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ECONOMIC DEVELOPMENT AND ENVIRONMENTAL QUALITY NEXUS IN DEVELOPING AND TRANSITION ECONOMIES

«Summary»

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Contents

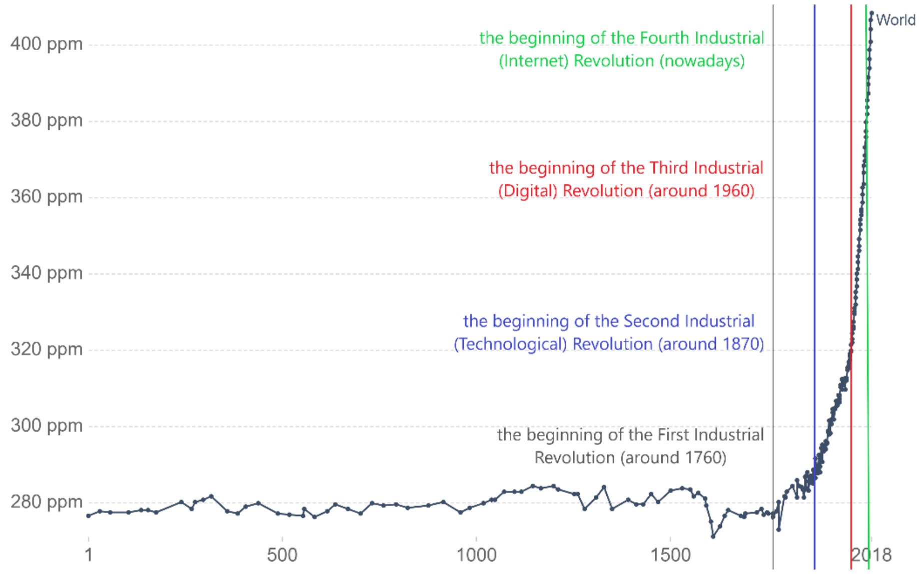
Summary

1. Context of the research

Over time, following the awareness of the adverse effects that the dynamic and multidimensional process of economic development has on the environment, the interest in maintaining and enhancing the quality of the environment has increased considerably. The First Industrial Revolution (FIR) onset was the basis for diversification and intensification of economic activities, leading to significant changes in nations' economic systems. More on this point, along with the development of the industry, various key changes interfere concerning the evolution of the economic sphere, such as (i) the gradual replacement of manual production with the mechanized ones (i.e. technical progress), (ii) the diversification of production/division of labor, (iii) the productivity gains due to increased production, (iv) the emergence of numerous conglomerates due to the process of concentration of production, and (v) shifts in the sectoral economic structure—the largest contribution to the gross domestic product belongs to the industry. Indeed, the aspects mentioned above, among others, have substantially contributed to the development of the countries, but they have also caused several threats to the environment.

Prior to the FIR, the population's activities were mainly agrarian and, thus, the connection between man and nature being also very tight. On the one hand, the FIR led to the acceleration of technological progress, which has significantly helped improve the population's living standards. However, on the other hand, the worrying increase in environmental degradation, accompanied by the alteration of the human-nature relationship, may be considered some of its main side effects. In this fashion, a straightforward example is given by the sharp increase of the atmospheric carbon dioxide (CO2) concentration, following the FIR's start. According to Figure 1, before the emergence of FIR, the average concentration of the CO2 in the atmosphere ranges between approximatively 270 and 280 parts per million (ppm), then the trend rapidly changes and the concentration reach in 2018 the record value of 400 ppm, and even exceed it. Put differently, considering an average CO2 concentration of about 277 ppm in 1760 and 400 ppm in 2018, the growth rate in 2018 compared with 1760 is roughly 44.4%.

Figure 1: Global CO2 atmospheric concentration



Notes: Average concentration of carbon dioxide (CO2) in the atmosphere, measured in parts per million (ppm). Source: Adapted from Ritchie & Roser (2017) based on National Oceanic and Atmospheric Administration (NOAA)/Earth System Research Laboratories (ESRL) (2018). https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions

Broadly speaking, two clear-curt conclusions may be drawn by evaluating this simple suggestive plot. First, globally, environmental degradation has reached unprecedented levels, endangering the well-being of societies. Second, its exponential evolution suggests, among others, the difficulty of combating these kinds of phenomena once they have been triggered. As Figure 1 illustrates, despite the passage of new industrial stages that assume, among others, an evolution of societies in terms of technologies and methods to mitigate environmental degradation, and also an inevitable shift in population's perceptions of environmental issues, the atmospheric concentration of CO2 has remained steady upward. These facts indicate that the efforts made today in the fight against climate change may only be seen after a fairly long period, while consistent international cooperation may underpin the efficacity of the related actions.

Accordingly, the last decades' actions of (supra)national authorities and several profile organizations, have been directed towards finding an equilibrium point between economic development and the environment, namely to ensure sustainable development. On this path, at the international level, the United Nations (UN) put into place the United Nations Framework Convention on Climate Change (UNFCCC), whose main scope is to adjust the "greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (UN, 1992, p. 9).[1] On the one hand, under this framework has been adopted the well-known Kyoto Protocol and the Paris Agreement, which governs the parties' actions regarding the reduction of GHG emissions. Notably, the former treaty has targeted merely the developed states, while the latter agreement has labor the point towards the involvement of both industrialized and developing economies in tackling climate change.

