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Does political stability hinder pollution? Evidence from developing states

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Abstract
We examine the nexus between CO2 emissions and political stability using a sample of low- and lower-middle-income countries over 1990-2015. Panel vector error correction model (PVECM) estimations unveil a non-linear, bell-shaped pattern between the two indicators. This suggests that political stability starts to reduce CO2 pollution only after the optimum level is reached. Moreover, we find important heterogeneities concerning countries' level of development and when considering political stability subcomponents. Overall, the findings suggest that both the formal and informal side of political stability plays a vital role in mitigating CO2 pollution in developing countries, and may provide meaningful insights for policymakers.

Keywords: CO2 emissions, political stability, developing states

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1. Introduction

Political stability has always been a central pillar in the well-being of society. Over the years, political crises have unrevealed some of the adverse effects they may have on an economy. Moreover, the factors behind the political distortions are among the most diverse and very often difficult to predict, ultimately causing a series of economic inefficiencies. Going back to late '80s and early '90s, we find the idea that an unstable political environment leads to economic inefficiencies as the binder of the studies of Alesina and Tabellini (1989, 1990), Tabellini and Alesina (1990), Cukierman et al. (1992), Ozler and Tabellini (1991), Alesina et al. (1992), and the related works. Specifically, the authors argue that when a government becomes uncertain about its functioning, it will jeopardize the state' regime, its successor will inherit, by adopting sub-optimal policies. However, this is just a straightforward example of how political stability might reflect on a country's environmental well-being through propensity of government failure, but the spectrum of channels is much broader.

In this regard, Margolis (2010) claim that state stability is just a fraction of political stability, which represents the concurrence of formal and informal roles and structures within a political object. Accordingly, looking in retrospective, it is inevitable not to notice that political conflicts encompass besides government-related crises, also religious and ethnic tensions, institutional and business imbalances, external crises, among others. Based on the Global Peace Index report (GPI, 2017), the number of political conflicts almost doubled in 2016 compared to 2006, reaching 402 from 268. During the ten years, violent crises (i.e., medium-intensity conflicts) registered the most significant increase, from 83 to 188, while 38 conflicts are classified as highly violent crises in 2016 (5 less compared to 2015). Furthermore, since 2006, Asia and Oceania, followed by Sub-Saharan Africa, has reported the highest increase in the number of conflicts, on average. Besides, the history has shown that such political distress episodes are more likely to be encountered in developing countries, when compared to the developed nations-the Central African Republic Bush War (2004-07), the conflict in the Niger Delta (2004-present), the Houthi insurgency in Yemen (2004-15), the Chadian Civil War (2005-10), the Djiboutian-Eritrean border conflict (2008), the Ivorian crises (2010-11), the Arab Spring (2010-12), the Central African Republic conflict (2012–present), the Burkinabé coup d'état attempt (2016), to mention just a few of them.

Consequently, the effects of political conflicts may impinge on the government position to environmental issues trough the associated policies and regulations, but also could influence both the business organizations' and population's view concerning environmental quality. The environmental degradation-political stability nexus literature is relatively new and sparse, with most of the studies documenting the effect of corruption along with other institutional quality proxies on pollution. On the one hand, in the early literature, Desai (1998) suggest that notably in developing states, corruption seems to contribute substantially to environmental degradation. Furthermore, Cole (2007) employing instrumental variables technique on a sample of 94 countries over the period 1987-2000, shows that corruption impacts positively both sulfur (SO_2) and carbon dioxide (CO_2) emissions per capita. Likewise, using cross country data for 99 developing states, Gani (2012) investigates the link between five dimensions of governance and CO_2 pollution. Overall, the results point out that good governance may reflect in lower CO_2 emissions. More recently, Zhang et al. (2016) examine the impact of corruption on CO_2 emissions in 19 Asia-Pacific Economic Cooperation (APEC) countries over 1992-2012. Panel quantile regression model is used in order to test if the corruption exhibits a heterogeneous effect for different levels of CO_2 pollution. The empirical findings indicate that for lower emissions countries, the impact is negative and statistically significant, while no statistical link is found between variables in higher emission states.

On the other hand, a growing strand of studies focuses on the relationship between growth and pollution while controlling for the potential effects of corruption and other political institution variables. In this regard, Welsch (2004) show in a cross-country study that corruption impacts significantly the relationship between per capita income and various pollution indicators. Ozturk and Al-Mulali (2015) for Cambodia and Sarkodie and Adams (2018) for South Africa, using time-series analysis find that better governess/corruption control and political institutional quality respectively could help in mitigating the pollution. Also, in the case of Romania, the results of Shahbaz et al. (2013) illustrate that democracy helps in reducing energy emissions. Moreover, Abid (2017) using panel data analysis show that a higher institutional quality could reduce CO_2 emissions in European Union (EU) countries, while for the Middle East and African (MEA) states the institutional quality indicators are not statistically significant. In the same vein, the empirical findings of Apergis and Ozturk (2015) for 14 Asian countries suggest that government effectiveness, quality of regulation, and corruption control reflects in lower CO2 emissions, while higher political stability and absence of violence reflects in more CO2 pollution.

Relatedly, other theoretical and empirical works show that corruption either reduces the stringency of environmental regulations (see e.g. Damania et al., 2003; Fredriksson et al., 2004, Pellegrini and Gerlagh, 2006), impacts positively the crucial income turning point[1] of the EKC[2] (Lopez and Mitra, 2000; Leitão, 2010), diminishes the effects of shadow economy on pollution (Biswas et al., 2012), or exhibits a non-linear relationship on pollution (Halkos and Tzeremes, 2013). Besides, Fredriksson and Svensson (2003) linked both corruption and political instability with environmental regulation. In their seminal contribution, authors argue that for low levels of corruption, political instability exerts a negative impact on the environmental regulation stringency, while for high levels, the effect becomes positive. Nevertheless, a limitation of their study is that the political instability proxy capture only sovereign crises. It is worth mentioning that a series of the studies mentioned above, along with others such as Leitão (2010), assess the indirect effect of corruption on pollution, mainly through the economic growth[3], and occasionally via other macro indicators (e.g., financial development, foreign direct investments, and public expenditure). Additionally, some recent contributions such as Bernauer and Koubi (2009), Adams and Klobodu (2017, 2018), Bae et al. (2017), Lægreid and Povitkina (2018), and Arminen and Menegaki (2019) documented, among others, the potential impact of various political framework factors on environmental degradation. On this last point, we note that some studies address the issue of states' actual and reported emissions in relationship with corruption and effectiveness of environmental regulations (Ivanova, 2011; Goel et al., 2013), or provide evidence of institutional quality spillover effect on environmental quality (Hosseini and Kaneko, 2013). For a survey of the empirical literature of the institutions and governance impact on environmental policy, environmental performance, and green investment see, e.g., Dasqupta and De Cian (2018).

