest not only to researchers but also policy makers around the world. Since the world economy is highly diverse and consists of countries at different stages of economic development, we analyze and compare countries grouped by income level.

The remainder of this paper is organised as follows. Section II reviews the literature on the economy–environment nexus, especially studies on emissions pollutants. Section III presents our empirical model, data, and methodology. Specifically, we introduce governance and vulnerability to climate change as new explanatory variables, and explain how we incorporate them into the empirical analysis. Section IV reports and discusses our main findings. Section V concludes the paper.

II. LITERATURE REVIEW

The link between income and environmental quality has been extensively studied. The evidence indicates that not all pollutants follow the inverted U-shape curve pattern suggested by the EKC hypothesis (Lipford and Yandle 2010). The main reason for this is that the EKC misspecifies the relationship between growth and the environment. A key source of misspecification is the omission of governance or institutional quality when estimating the relationship. Wood and Herzog (2014) assert that economic freedom, one measure of the quality of economic institutions, plays a particularly important role in the linkage between economic development and environmental quality. Failure to incorporate this factor in economic models of pollution can thus lead to spurious results.

Regarding the effects of governance and institutional quality on the environment, Carlsson and Lundström (2001) present four simplified hypotheses, including (i) government size effect, (ii) efficiency effect, (iii) trade regulation effect, and (iv) stability effect. First, the government size effect hypothesizes a hump-shaped relationship between government size and emissions. Specifically, when the government is small, much of government expenditures are typically allocated to basic infrastructure such as roads and power plants. As government size increases, however, expenditures will include redistributive transfers to mitigate income inequality. Lower inequality has a positive effect on the demand for cleaner environment (see, for example, Magnani 2000). If the environment is a luxury public good, it will be demanded only when the demand for other public goods has been satisfied—i.e., at large levels of government size.

The efficiency effect arises under the assumption that economic freedom leads to efficient and competitive markets. The correlation between economic freedom and environmental quality is expected to be positive. First, an efficient use of resources could result from, for example, externality-correcting taxes which reduce emissions per unit of environmental resources. Second, efficient and competitive markets can better satisfy government regulations and consumer preferences. Competitive pressures will force firms to adapt to changes in the market environment in order to survive. Clearly, these two effects are only relevant in the presence of environmental regulations or strong consumer demand for cleaner environment (Carlsson and Lundström 2001).

The trade regulation effect relates to restrictions and taxes on trade. Trade liberalization could have both positive and negative effects on the environment. On one hand, trade liberalization can improve resource allocation of resources, including environmental resources. Freer trade leads to cross-border diffusion of new clean technologies that reduce pollution. On the other hand, the scale effect, proposed by Antweiler, Brian, and Scott (2001), refers to how freer trade increases output, which in turn increases pollution. More trade also changes the composition of industry, which can have either a positive or negative effect on pollution, depending on factor endowments. Antweiler, Brian, and Scott (2001) showed that freer trade can lead to an overall cleaner environment for some pollutants. However, pollution can increase in some locations due to technology diffusion and a change in industrial composition.

Finally, the stability effect implies a lower inflation rate and clearer pricing signals resulting in more efficient investment and consumption decisions. A stable macroeconomic environment encourages longer investment horizons and thus environmental investments. Another important part of the stability effect is secure property rights and enforceable contracts (see, for example, Panayotou 1997). More secure property rights facilitate long-term investments. For example, farmers with more secure title to their land are more likely to invest in soil conservation and sustainable cultivation techniques. However, stability will also promote investment and consumption in general, which can harm the environment.