The goal of this paper is to widen the extant literature on the relationship between environmental degradation and political stability in developing countries, by accounting for the limitations of the previous related works. Indeed, is such countries the politico-economic structure posses different characteristics compared to developed nations, making a difficult task for decisions bodies to maintain a balance between the political-economic system and environmental degradation. Furthermore, the more pronounced dynamicity of political framework requires also a continuous adaptation and proper monitoring of environmental related policies and regulations. As such, given that the outcomes of environmental policies are more visible in the long-run, sudden political changes could interfere or even deter the achievement of the associated goals. Besides, simple stylized facts show that over 1990-2015 period, in our sample of 47 low- and lower-middle-income states the evolution of political stability and CO2 emissions seems to be non-linear, characterized by significant ups and downs (see Figure 1(b) in Appendix). In this context, examining the potential (threshold) effect of political stability on CO2 pollution in a large sample of developing countries could be of interest to both academia and policymakers.

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[1] Conversely, Galinato and Galinato (2012) show that the income turning point is not significantly impacted by political stability and corruption control.
[2] EKC=Environmental Kuznets Curve. The EKC states that the relationship between pollution and economic growth is bell-shaped, as suggested by Grossman and Krueger (1991).
[3] The corruption degree may hinder economic growth, thus decreasing the pollution levels. As such, if the indirect effect of corruption is negative and larger in absolute value, it would surpass the positive direct effect, thus resulting in an overall negative impact (Cole, 2007).

The contribution of our analysis is threefold. First, to the best of our knowledge, none of the related studies explore the potential common long-run pattern between variables, while allowing country-specific short-run heterogeneities. Despite that the effects of political stability on environmental degradation seem to be more noticeable in the long-run, the vast majority of studies mentioned above do not explore a possible cointegration relationship between variables. Moreover, we test for potential heterogeneities of political stability impact on CO2 emissions by augmenting the initial model with the squared term of political stability variable. In doing so, we build upon a panel vector error correction model (PVECM) via the Pooled Mean Group (PMG) estimator introduced by Pesaran et al. (1999). Second, in the spirit of Margolis (2010), we adopt a broader definition of political stability, captured by the political risk index of International Country Risk Guide (ICRG) of Political Risk Services (PRS) Group. Third, we enrich the empirical literature dedicated to developing countries by focusing on a large sample of 47 low- and lower-middle-income states.

The findings are as follows. We find evidence of a significant non-linear, bell-shaped impact of political stability on CO2 emissions. This implies that political stability contributes to decreasing CO2 pollution, but only after the 68,51 threshold is reached. According to political stability index[4], this value is near the borderline of a moderate to high political stability. Nonetheless, it is worth mentioning that political stability index's values in our sample signal that several countries did not achieve the turning point yet. Furthermore, our findings are sensitive to countries' level of development and when we disaggregate political stability, thus providing some meaningful insights. On the one hand, estimations reveal that countries with low-income have to ameliorate political unrest to reach the optimal level above which the CO2 emissions would fall. On the other hand, when political stability is disaggregated, its impact on CO2 pollution seems to be either non-linear, inverted-U shaped, U shaped, or monotonically increasing.

The rest of the paper is structured as follows. Section 2 describes the data and estimation technique, Section 3 reports the results, Section 4 explores potential heterogeneities, and Section 5 concludes.

2. Data and estimation technique

This section aims at describing the data used in empirical analysis and the estimation technique.

2.1. Data

The analysis focuses on countries classified by World Bank (2018) as economies with low- and lower-middle-income. We select the states based exclusively on the data availability of our main variable of interest, i.e., political stability. Hence, our unbalanced panel contains 47 out of 81 low- and lower-middle-income states. The environmental pollution is proxied by CO2 emissions per

[4] According to ICRG methodology, a value of political risk between 0.0% to 49.9% indicates a very high risk; 50.0% to 59.9% high risk; 60.0% to 69.9% moderate risk; 70.0% to 79.9% low risk; and 80.0% or more very low risk. As we refer to the index in terms of political stability in order to reflect the increasing scale, we interpret the values as follows: 0.0% to 49.9% suggests a very low political stability, 50.0% to 59.9% low political stability, 60.0% to 69.9% moderate political stability; 70.0% to 79.9% high political stability; and 80.0% or more very high political stability.

capita obtained from Janssens-Maenhout et al. (2017), while data for political stability (POLSTAB) come from ICRG (2019) of PRS Group. The POLSTAB is a broad index that comprises 12 weighted political and social components.[5] Besides, one of the main advantages is that it gives a comparable basis for countries covered by ICRG, based on associated political stability score.[6]

The controls variables, namely gross domestic product per capita (GDP), renewable energy (RENEW), and urbanization (URB) that we included in the analysis and may equally affect CO2 emissions come from World Development Indicators (World Bank, 2019). The selection of these explanatory factors has its roots in the well-known STIRPAT[7] and EKC literature, whereas they are also in line with 2030 Sustainable Development Goals. All the variables included in regression models are expressed in natural logarithm, thereby the coefficients can be interpreted as elasticity. Table 1 and Table 2 in the Appendix shows the variables' definitions and summary statistics, while Figure 1 provides some stylized facts for the main variables.

2.2. Estimation technique

To estimate the long-run elasticities of cointegration vector and capture the short-run dynamics between variables, we use a PVECM trough the autoregressive distributed lag (ARDL) approach.[8] More specifically, we employ the PMG estimator developed by Pesaran et al. (1999). On the one hand, the main advantage of PMG estimator is given by the flexibility in short-run coefficients and error variances which are allowed to vary depending on the individual panel members (groups), while the long-run slopes are pooled across panel members. Thus, this technique allows for short-run country-specific heterogeneities, while assuming a common long-run trajectory between environmental pollution and political stability. The long-term pattern could be explained by the well-known global environmental instruments to fight climate change such Kyoto Protocol and Paris agreement, and the willingness of the states to achieve political stability through mitigating corruption, reducing conflicts and improving the overall socio-economic and -political conditions. However, it is reasonable to believe that countries included in analysis possess at least different short-run dynamics. First, the environmental regulations and macroeconomic policy are different across states; each country adopts the macroeconomic policy and environmental regulations that best fit the peculiar economic context. Second, we mix countries with both low- and lower-middle-income levels from various regions around the globe. As a consequence, we expect that the distinct cultural heritage might play an essential role in how population and policymakers relate to environmental and political aspects. Third, the countries' adhesion of regional intergovernmental organizations (see e.g. Common Market for Eastern and Southern Africa (COMESA), Union Economique et Monétaire Ouest Africaine (UEMOA), Economic Community of West African States (ECOWAS)-African states; Association of

[5] The components are government stability, socioeconomic conditions, investment profile, internal conflict, external conflict, corruption, military in politics, religious tensions, law and order, ethnic tensions, democratic accountability, and bureaucracy quality.
[6] https://www.prsgroup.com/wp-content/uploads/2014/08/icrgmethodology.pdf
[7] STIRPAT= Stochastic Impacts by Regression on Population, Affluence, and Technology. The STIRPAT framework was developed by Dietz and Rosa (1994, 1997) as the stochastic counterpart of IPAT identity proposed by Ehrlich and Holdren (1971, 1972).
[8] The ARDL approach provides consistent estimates even if the variables are integrated of different orders, i.e., I(0) and I(1) (Pesaran and Smith, 1995).

Caribbean States, Caribbean Community (CARICOM), Organization of American States (OAS)-American states; Asia-Pacific Economic Cooperation, Asian Development Bank, Association of Southeast Asian Nations (ASEAN)-Asian states; European Union (EU), Central European Free Trade Agreement (CEFTA), North Atlantic Treaty Organization (NATO)-European states; Pacific Islands Forum Secretariat, East-West Center, Secretariat of the Pacific Regional Environment Program (SPREP)-Pacific states) could impact differently both the economic and political system.

On the other hand, from the econometric perspective, in dealing with macro-panels (i.e., time-series panels with large or moderate N and T dimensions) the most suitable estimators are those that can also be used for exploring the slopes heterogeneity across groups such as PMG and A(MG) estimators (Eberhardt, 2011). Moreover, when the variables' series exhibit unit root and are cointegrated, the applicability of an error correction model is strongly recommended.
Following the work of Pesaran et al. (1999), the mathematical specification of autoregressive distributed lag [ARDL$(p, q_1 \dots q_k)$] dynamic panel model can be written as:

$$CO2_{it} = \sum_{j=1}^{p} \partial_{ij} CO2_{i,t-j} + \sum_{j=0}^{q} \gamma'_{ij} Z_{i,t-j} + \mu_i + \varepsilon_{it}, \quad (1)$$

where the subscript $i = \overline{1, N}$ represents panel members (countries) and $t = \overline{1, T}$ designates the periods (number of years); CO2 is our dependent variable, the log CO2 emissions per capita, and Z_{it} $(k \times 1)$ is the vector of explanatory variables, with $\gamma_{ij}(k \times 1)$ associated coefficients vector; μ_i and ε_{it} denote the country-specific fixed effects and the error term, respectively. We are mainly interested in the coefficient associated with the log of POLSTAB variable, but given the drawbacks caused by omitted variable bias, we augment the model by other important factors that may influence the CO2 pollution, namely the log of GDP per capita, the log of RENEW, and the log of URB. Such factors that account for the size of the economy, the technological progress, the stringency of environmental regulations, and the ongoing urbanization process may equally distort the CO2-POLSTAB nexus if omitted from the model. Moreover, these are one of the most used explanatory variables of environmental degradation according to EKC and STIRPAT literature (see e.g. Apergis et al., 2010; Narayan and Narayan, 2010; Shaifei and Salim, 2014; Al-mulali et al., 2015; Apergis, 2016; Ben Jelbi et al., 2016; Awad and Warsame, 2017; Wang and Lin, 2017; Pablo-Romero and Sánchez-Braza, 2017; Joshi and Beck, 2018; Lazăr et al., 2019; among others).

Assuming that the variables from equation (1) are non-stationary and cointegrated, the above equation can be rewritten into a PVECM. Hence, the equation that incorporates along with long-term coefficients both the short-run elasticities and the error correction term (ECT) has the following form:

$$\Delta CO2_{it} = \phi_i (CO2_{it-1} - \lambda'_i Z_{it}) + \sum_{j=1}^{p-1} \partial^*_{ij} \Delta CO2_{it-j} + \sum_{j=0}^{q-1} \gamma'^*_{ij} \Delta Z_{it-j} + \mu_i + \varepsilon_{it}, \quad (2)$$

where $\phi_i = -(1 - \sum_{j=1}^{p} \partial_{ij})$, $\lambda_i = \sum_{j=0}^{q} \gamma_{ij} / (1 - \sum_k \partial_{ik})$, $\partial^*_{ij} = -\sum_{m=j+1}^{p} \partial_{im}$ $for\ j = 1, \dots, p-1$, $\gamma^*_{ij} = -\sum_{m=j+1}^{q} \gamma_{im}$ $for\ j = 1, \dots, q-1$, and Δ denotes the difference operator.

With regard to ϕ_i, the coefficient of ECT, we expect to be negative and statistically significant, in order to confirm the long-run relationship between variables and determine the speed of adjustment.

3. Results

Before estimation, we examine the properties of our variable' series, namely the cross-sectional dependence, the stationarity, and cointegration relationship. Concerning political stability impact on CO2 emissions, first we report the baseline results, and further, we account for a potential threshold effect. Both the preliminary analysis and regression models cover the period 1990-2015.

3.1. Preliminary analysis

3.1.1. Cross-sectional dependence

To test the series cross-sectional dependence, we used a battery of four tests such as Baltagi et al. (2012) Bias-Corrected (BC) scaled LM, Pesaran (2004) CD, Pesaran (2004) LM scaled, and Breusch-Pagan LM (1980). The results of variable cross-sectional dependence tests are provided in Table 1. We note that the null hypothesis of cross-sectional independence is rejected in all cases in favor of the cross-sectional dependence; all test statistics are statistically significant at 1% level.

Table 1 - Cross-sectional dependence analysis

Test/Variable	CO2	POLSTAB	GDP	RENEW	URB
BC scaled LM	232.61***	150.71***	282.43***	213.50***	463.80***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Pesaran CD	52.10**	60.72***	79.49***	54.72***	94.36***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Pesaran scaled LM	233.55***	151.65***	283.37***	214.44***	464.74***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Breusch-Pagan LM	11940.76***	8132.67***	14257.32***	11051.94***	22690.28***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Notes: H0 is "cross-sectional independence (i.e. no correlation)". P-values in brackets. ***, **, * denote statistical significance at the 1%, 5%, and 10% level, respectively.