There have been a number of cross-country studies that relate environmental quality to governance or institutional quality (see, for instance, Panayotou 1997; López 1997; Barrett and Graddy 2000; Bhattarai and Hammig 2001; Antweiler, Brian, and Scott 2001; Carlsson and Lundström 2001; Stroup 2003; Bernauer and Koubi 2009; Leitaó 2010; Wood and Herzog 2014). Specifically, for property rights and quality of institutions, Panayotou (1997) initiated the interest in institutions and found that faster economic growth and higher population density increase moderately the environmental price of economic growth, but better policies can offset these effects and make economic growth more environmentally friendly and sustainable. Bhattarai and Hammig (2001) also highlight the positive effects of an improvement in political institutions and governance for forest preservation while measuring institutional quality with indices of political rights and civil liberty. For trade restrictions, López (1997) found that trade liberalization induced a faster rate of deforestation in Ghana. Antweiler, Brian, and Scott (2001) argued that the effects of trade on the environment can be broken down into scale, technique, composition, and growth effects.

Leitaó (2010) and Bernauer and Koubi (2009) highlighted the role of political institutions in improving environmental quality. Bernauer and Koubi (2009) test the effects of political institutions on air quality in 42 countries over the period 1971–1996 and find interesting results. First, democracy has a positive effect on air quality. Second, presidential systems favor environmental protection than parliamentary systems. Third, they show that labor union strength reduces the environment protection whereas the green parties improve it. Barrett and Graddy (2000), Carlsson and Lundström (2001), Stroup (2003), and Wood and Herzog (2014) find evidence that economic freedom has a favorable environmental impact. Wood and Herzog (2014) examine a multicountry data set for over 100 countries spanning a period from 2000 to 2010 to identify the relationship between economic freedom and two environmental indicators (concentrations of fine particulate matter and carbon dioxide emissions). While their results do not indicate an effect of economic freedom on carbon dioxide emissions, there is evidence that economic freedom is indeed important for reducing local environmental problems.

While these studies acknowledge that political institutions, corruption, or social structure are instrumental in accurately measuring the relationship between economic activity and environmental quality, they do not fully account for those factors in their analysis (see, for example, Panayotou 1997; Barrett and Grady 2000; Bhattarai and Hammig 2001; Bernauer and Koubi 2009; Leitaó 2010; Lin and Liscow 2013). As such, our study contributes to the literature by more explicitly incorporating governance into the empirical analysis.

Relative to the governance–environment literature, there are far fewer studies on the link between vulnerability to climate change and environmental quality. The Intergovernmental Panel on Climate Change defines vulnerability as “the extent to which climate change may damage or harm a system” (Watson, Zinyowera, and Moss 1996). Vulnerability to climate change is not due solely to climate but is determined by multiple factors such as the sociopolitical environment and the economic

structure (Diaz and Ortega 2011). This suggests that the relationship between vulnerability and the environment may not be straightforward. For example, poor tropical countries may be highly vulnerable to rising sea levels but their underdevelopment and relatively small consumption may limit their damage on the environment.

The literature offers alternative definitions of vulnerability. Timmerman (1981) defines it as the degree to which a system reacts adversely to the occurrence of an event. Liverman (1990) defines vulnerability on the basis of socioeconomic, political, and geographical conditions. The Intergovernmental Panel on Climate Change (2014) defines it as “a system’s capacity to absorb and recover from the occurrence of a hazardous event.” In general, vulnerability depends on the sensitivity of the different elements composing a system and the connectivity between the elements. The complex nature of vulnerability rules out a simple, straightforward relationship between vulnerability and the environment.

Overall, the literature has not identified a straightforward relationship between governance, vulnerability to climate change, and environmental quality. This could be attributable to several factors. First, empirical studies have not controlled for more structural factors in modeling the relationship. Second, the empirical methods employed in the estimation have often failed to account for statistical problems in data such as cross-sectional dependence, heteroskedasticity, and serial correlation. Third, the level of a country’s income and economic development is ignored.

In this study, we aim to fill the three gaps in the literature outlined above. Specifically, (i) we build up a baseline model which includes more relevant variables that may affect environmental performance; (ii) we employ an advanced empirical methodology that controls for a number of problems in estimating panel data; and (iii) besides estimating the global sample, we break the sample down into three subsamples of countries at different income levels to examine how the environmental effects of governance and vulnerability vary according to income.

III. EMPIRICAL FRAMEWORK

In this section, we present the data and methodology used for our empirical analysis.