3.1.2. Stationarity

We test the stationarity using two tests, namely the Fisher-type based on augmented Dickey-Fuller (ADF) first-generation unit root test developed by Choi (2001), and the second-generation unit root test introduced by Pesaran (2003). The second generation of tests is robust to cross-sectional dependence, while for the Phillips-Perron test, we demean the data to alleviate its potential effects. Additionally, both tests work well with unbalanced panel datasets. Table 2 shows the results for three-lags regressions specification. For the variables in levels, we include in the equation both constant and trend, whereas for their first difference only the constant term. Overall, the findings confirm that the variables series are integrated of order one (I(1)).

Table 2 - Stationarity analysis

Test/ Variable	Pesaran test				Fisher-type ADF test			
	Level (cons & trend)		Δ (cons)		Level (cons & trend)		Δ (cons)	
	t-bar	p-value	t-bar	p-value	t-bar	p-value	t-bar	p-value
CO2	-2.041	(0.976)	-2.214***	(0.001)	-3.343***	(0.000)	-9.855***	(0.000)
POLSTAB	0.244	(0.596)	-7.506***	(0.000)	-1.409*	(0.079)	-13.554***	(0.000)
GDP	0.212	(0.584)	-8.904***	(0.000)	1.1375	(0.872)	-6.824***	(0.000)
RENEW	1.633	(0.949)	-2.966***	(0.002)	2.5706	(0.994)	-6.935***	(0.000)
URB	-2.028	(0.981)	-1.967*	(0.072)	-6.840***	(0.000)	-4.203***	(0.003)

Notes: Pesaran (2003) H0 is "all series are non-stationary", and Fisher-type (ADF) (Choi, 2001) H0 is "all panels contain a unit root". P-values in brackets. ***, **, * denote statistical significance at the 1%, 5%, and 10% level, respectively.

3.1.3. Cointegration

To examine the potential cointegration relationship between variables, we employ the Engle-Granger based test of Kao (1999) and Pedroni (1999, 2004), and Westerlund (2007) ECM panel cointegration test. The former imposes that the coefficients' slopes are homogeneous, while the latter two allow for slopes heterogeneity. Likewise, under the null hypothesis, all tests assume that there is no cointegration relationship between variables. The results of cointegration tests are provided in Table 3. For Pedroni (1999, 2004) test, the panel PP- and ADF-statistic, normal and weighted version, corresponds to the homogeneous alternative hypothesis (or within dimension), and group PP- and ADF-statistic refers to heterogeneous alternative (or between dimension) (Pedroni, 1999, 2004). We report the results both for individual intercept and individual intercept and trend specification. For Westerlund's (2007) test we report the group mean (Gt) statistic designed to test the alternative hypothesis that at least one cross-section unit is cointegrated, and panel (Pt) statistic constructed to test the alternative that the whole panel is cointegrated (Persyn and Westerlund, 2008). Unanimously, the results indicate that our variables are cointegrated.

Table 3 - Cointegration analysis

Pedroni test	Individual intercept		Individual intercept & trend	
	statistic	p-value	statistic	p-value
Within dimension				
Panel PP-Statistic	-3.203***	(0.000)	-6.402***	(0.000)
Panel ADF-Statistic	-4.100***	(0.000)	-7.198***	(0.000)
Panel PP-Statistic (Weighted)	-5.345***	(0.000)	-8.040***	(0.000)
Panel ADF-Statistic (Weighted)	-6.112***	(0.000)	-8.717***	(0.000)
Between dimension				
Group PP-Statistic	-5.034***	(0.000)	-10.402***	(0.000)
Group ADF-Statistic	-5.242***	(0.000)	-8.044***	(0.000)
Kao test	t-statistic	p-value		
ADF	-2.164**	(0.015)		
Westerlund test	statistic	p-value		
Gt	-2.847***	(0.005)		
Pt	-18.516***	(0.001)		

Notes: Automatic lag length selection based on SIC with a maximum lag of 3. Newey-West automatic bandwidth selection and Bartlett kernel. The statistics' significance was determined by comparing the calculated and tabulated values provided by Pedroni (1999). H0 is "no cointegration". ***, **, * denote statistical significance at the 1%, 5%, and 10% level, respectively. For Westerlund's (2007) test we use three lags following the Akaike Information Criterion (AIC) test.

3.2. Pollution and political stability: baseline estimates

Table 4 provides the estimated long-run elasticities together with the short-run dynamics both for the reduced model (i.e., when we capture the pure effect of POLSTAB on CO2 emissions) and extended model (i.e., when we introduce the explanatory factors to mitigate a potential omitted variable bias). We estimate an ARDL(p=1, q=2) model, as suggested by the Akaike Information Criterion (AIC). To validate from the econometric perspective the choice of PMG approach, we also estimated the model using Dynamic Fixed Effects (DFE) and Mean Group (MG) estimator proposed by Pesaran and Smith (1995).

The DFE technique assumes that both the long- & short-run coefficients together with the ECT are equal for all panel members, while only the intercept varies across panel members. Conversely, the MG estimator allows heterogeneous long-, and short-run slopes, intercepts and also error variances. Further, we applied the Hausman Chi-2 test to choose the appropriate modeling technique. According to test results, the null hypothesis of a common long-run path was accepted (see column (1) of Table 4), thus confirming that the PMG estimator is the most appropriate to model our data.

On the one hand, regardless of the estimation technique, the findings show that the ECT is negative and strongly statistically significant, consolidating the existence of long-run relationships between variables. Likewise, it validates our modeling strategy and suggests that our model is correctly specified. Moreover, if an exogenous shock alters the system's equilibrium, the CO2 emissions help the system to readjust to the long-run equilibrium, with the associated speed of adjustment.

On the other hand, the PMG results (see column (1) of Table 4), show that political stability exhibits a significant long-term positive impact on CO2 pollution. Following the most existing literature, this finding seems somehow counterintuitive, as we would think that a higher politically stable society could, for instance, foster the stringency of the environmental regulations, causing a decrease in pollution levels ultimately.

As such, in the following, this result calls for a reassessment of the model in terms of its specification.

Table 4 – CO_2 emissions and political stability: baseline estimates

Dependent variable: ΔCO2						
	PMG		DFE		MG	
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
Long-run coefficients						
POLSTAB	0.218***	0.089*	1.003***	0.484***	2.021	0.189
	(0.036)	(0.046)	(0.221)	(0.155)	(1.305)	(0.210)
GDP		0.521***		0.304***		0.098
		(0.041)		(0.096)		(0.261)
RENEW		-0.146***		-0.464***		-3.234**
		(0.022)		(0.125)		(1.637)
URB		-0.088		0.379*		5.417
		(0.091)		(0.207)		(7.771)
Short-run coefficients						
ECT	-0.190***	-0.318***	-0.109***	-0.167***	-0.215***	-0.847***
	(0.026)	(0.043)	(0.012)	(0.016)	(0.030)	(0.068)
ΔPOLSTAB	-0.016	0.052	0.051	0.075	-0.095	-0.146
	(0.075)	(0.066)	(0.049)	(0.052)	(0.084)	(0.337)
ΔPOLSTAB(t-1)	0.047	-0.020	0.038	-0.021	0.100	0.091
	(0.058)	(0.046)	(0.038)	(0.040)	(0.067)	(0.136)
ΔGDP		0.413***		0.175**		0.647***
		(0.141)		(0.085)		(0.245)
ΔGDP(t-1)		0.004		0.120*		-0.255*
		(0.130)		(0.063)		(0.141)
ΔRENEW		-1.962***		-0.163**		-0.025
		(0.587)		(0.070)		(1.220)
ΔRENEW(t-1)		0.218		-0.148***		0.045
		(0.237)		(0.049)		(0.159)
ΔURB		42.776		1.279**		23.803
		(35.594)		(0.587)		(50.329)
ΔURB(t-1)		-22.989		0.890		0.820
		(39.579)		(1.137)		(38.457)
C	-0.393***	-1.791***	-0.526***	-0.808***	-0.883***	-28.190
	(0.071)	(0.358)	(0.092)	(0.207)	(0.194)	(39.336)
Log Likelihood	1548.222	2081.575				
Hausman Chi-2 test p-value	0.224	0.557				
Groups	47	47	47	47	47	47
Observations	1111	1091	1111	1091	1111	1091

Notes: We use the difficult option to avoid difficulty to maximize the likelihood function when nonconcave regions appear during estimation. The Hausman's test H0 is that "countries share a common long-run trend". According to test results (p-value=0.224 for the reduced model, and 0.557 for the extended model), the H0 is accepted, confirming that the PMG estimator is preferred. Standard errors in brackets. ***, **, * denote statistical significance at the 1%, 5%, and 10% level, respectively.

3.3. Pollution and political stability: threshold effect estimates

The previous baseline results have risen some question marks regarding a potential threshold effect of political stability on CO_2 pollution. Hence, our novel hypothesis is that the negative effect of political stability on environmental pollution could arise after a certain threshold is reached. We rely on the most appropriate estimation technique (i.e., the PMG estimator) and we include as additional variable the quadratic term of political stability (POLSTAB2) in the model. If our hypothesis holds, we expect a positive significant coefficient for POLSTAB and a negative one for its squared term.

The results for the overall panel are displayed in columns (1a) and (1b) of Table 5.[9] Let us discuss the long-term findings. First, we find evidence in favor of a long-run, bell-shaped relationship between CO2 emissions and political stability, given that the coefficient of political stability (political stability squared) is positive (negative). As such, our hypothesis holds and suggest that above 68.51 threshold[10] a more politically stable environment is associated with a decrease in CO2 emissions, on average (see column (1b) in Table 5). Also, we note that the findings remain robust when we estimate the model without the control variables, and the turning point occurs for a lower value of political stability (see column (1a) in Table 5). On the one hand, the results complement the ones of Zhang et al. (2016) who show that there is a heterogeneous impact of corruption on CO2 emissions among APEC states. However, our model specification, empirical methodology, and sample differ considerably from Zhang et al. (2016). Besides, we use a broader political stability index which contains besides corruption other important components of the political system. On the other hand, distinct from the findings of Apergis and Ozturk (2015)[11], our estimates suggest that a threshold effect is at work when modeling the link between CO2 emissions and political stability in developing states. Thus, after the optimum level is reached along with corruption control (see, e.g., Desai, 1998; Cole, 2007; Gani, 2012; Apergis and Ozturk, 2015) altogether, the subcomponents of political stability index contribute in reducing CO2 pollution. Second, the estimates point out that the economic growth contributes in increasing CO2 pollution levels (see, e.g., He and Richard, 2010; Wang, 2012; Joshi and Beck, 2018; Lazăr et al., 2019).

The result is expected, as developing countries exhibit among the faster growth rates along with an intensive process of industrialization which requires a substantial amount of energy use, but all with the cost of damaging the environment. However, it is encouraging to see that both renewable energy technologies (see, e.g., Ben Jelbi et al., 2016; Dogan and Seker, 2016) and the urbanization process (see, e.g., Liddle, 2004; Poumanyvong and Kaneko, 2010) inclines the balance in favor of the environment and helps in reducing the CO2 emissions. This may imply that the positive outcomes of renewable energy and energy efficiency projects implemented since 2005 in developing countries are becoming visible, and crucial tools in mitigating the pollution.

Moreover, according to the United Nations Environment Programme (2017), these projects are expected to decrease by 2020 the greenhouse gas emissions by 0.6 gigatons of CO2 per year. Also, the urbanization process seems to incentive the use of more green technologies, since it contributes in diminish environmental degradation. Third, the strongly significant ECT coefficient confirms yet again the accuracy of our results, while it indicates an average speed of adjustment towards the long-run equilibrium. Finally, we note that on the short-run, only the first difference in GDP (RENEW) significantly increase (decrease) CO2 emissions.

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[9] As on the short-run, we are interested in testing the non-linear relationship only for the first difference (Δ), we add one lag for the quadratic term of POLSTAB variable in the baseline model. Nonetheless, the AIC validates the chosen of the lag structure (i.e. ARDL(1,2,2,2,2,1)), compared with different lag structure specifications.

[10] We compute the threshold values based on the first derivative of CO2 with respect to POLSTAB.

[11] In particular, the authors find that in terms of the probability of a government to be destabilized/abolished by unconstitutional or forceful means, higher political stability and absence of violence increase CO2 emissions in Asian countries.