A. Data and Model

In this section, we describe the model, data, and methodology we use for our empirical analysis. The aforementioned literature suggests there is a relationship between environmental quality and various variables such as income, governance structure, and institutional quality. The baseline model of our empirical analysis is constructed as follows:

$$ENV_{it} = \alpha_{it} + \beta_{1i}GOV_{it} + \beta_{2i}VUL_{it} + \beta_{3i}Y_{it} + \beta_{4i}ENE_{it} + \varepsilon_{it} \quad (1)$$

where $i = 1, 2, 3, \dots, N$ for each country in the panel and $t = 1, 2, 3, \dots, T$ refers to the time period. ENV_{it} is the indicator of environmental quality, proxied by pollutant emissions, GOV_{it} is the indicator of governance, VUL_{it} is the indicator of vulnerability to climate change, Y_{it} is per capita real gross domestic product (GDP) in constant 2005 United States (US) dollars, ENE_{it} is the primary energy consumption per capita, and ε_{it} is the error term. The novelty of this structure is to explicitly consider the possible impact of the level of energy consumption on the relationship between governance, vulnerability to climate change, and air quality. The primary energy usage per capita is added to the regressions since a large share of pollutant emissions come from the energy sector. Hence, this control

variable reflects potential pollutant emissions loading. All variables are converted into natural logarithms to obtain the growth rate of the relevant variables by their differenced logarithms.

The coefficients $\beta_1, \beta_2, \beta_3, \beta_4$ correspond to the elasticities of environmental quality indicator with respect to governance, vulnerability to climate change, real GDP per capita, and primary energy use per capita, respectively. The sign and statistical significance of β_1 and β_2 is of main interest for our study. In theory, as presented in the literature review section, the environmental effects of governance and vulnerability are uncertain.

We choose the Index of Economic Freedom as a proxy for the governance. The index is provided by the Heritage Foundation (2016) and available for the years 1995 to 2012. Data availability differs for each country. The index measures economic freedom of 186 countries based on trade freedom, business freedom, investment freedom, and property rights. The index ranges from 0 to 100 and the higher score, the freer. We believe that this Index of Economic Freedom captures, to a significant degree, the four theoretical effects of governance on the environment: (i) government size effect, (ii) efficiency effect, (iii) trade regulation effect, and, (iv) stability effect. For robustness check, in addition to the Index of Economic Freedom, we use the index for Government Effectiveness, for which higher values indicate higher levels of effectiveness. The Government Effectiveness index is obtained from the World Bank's (2016) Worldwide Governance Indicators. This index captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies.

We acknowledge that a better proxy for governance factor would be variables related to pollution regulations, a proxy for which is the World Bank's Country Policy and Institutional Assessment (CPIA) indicators on the environment. However, this data series is only available from 2005 to 2014. Given that our data on air quality is only available until 2012, the investigation period from 2005 to 2012 is insufficient to conduct any meaningful empirical analysis. Alternatively, one might think about including dummy variables or indices which could represent the degrees to which regulations seek to control fine particulate matter (PM) emissions, such as vehicular emissions standards (e.g., Euro 2 or Euro 4), technological standards for coal power plants (e.g., whether flue desulphurisation is required), national air quality standards, and so forth. Unfortunately, all of these possible data series are inadequate, in terms of both time series and cross-section of countries.

For vulnerability to climate change, we employ the Vulnerability index from the University of Notre Dame Global Adaptation Index (ND-GAIN 2016). The vulnerability score "measures a country's exposure, sensitivity and capacity to adapt to the negative effects of climate change" (ND-GAIN 2016). ND-GAIN measures overall vulnerability by considering six life-supporting sectors: food, water, health, ecosystem service, human habitat, and infrastructure. A higher score indicates greater vulnerability. For robustness check, we use another proxy, namely the Sensitivity score from ND-GAIN. This score "measures the extent to which a country is dependent upon a sector negatively affected by climate hazard, or the proportion of the population particularly susceptible to a climate change hazard" (ND-GAIN 2016). A country's sensitivity can fluctuate over time.