Table 5 - CO2 emissions and political stability: threshold estimates

Dependent variable: ΔCO2					
	Full sample		LICs	LMICs	
	(1a)	(1b)	(2)	(3a)	(3b)
		Long-run coefficients			
POLSTAB	15.562***	7.413***	2.226***	-3.175	0.041
	(1.545)	(1.139)	(0.792)	(2.922)	(0.096)
POLSTAB2	-1.986***	-0.876***	-0.239**	0.396	
	(0.197)	(0.143)	(0.099)	(0.359)	
GDP		0.482***	-0.011	0.561***	0.563***
		(0.039)	(0.030)	(0.046)	(0.050)
RENEW		-0.149***	0.741***	-0.171***	-0.162***
		(0.024)	(0.101)	(0.025)	(0.025)
URB		-0.174**	1.155***	-0.331*	-0.241
		(0.070)	(0.046)	(0.204)	(0.211)
		Short-run coefficients			
ECT	-0.212***	-0.352***	-0.513***	-0.280***	-0.250***
	(0.037)	(0.045)	(0.095)	(0.047)	(0.050)
ΔPOLSTAB	-1.162	3.907	-2.986	10.083	0.049
	(4.770)	(5.255)	(5.692)	(7.571)	(0.105)
ΔPOLSTAB2	0.131	-0.481	0.350	-1.212	
	(0.587)	(0.639)	(0.710)	(0.909)	
ΔPOLSTAB(t-1)	0.008	0.011	-0.013	-0.041	0.014
		(0.059)	(0.080)	(0.087)	(0.069)
ΔGDP		0.324**	0.545***	0.438*	0.442**
		(0.154)	(0.185)	(0.231)	(0.208)
ΔGDP(t-1)		-0.043	-0.043	-0.127	-0.030
		(0.011)	(0.119)	(0.186)	(0.219)
ΔRENEW		-1.901***	-3.343***	-1.335***	-1.346***
		(0.585)	(1.239)	(0.436)	(0.440)
ΔRENEW(t-1)		0.338	1.034*	-0.00	0.007
		(0.319)	(0.644)	(0.104)	(0.119)
ΔURB		37.947	29.183	58.537	65.365
		(32.948)	(23.848)	(56.618)	(62.169)
ΔURB(t-1)		-16.296	-11.790	-23.704	-53.969
		(35.621)	(38.437)	(64.359)	(66.971)
C	-6.720***	-7.060***	-7.677***	0.616	-1.270**
	(1.210)	(0.938)	(1.382)	(0.445)	(0.500)
Log Likelihood	1619.764	2162.273	866.0368	1325.866	1287.301
Groups	47	47	20	27	27
Observations	1111	1091	460	631	631
Turning point (long-run)	3.9180	4.22693	out of sample	-	-

Notes: We use the difficult option to avoid difficulty to maximize the likelihood function when nonconcave regions appear during estimation. The value of turning point is expressed in log. Standard errors in brackets. ***, **, * denote statistical significance at the 1%, 5%, and 10% level, respectively.

4. Heterogeneity

So far, we unveil that political stability exhibits a significant long-term non-linear effect on CO2 emissions, in our group of developing countries. Next, we investigate the presence of potential heterogeneities concerning the country's level of income and political stability subcomponents.

Considering that the implications of political stability on environmental degradation are rather a long-run phenomenon, we focus on highlighting the associated findings.

4.1. Level of economic development

Based on World Bank (2018) classification, we split our sample into two groups, namely LICs and LMICs. As shown in the last three columns of Table 5, our hypothesis stands only for LICs, indicating that the relationship between political stability and CO2 emissions is bell-shaped. However, the computed turning point lies outside the sample values and may suggest that LICs have not yet reached the optimal value of political stability that would ensure a reduction in CO2 pollution. For LMICs, we found no statistically significant link between variables. Next, to check the possibility of a linear relationship, we estimated the model dropping the squared term of political stability. The results in column (3b) of Table 5 strengthen the previous ones and indicate that political stability does not significantly affect CO2 pollution.

4.2. Political stability subcomponents

First, in line with Bekaert et al. (2006), we build the POLSTAB_SC1 and POLSTAB_SC2, which measures the quality of institutions and security status[12], respectively. Second, we further disaggregate the proxy for security status in two separate variables, namely POLSTAB_SC3 and POLSTAB_SC4. The former assesses the internal and external security, whereas the latter refers to religious and ethnic security. Third, we construct two more subcomponents which describe the government quality (POLSTAB_SC5), and politico-economic equilibrium (POLSTAB_SC6). Table 2 in the Appendix illustrates the way we define the subcomponents.[13]

Based on columns (3) and (5) in Table 6, the long-run effect of associated POLSTAB subcomponents on CO2 emissions exhibits an inverted-U shape pattern. Hence, CO2 pollution increases in the long-run for low levels of internal and external security and government quality, but the trend reverses in favor of the environment after the threshold is reached. Conversely, further levels of institutional quality (i.e., the sum of corruption, law, and order, and bureaucracy quality), politico-economic equilibrium (i.e., the sum of socioeconomic conditions, investment profile and democratic accountability), and religious and ethnic security could be linked with an increase in CO2 emissions. First, states with highly efficient regulatory settings may be tented to report larger pollution levels, yet the real and underreported emissions levels may be lower (Ivanova, 2011). Second, higher institutional quality and government effectiveness may amplify environmental policy stringency, and under some circumstances, pollution could rise. For example, a carbon tax policy that would entirely exempt energy- and trade-intensive sectors may generate an increase in sectoral CO2 emissions (Liang et al., 2007).

[12] In contrast to Bekaert et al. (2006), we name the variable "security status" instead of "conflict", as the higher the values, the lower the conflict, i.e., higher the security.
[13] It is worth mentioning that all newly six subcomponents could be interpreted in the same manner: the higher the values, the higher the institution quality, security, internal and external security, religious and ethnic security, government quality, and politico-economic equilibrium.

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The ECT term is negative and strongly statistically significant in all models, showing an average speed of adjustment to the long-run equilibrium, ranging from -0.315 (see column (1) of Table 6) to -0.353 (see column (3) of Table 6).

Table 6 - CO2 emissions and political stability: political stability subcomponents