For an environmental quality indicator, the population weighted exposure to particles smaller than 2.5 microns in diameter, known as PM_{2.5}, is obtained from Yale Center for Environmental and Policy (2016). Apart from data availability for a relatively large number of countries, we chose PM_{2.5} in our study since the fine particulate matter (PM_{2.5}) problem has attracted a lot of scientific and public attention, due to its effects on visibility, human health, and global climate. According to the Yale

Center for Environmental and Policy, PM2.5 is generally the product of combustion, whether manmade like car emissions and coal burning, or natural like forest fires and volcanic activity. PM2.5 is recognized as “a major global killer” by the WHO (WHO nd). PM2.5 is fine enough to lodge deep into human lung and blood tissue. Exposed populations are at risk of heart and lung diseases, ranging from stroke to lung cancer, which might cause death in severe cases. Specifically, for vulnerable lungs, high concentrations of PM2.5 can be a virulent killer. Furthermore, a leading cause of child mortality worldwide is pneumonia, and fine particulates including PM2.5 are a major global contributor to the incidence of pneumonia (WHO 2016). Despite its well-known health impact, many countries do not monitor PM2.5, due to lack of capacity, resources, technology, or public demand.

Particulate matter is believed to be carcinogenic (IARC 2013). Reducing emissions of PM2.5 not only has an immediate effect on air quality, but also mitigates near-term climate change and helps promote food security. Improving air quality has the potential to provide enormous economic benefits. In the United States, the direct economic benefits of reducing PM2.5 and ground-level ozone pollution under the 1990 Clean Air Act Amendments are estimated to be up to 90 times the cost of implementing them. About 85% of the economic benefits would be due to fewer premature deaths linked to reducing PM2.5 in the outdoor environment, with 230,000 premature deaths avoided in 2020 alone (UNEP 2014).

Data for per capita real GDP (constant 2005 US dollars) and per capita primary energy use are extracted from the World Development Indicators. All the data used in this study are pooled annual time series. Our country sample includes 122 countries and our sample period spans from 2000 to 2012. Data availability was the main criterion for both country sample and time period. The countries are at various stages of economic development. As such, in addition to the full sample, we divide the countries into three subsamples according to the World Bank’s income classification. Specifically, one subsample comprises high-income countries, another subsample comprises upper-middle-income countries, and a third subsample comprises lower-middle-income and low-income countries.¹ Table 1 summarizes the list of countries in the sample.

Table 1: List of Countries in the Study Sample

Income Groups	Country List (122 in total)
High-income countries (49 countries)	Argentina, Australia, Austria, Bahrain, Belgium, Canada, Chile, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Republic of Korea, Kuwait, Latvia, Lithuania, Luxembourg, Malta, The Netherlands, New Zealand, Norway, Oman, Poland, Portugal, Qatar, Russian Federation, Saudi Arabia, Singapore, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Trinidad and Tobago, United Arab Emirates, United Kingdom, United States, Uruguay, Venezuela
Upper-middle-income countries (35 countries)	Albania, Algeria, Azerbaijan, Belarus, Bosnia and Herzegovina, Botswana, Brazil, Bulgaria, People’s Republic of China, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, Gabon, Iran, Jamaica, Jordan, Kazakhstan, Lebanon, Libya, Malaysia, Mauritius, Mexico, Mongolia, Namibia, Panama, Paraguay, Peru, Romania, South Africa, Thailand, Tunisia, Turkey, Turkmenistan
Lower-middle and low-income countries (38 countries)	Armenia, Bangladesh, Benin, Bolivia, Cambodia, Cameroon, Egypt, El Salvador, Ethiopia, Georgia, Ghana, Guatemala, Haiti, Honduras, India, Indonesia, Kenya, Kyrgyz Republic, Moldova, Morocco, Mozambique, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Philippines, Senegal, Sri Lanka, Tajikistan, Tanzania, Togo, Ukraine, Uzbekistan, Viet Nam, Yemen, Zambia, Zimbabwe

Source: World Bank’s income classification. The groups are: low income, \$1,045 or less; lower middle income, \$1,046–4,125; upper middle income, \$4,126–12,735; and high income, \$12,736 or more.

¹ According to the World Bank, the groups are: low income, \$1,035 or less; lower middle income, \$1,036–\$4,085; upper middle income, \$4,086–\$12,615; and high income, \$12,616 or more.

Table 2 provides the means of the raw data of the variables. On average high-income countries perform better than upper-middle-income countries, and both groups perform better than lower-middle and low-income countries in terms of most indicators. The only exception is the population weighted exposure to PM2.5, for which high-income countries perform best, followed by lower-middle and low-income countries and then upper-middle-income countries.

Table 2: Mean of the Variables in the Study, 2000–2012

Variables	All Countries	High-income Countries	Upper-middle-income Countries	Lower-middle and Low-income Countries
Economic freedom	61.414	68.955	57.683	55.127
Government effectiveness	55.392	80.248	45.908	32.076
Vulnerability	0.399	0.314	0.409	0.498
Sensitivity	0.366	0.305	0.375	0.436
GDP (US dollar per capita)	12,599.654	27,703.538	4,123.968	930.147
Energy use (kilogram of oil equivalent per capita)	2,625.702	4,988.623	1,520.559	596.673
PM2.5 (micrograms per cubic meter)	10.100	9.425	10.535	10.160

GDP = gross domestic product, US = United States.

Source: Authors' calculation.

B. Methodology

To investigate the relationships between particulate matter emissions (*PM2.5*) and governance (*GOV*), vulnerability to climate change (*VUL*), real GDP per capita (*GDP*), and primary energy use per capita (*ENE*) for 122 countries across the world for the period 2000 to 2012, we use a panel data model since it has many advantages over cross-sectional or time series data. First, panel data allows for more observations by pooling the time series data across countries and results in higher power for the Granger causality test (Pao and Tsai 2010). This advantage is particularly relevant in the case of short time series. Second, by controlling for individual heterogeneity, panel data allows for “more informative data, more variability, less collinearity among the variables, more degrees of freedom, and more efficiency” as compared to time series and cross-sectional data (Baltagi 2005).

Depending on the presence of cointegration (i.e., a seeming long-run relationship), we estimate the parameters in the cointegrating vector, which imply there is a long-run relationship. We perform estimations on the four following samples. The first sample includes all the 122 countries in our global sample. The second sample includes only high-income countries, the third sample includes only upper-middle-income countries, and the fourth panel includes only lower-middle and low-income countries.

Three preliminary tests are performed prior to estimating the panel models. The Wooldridge test (see Drukker 2003 and Wooldridge 2002) was performed to test for serial correlation in panel-data models, and the Modified Wald statistic (Greene 2008) was derived as part of the test for the presence of groupwise heteroskedasticity in the fixed effect model. We also use the Lagrange multiplier CD_{LM} test by Pesaran (2004) to check for cross sectional dependency as this test is more suitable when the number of observations, N is large and the number of time period, T is small ($T < N$), which is the case for our data. The results show the presence of serial correlation and groupwise

heteroskedasticity. Furthermore, there is also evidence on the presence of cross-sectional dependence under a fixed effect (FE) specification.² The finding is robust to different measures of governance and vulnerability.³

We thus estimate the proposed models using the robust standard errors proposed by Driscoll and Kraay (1998) for panel regressions with cross-sectional dependence (SCC). Erroneously ignoring cross-sectional correlation during the estimation of panel models can lead to severely biased statistical results. We use the xtscv program presented in Hoechle (2007) which produces Driscoll and Kraay's (1998) standard errors for linear panel models. Driscoll and Kraay's approach loosely applies a Newey–West-type correction to the sequence of cross-sectional averages of the moment conditions. Besides being heteroskedasticity consistent, this estimation accounts for cross-sectional dependence problems and corrects for autocorrelation of any order. When the standard error estimates are adjusted in this way, the covariance matrix estimator is guaranteed to be consistent and independent of the cross-sectional dimension N (i.e., also for $N \rightarrow \infty$) (Hoechle 2007). The xtscv program by Hoechle (2007) works well with balanced panels as well as unbalanced panels such as the one we use.