Dependent variable: ΔCO2						
	POLSTAB_SC1	POLSTAB_SC2	POLSTAB_SC3	POLSTAB_SC4	POLSTAB_SC5	POLSTAB_SC6
	(1)	(2)	(3)	(4)	(5)	(6)
			Long-run coefficients			
POLSTAB_SC[*]	-0.379**	1.033*	0.890***	-1.681***	0.826***	-0.661***
	(0.163)	(0.623)	(0.270)	(0.235)	(0.183)	(0.190)
POLSTAB_SC[*]2	0.120**	-0.127	-0.141***	0.460***	-0.177***	0.127***
	(0.049)	(0.098)	(0.049)	(0.065)	(0.040)	(0.038)
GDP	0.644***	0.427***	0.478***	0.319***	0.598***	0.446***
	(0.043)	(0.035)	(0.035)	(0.043)	(0.044)	(0.038)
RENEW	-0.145***	-0.382***	-0.141***	-0.422***	-0.152***	-0.108***
	(0.019)	(0.051)	(0.027)	(0.063)	(0.027)	(0.019)
URB	-0.248***	-0.339***	-0.171**	0.066	-0.401***	-0.231***
	(0.092)	(0.081)	(0.068)	(0.104)	(0.094)	(0.082)
			Short-run coefficients			
ECT	-0.315***	-0.342***	-0.353***	-0.321***	-0.341***	-0.327***
	(0.042)	(0.041)	(0.039)	(0.046)	(0.054)	(0.045)
ΔPOLSTAB_SC[*]	0.306	0.640	-3.907	-3.496	-0.244	-0.070
	(0.819)	(3.441)	(2.835)	(7.485)	(0.402)	(1.710)
ΔPOLSTAB_SC[*]2	-0.091	-0.077	0.690	0.781	0.041	0.009
	(0.215)	(0.518)	(0.482)	(1.767)	(0.086)	(0.317)
ΔPOLSTAB_SC[*](t-1)	0.025	-0.002	-0.001	-0.037	0.032	-0.013
	(0.035)	(0.051)	(0.038)	(0.113)	(0.021)	(0.029)
ΔGDP	0.515***	0.556***	0.523***	0.750***	0.505***	0.514***
	(0.154)	(0.153)	(0.151)	(0.163)	(0.148)	(0.152)
ΔGDP(t-1)	-0.064	-0.081	-0.063	-0.196*	-0.005	-0.066
	(0.124)	(0.124)	(0.116)	(0.107)	(0.129)	(0.134)
ΔRENEW	-2.174***	-1.798***	-1.894***	-1.716***	-1.871***	-2.036***
	(0.622)	(0.547)	(0.499)	(0.572)	(0.513)	(0.562)
ΔRENEW(t-1)	0.455	0.140	0.204	0.096	0.284	0.318
	(0.389)	(0.189)	(0.185)	(0.151)	(0.242)	(0.281)
ΔURB	31.120	31.540	31.606	34.082*	34.625	30.547
	(25.870)	(28.155)	(27.925)	(20.922)	(25.950)	(22.509)
ΔURB(t-1)	-43.310	-4.904	-25.791	-26.442	-36.419	-20.780
	(39.301)	(32.646)	(37.197)	(25.383)	(35.803)	(33.525)
C	-1.578***	-1.504***	-2.012***	-0.507**	-1.879***	-1.034***
	(0.305)	(0.290)	(0.314)	(0.219)	(0.374)	(0.246)
Log Likelihood	2124.136	2174.824	2168.929	2130.259	2097.132	2124.131
Groups	47	47	47	47	47	47
Observations	1091	1091	1091	1091	1091	1091
Turning point (long-run)	1.58099	-	3.15498	1.82577	2.32402	2.60461

Notes: We use the difficult option to avoid difficulty to maximize the likelihood function when nonconcave regions appear during estimation. Each column from (1) to (6) corresponds to the associated POLSTAB subcomponent model. For instance, in column (1) the POLSTAB_SC[*] variables takes value 1 and describe the model of POLSTAB_SC[1]; the principle is preserved for all subcomponent's models. The values of turning point are expressed in log. Standard errors in brackets. ***, **, * denote statistical significance at the 1%, 5%, and 10% level, respectively.

5. Conclusions and policy implications

The events of the last ten-twenty years have shown that poorer countries are more prone to political conflicts and, more often, they are more violent compared to developed nations. Political stability is at the core of many economic implications, including environmental policies and regulations. According to empirical research, the findings are still inconclusive concerning pollution-political stability nexus. Also, the vast majority of studies focused on the impact of corruption and other institutional quality proxies on environmental degradation in developed nations, whereas the evidence for developing states remains incomplete.

This paper shed light on the effect of political stability on pollution in a sample of 47 developing countries over 1990-2015. More specifically, we examined a potential political stability threshold effect on CO2 emissions by controlling simultaneously for the size of the economy, the technological progress, the stringency of environmental regulations, and the ongoing urbanization process. In doing so, we relied on the PVECM technique, which allowed us to control for the presence of short-run heterogeneities across panel members while considering a common long-term path. Results supported the non-linear impact hypothesis and revealed a long-term bell-shaped pattern between political stability and CO2 emissions. Thus, political stability starts to reduce CO2 pollution only after the 68.51 threshold is reached. Hence, judging based on the range of political stability index values, some of the countries in our sample still have to improve their political stability condition, to be environmentally effective. Moreover, we unveiled significant heterogeneities in CO2 emissions-political stability nexus in terms of countries' income level and political stability subcomponents.

According to the overall results, some relevant policy implication could be drawn. First, developing countries often face a trade-off between growth and environmental degradation, demanding much more attention from policymakers. To avoid a possible 'pollution-trap' and reduce environmental degradation, the adoption of more environmentally friendly policies and low-carbon growth strategies that would closely track the environmental issues and ensure long-term sustainability is required. Consequently, the proper functioning and stability of the political system as a whole, play a vital role in shaping the environmental policies. As our empirical findings suggest, both the formal (i.e., political roles and structures) and informal side (i.e., social roles and structures) of the political framework contributes substantially to reducing environmental degradation. As such, close cooperation of government and non-government structures could foster political stability, which in turn may reflect in more efficient and effective policies and regulations. Second, the least poor countries, where the political optimum is not yet achieved, should be more carefully monitored regarding the political stability evolution and its potential effects on CO2 pollution. Third, to eliminate possible deviations from the optimal path, also more attention should be directed towards the subcomponents of political stability index associated with an increase in CO2 emissions. Fourth, the maximization of energy efficiency and replacement of old fossil fuel-based energy with the new generation of renewable and nuclear technologies may help in lowering CO2 pollution. Future perspectives could be a regional or sectorial analysis to capture potential disparities in the environmental degradation-political stability nexus within countries and/or economic sectors.

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Appendix

Table 1 – List of countries

Geographic region					
East Asia and Pacific (6)	Europe and Central Asia (2)	Latin America and Caribbean (5)	Middle East and North Africa (4)	South Asia (4)	Sub-Saharan Africa (26)
Indonesia	Moldova	Bolivia	Egypt, Arab Rep.	Bangladesh	Angola
Mongolia	Ukraine	El Salvador	Morocco	India	Burkina Faso*
Myanmar		Haiti*	Tunisia	Pakistan	Cameroon
Papua New Guinea		Honduras	Yemen, Rep.*	Sri Lanka	Congo, Dem. Rep. *
Philippines		Nicaragua			Congo, Rep.
Vietnam					Côte d'Ivoire
					Ethiopia*
					Gambia*
					Ghana
					Guinea*
					Guinea-Bissau*
					Kenya
					Liberia*
					Madagascar*
					Malawi*
					Mali*
					Mozambique*
					Niger*
					Nigeria
					Senegal*
					Sierra Leone*
					Tanzania*
					Togo*
					Uganda*
					Zambia
					Zimbabwe*

Notes: (*) indicates that the respective country belongs to the low-income group.