IV. EMPIRICAL RESULTS

In this section, we report and discuss the results of our empirical analysis. We first perform panel unit root tests that take into account cross-sectional dependence. These include the IPS unit root test by Im, Pesaran, and Shin (2003) and the Pesaran (2007) unit root test. The results reveal that the variables have a unit root in level but are stationary in first difference.⁴ Having established that all variables are integrated of order 1, we examine the cointegration relationship among our variables of interest *ENV*, *GOV*, *VUL*, *GDP*, and *ENE* using the Durbin Hausman-group mean test (DHg) and panel test (DHp) developed by Westerlund (2008). This test allows for cross-sectional dependence modeled by a factor model in which the errors of equation (1) are obtained by idiosyncratic innovations and unobservable factors that are common across units of the panel (Auteri and Constantini 2005). In this case, heterogeneous autoregressive parameters are assumed across panel units. The results indicate that the variables *ENV*, *GOV*, *VUL*, *GDP* and *ENE* are bound by a cointegrating relationship. This result holds across different income groups of countries and is robust to different measures of governance and vulnerability.⁵ Our finding of a long-term relationship among the variables supports the presence of important channels through which a country's governance and vulnerability to climate change can affect the environment, as reviewed in section II.

Given the presence of cointegration, this study estimates the parameters in the cointegrating vector that show the long-run relationship. This study first employs variance inflation factor (VIF) in the proposed model to identify potential multicollinearity (Alin 2010). VIF is an effective approach for multicollinearity assessment. In addition, VIF calculations are straightforward and comprehensive. The

² We conducted the Hausman test (with pooled ordinary least squares is preferred under the null hypothesis, while under the alternative, fixed effects is at least consistent and thus preferred) for all models in our study. The results suggested fixed effects are preferred for all the models, regardless of the different measures of governance and vulnerability. The Hausman test results are available upon request.

³ To conserve spaces, the results of these three preliminary tests are not presented here but they are available upon request.

⁴ The unit root statistics (for the logged variables in level and first difference) are not presented to conserve space, but they are available upon request.

⁵ The cointegration results are not reported here to conserve space but they are available upon request.

higher the value of VIF, the higher the collinearity is between the related variables. The obtained VIF values are all below 10, indicating that there is no multicollinearity in this data set.⁶

This study then estimates the long-run parameters in the cointegrating vector using the xtsc program presented in Hoechle (2007) which produces Driscoll and Kraays' (1998) standard errors for linear panel models.⁷ The results are reported in Table 3. Since all variables are expressed in natural logarithms, the coefficients can be interpreted as long-run elasticity. The full sample results show that governance promotes environmental performance, while vulnerability degrades the environment. As discussed in section II, the effect of governance and vulnerability to climate change on the environment is uncertain. For example, while trade liberalization can benefit the environment by promoting the cross-border diffusion of cleaner technologies, it can also harm the environment by expanding output and consumption. In addition, the complex multidimensional nature of vulnerability to climate change, which depends only partly on the climate, introduces uncertainty into the vulnerability–environment nexus. Our evidence suggests that the factors which underlie a positive governance relationship dominate those that underlie a negative relationship and likewise, the negative underlying factors dominate the vulnerability–environment relationship.

These results hold qualitatively for the high-income subsample. On the other hand, for the subsamples of upper-middle-income countries and low-income and lower-middle-income countries, vulnerability has a significant effect on environmental performance, but governance is no longer significant. Our results are robust to different measures of governance and vulnerability as well as environmental performance. The findings imply that while high-income countries have strong environmental policies that benefit the environment, some upper-middle-income countries and low-income and lower-middle-income countries have relatively weak environmental policies which need to be strengthened.

Our results are in line with UNEP Year Book 2014 Update, which finds that air pollution in developed countries has decreased in recent years, partly due to tighter emission controls, including on vehicles. On the other hand, as a result of rapid growth of road traffic in developing countries such as the People's Republic of China (PRC) and India, air pollution has outpaced the adoption of tighter vehicle emission standards. Our findings are also consistent with a World Bank study which stressed the importance of “institutional development, with significant roles for private property protection, effectiveness of the legal/judicial system and efficiency of public administration” (Dasgupta et al. 2001, p. 173). Overall, our analysis recognizes the central role of governance factors in environmental performance since “a full response to the environmental challenge of globalization will therefore require serious attention to the long-run development of public sector administrative and decision-making capacity and financing mechanisms.” (Dasgupta et al. 2005, p. 416).

⁶ The VIF test results are not reported here to conserve space but they are available upon request.

⁷ Before the estimation, the Di Iorio and Fachin's (2008) test for breaks in cointegrated panels is performed to examine the stability of the relationship between the variables of interest. The results show that we can accept the null hypothesis of no break. That is, the relationship among the investigated variables is stable and not subject to structural breaks during the investigation period. To conserve space, the results are not presented here but they are available upon request.

Table 3: Long-Run Estimation Results

All Countries				
	(1)	(2)	(3)	(4)
	PM2.5	PM2.5	PM2.5	PM2.5
Economic freedom	-0.555***		-0.557**	
	(-3.498)		(-3.336)	
Vulnerability	0.716***	0.692***		
	(8.158)	(7.239)		
GDP	-0.070*	-0.152***	-0.008	-0.099***
	(-2.355)	(-11.675)	(-0.244)	(-5.746)
Energy	0.058	0.108***	0.094***	0.148***
	(1.909)	(5.546)	(3.905)	(11.999)
Government effectiveness		-0.045*		-0.064**
		(-2.333)		(-3.298)
Sensitivity			0.100**	0.077**
			(3.201)	(3.334)
_Cons	1.702***	0.785***	1.611***	0.681***
	(4.949)	(53.408)	(4.565)	(32.417)
N	1586	1586	1586	1586
High-income Countries				
	(1)	(2)	(3)	(4)
	PM2.5	PM2.5	PM2.5	PM2.5
Economic freedom	-1.715***		-1.737***	
	(-4.390)		(-4.735)	
Vulnerability	0.171***	0.192***		
	(4.920)	(4.004)		
GDP	-0.280***	-0.134***	-0.270***	-0.126***
	(-15.802)	(-9.386)	(-7.799)	(-4.821)
Energy	0.188***	0.185***	0.179***	0.176***
	(12.169)	(8.285)	(6.594)	(5.083)
Government effectiveness		-0.040***		-0.067***
		(-4.816)		(-3.820)
Sensitivity			0.150**	0.136*
			(3.340)	(2.409)
_Cons	3.662***	1.225***	3.709***	1.257***
	(6.043)	(21.979)	(6.308)	(23.769)
N	637	637	637	637

continued on next page

Table 3 continued

Upper-middle-income Countries				
	(1)	(2)	(3)	(4)
	PM2.5	PM2.5	PM2.5	PM2.5
Economic freedom	-0.189		-0.227	
	(-1.793)		(-1.578)	
Vulnerability	1.433***	1.342***		
	(16.667)	(17.520)		
GDP	0.290***	0.336***	0.309***	0.362***
	(29.155)	(21.128)	(41.801)	(21.292)
Energy	0.259***	0.323***	0.405***	0.474***
	(9.982)	(13.754)	(12.956)	(19.923)
Government effectiveness		-0.062*		0.081
		(-2.677)		(0.066)
Sensitivity			0.314***	0.253***
			(11.945)	(13.922)
_Cons	0.888***	0.456***	0.989**	0.464***
	(3.785)	(7.544)	(3.049)	(6.163)
N	455.000	455.000	455.000	455.000
Lower-middle and Low-income Countries				
	(1)	(2)	(3)	(4)
	PM2.5	PM2.5	PM2.5	PM2.5
Economic freedom	-0.413		-0.309	
	(-1.390)		(-1.070)	
Vulnerability	1.456***	1.335***		
	(18.910)	(23.828)		
GDP	-0.019	0.100***	0.006	0.089***
	(-0.489)	(13.706)	(0.153)	(10.571)
Energy	0.137***	0.068***	0.055**	0.108***
	(4.394)	(4.075)	(3.223)	(5.405)
Government effectiveness		0.053		0.098
		(0.341)		(0.292)
Sensitivity			0.501***	0.476***
			(7.554)	(6.010)
_Cons	1.630***	0.919***	1.120*	0.585***
	(3.612)	(18.942)	(2.683)	(11.642)
N	494	494	494	494

GDP = gross domestic product.