Table 2 – Variable definitions

Variable	Definition	Source
CO2	CO2 per capita emissions totals of fossil fuel use and industrial processes. [tonnes]	The European Commission. Janssens-Maenhout, Crippa, Guizzardi, Muntean, Schaaf, Olivier, Peters and Schure (2017) http://edgar.jrc.ec.europa.eu/overview.php?v=booklet2017&dst=CO2pc
POLSTAB	ICRG political risk index. [scale from 0-100, 0 designating the highest risk, and 100 the lowest risk]	International Country Risk Guide (ICRG), Political Risk Services (PRS) Group https://www.prsgroup.com/explore-our-products/international-country-risk-guide/
POLSTAB_SC1	The sum of corruption, law and order, and bureaucracy quality.	
POLSTAB_SC2	The sum of internal conflict, external conflict, religious tensions, and ethnic tensions.	
POLSTAB_SC3	The sum of internal conflict and external conflict.	
POLSTAB_SC4	The sum of religious tensions and ethnic tensions.	
POLSTAB_SC5	The sum of government stability and military in politics.	
POLSTAB_SC6	The sum of socioeconomic conditions, investment profile and democratic accountability.	
GDP	GDP per capita, PPP. [constant 2011 international $]	World Development Indicators (WDI), World Bank (2019) https://databank.worldbank.org/data/home.aspx
RENEW	Renewable energy consumption. [% of total final energy consumption]	
URB	Urban population. [% of total population]	

Table 3 – Summary statistics

Variable	Mean	Std. dev	Median	Min	Max	Observations
CO2	0.861	1.431	0.399	0.0311	15.298	1222
POLSTAB	55.645	9.929	56.840	9.750	75	1205
GDP	3156.883	2211.214	2657.992	354.284	11411.940	1207
RENEW	61.488	28.848	70.569	0.600	98.342	1212
URB	37.840	14.942	36.556	11.076	69.70	1222
POLSTAB_SC1	6.642	1.962	7	0.75	11	1205
POLSTAB_SC2	25.153	4.708	25.5	5.09	34.17	1205
POLSTAB_SC3	17.603	3.347	18.04	2.17	24	1205
POLSTAB_SC4	7.550025	2.113933	8	1.5	12	1205
POLSTAB_SC5	10.26432	2.613782	10.5	1	16.13	1205
POLSTAB_SC6	13.58563	3.462018	14.08	1	20.67	1205

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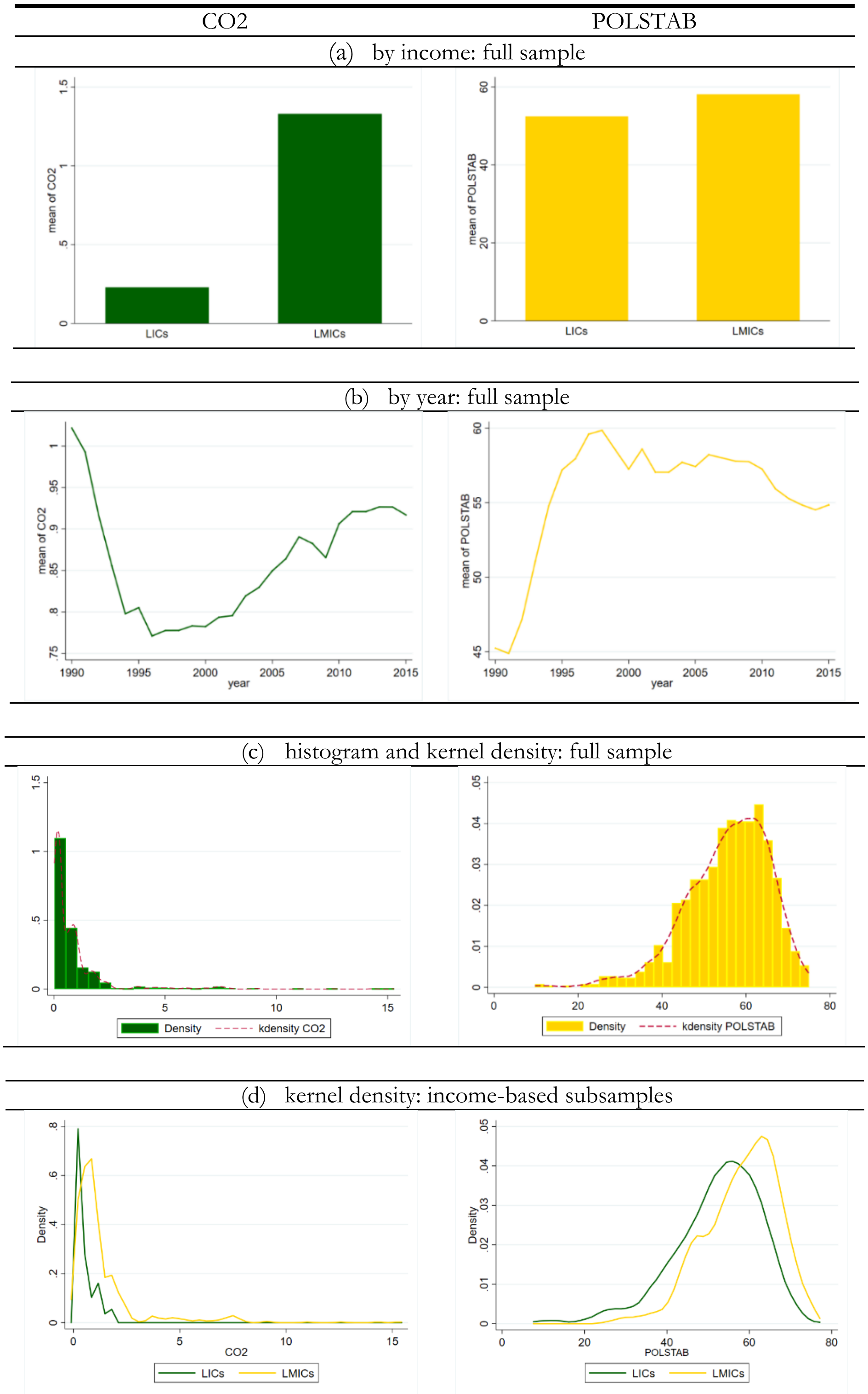

Notes: All graphs refer to the raw values of CO2 and POLSTAB variables (i.e., prior applying natural logarithm transformation). From (a) to (d), column (1) shows the CO2 emissions graphs, while column (2) POLSTAB related graphs. LICs stands for lower-income countries, and LMICs for lower-middle-income countries.

Figure 1 – CO2 emissions and political stability stylized facts