Notes: ***, **, and *, respectively indicate statistical significance at the 1%, 5%, and 10% levels. t statistics are in parentheses.

Source: Authors' calculation.

Possible interpretations of our findings are as follows. Some countries specialize in relatively clean industries and production techniques as they become richer. Higher income can also provide more fiscal resources for public investment in environmental protection (Bhagwati 1993). On the other hand, developing countries face significant governance and environmental issues in tackling environmental policy issues, which may be the reason why they find it hard to move from relatively poor and dirty to relatively poor and clean. Furthermore, the environmental awareness of the general public tends to be lower in developing countries and there are thus fewer mechanisms for advocacy. For instance, in the PRC, while there seems to be a growing level of dissatisfaction with pollution in big cities such as Beijing, there is little public debate about solutions. The prevailing perception among stakeholders seems to be that environmental deterioration is a price worth paying for economic growth. Compared to developed countries, in many developing countries, there are fewer mechanisms in place for citizens to lobby for green transformation. For example, in the PRC there are no institutional channels for public and social organizations to participate in environmental protection, and only very few environmental nongovernmental organizations exist.

V. CONCLUDING OBSERVATIONS

Our study highlights the importance of governance and vulnerability to climate change in pursuing green growth. While there is a vast empirical literature on the Environmental Kuznets Curve (EKC), not all pollutants follow the inverted U-shaped EKC pattern (Lipford and Yandle 2010). This is partly due to the omission of important structural factors underlying the relationship between income and emissions. For example, bureaucratic inefficiency, the influence of special interest groups, and the resistance of state-owned enterprises can hinder the ability of a government to tackle environmental degradation. Such institutional factors are captured in the Index of Economic Freedom, which is the main indicator we use in our study. We explicitly incorporate two key factors, namely governance and vulnerability to climate change, into an empirical analysis of air pollution in a global sample of countries.

More specifically, we examine the relationship between environmental performance and governance, climate change vulnerability, and other factors for a panel data of 122 countries from 2000 to 2012. For the full sample of countries, we find that better governance improves environmental performance, while higher vulnerability causes environmental degradation. In principle, the effect of governance and climate change vulnerability on the environment is uncertain but our evidence indicates that better governance and reduced vulnerability benefits the environment. This suggests that policies which improve governance and reduce vulnerability to climate change can contribute to a cleaner environment.

The evidence for different income groups of countries is more ambiguous. The results for the full sample of countries hold qualitatively for the high-income subsample. However, for the subsamples of upper-middle-income countries as well as low-income and lower-middle-income countries, vulnerability to climate change adversely affects environmental performance but governance is no longer significant. The evidence thus suggests that developed countries are more successful in tackling environmental destruction. In contrast, developing countries are still struggling to create environment-protecting synergy between infrastructure, policies, and governance. Our results are robust to different measures of governance, vulnerability to climate change, and environmental performance.

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Governance, Vulnerability to Climate Change, and Green Growth: International Evidence

We examine the role of governance and vulnerability to climate change in green growth using a global panel data set. We find that governance has a positive effect on environmental performance and vulnerability to climate change has a negative effect. Promoting good governance and reducing climate change vulnerability can thus contribute to a cleaner environment. We find qualitatively similar results for the subsample of high-income countries, but governance has an insignificant effect for the subsamples of upper-middle-income, lower-middle-income, and low-income countries. High-income countries have strong environmental policies to protect the environment whereas other countries need to strengthen their relatively weak environmental policies.

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