On the other hand, within the Kyoto Protocol also operates three flexible mechanisms, one of which [i.e. the Clean Development Mechanism (CDM)] is designed to jointly engage developed and developing states in limiting emissions and securing sustainable development. Specifically, industrialized countries (i.e. Annex B Parties to the Kyoto Protocol) can contribute to meeting their climate commitments by purchasing the Certified Emission Reductions (CERs) issued following the implementation of projects and/or programs aimed to reduce GHG emissions in developing economies (i.e. Non-Annex I states). Indeed, probably as any other market-based mechanism, the CDM has its weaknesses and strengths [see e.g. Carbon Market Watch (CMW), 2018] but, overall, it has proven to be an effective tool in the fight against climate change [see UN Climate Change (UNCC), 2018]. Based on the last report mentioned above, over the period 2001-2018, the CDM has engaged 140 countries (36 being included in the group of 46 of the poorest countries in the world), while the projects and programs that have been registered in 111 developing countries have reached a record number of 8116. Moreover, among its many achievements, one of the most prominent is the equivalent reduction of roughly 2 billion tonnes of CO2 in Non-Annex I economies (i.e. 2 billion CERs have been issued due to a reduction in emissions through the projects and programs implemented in developing states), following the financing of the significant number of climate action projects totaling 303,8 billion US$ (UN, 2018).

Certainly, the CDM has represented a first step regarding the involvement at the global level of developing countries in the fight against climate change, paving the way for a more active contribution of these states in reducing GHG emissions alongside the developed ones. In this vein, the Paris Agreement has provided a novel framework concerning the actions aimed at tackling climate change, which equally targets both

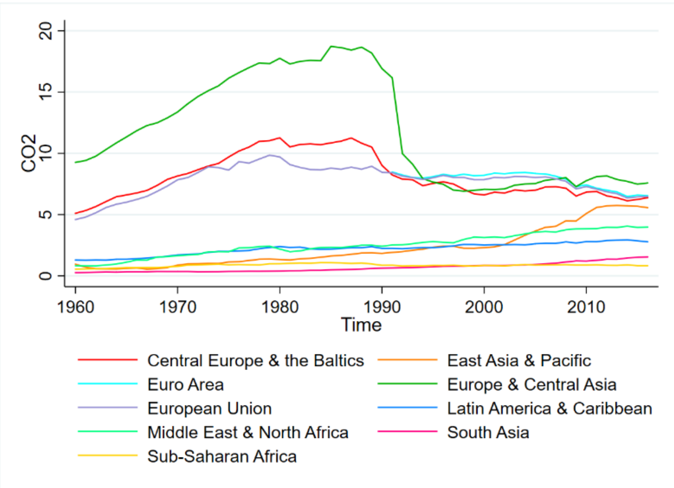
[1]https://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf.

industrialized and developing economies. Likewise, it has established the basis of the CDM's predecessor, namely the Sustainable Development Mechanism (SDM), which borrows some of the characteristics and builds on the shortcomings that CDM has revealed during its implementation; thus, post-2020, the SDM may represent the next phase of international carbon markets and a vital tool in lowering the global emissions levels (CMW, 2017).

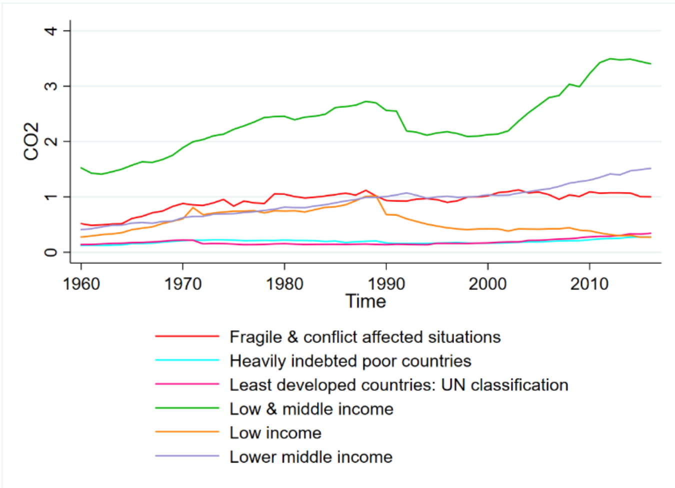
As stated previously, regarding climate change mitigation, the emphasis was initially put more on industrialized economies due to their predisposition to pollute more than developing countries and financial capacity to contribute to related actions. However, along with economic development, circumstances are gradually changing, and major transformations occur in developing countries from both economic, social, and political perspectives, leading (more or less) to an increase in environmental degradation. As such, their propensity to contribute to the worsening of climate change is growing concurrently with their active involvement at the (inter)national level in combating it. Figure 2 illustrates the evolution of CO2 per capita by region and income group or other classifications, paying particular attention to developing economies. Overall, apart from the nonlinearities visible in some series' evolution, the vast majority of them seem to be characterized by an upward trend, which is more or less pronounced over the analyzed period and/or the recent years.

Figure 2: CO2 per capita emissions over time [1960-2016]

(a) by region



(b) by income group and other classifications



Notes: CO2 emissions are measured in metric tonnes per capita. The starting date for the Euro Area group is 1991. We use the World Bank classification that excludes the high income economies for the regions where this is available, namely East Asia & Pacific, Europe & Central Asia, Latin America & Caribbean, Middle East & North Africa, and Sub-Saharan Africa. Source: Author's elaboration using the World Development Indicators Data-World Bank (2020).

Given the (sudden) dynamics of climate change and the desire to find some legitimacies about its evolution/behavior and explore its potential determinants, the related macroeconomic literature has seen a real breakthrough. Undeniably, the wave of the research in the field was even more noticeable since the early 1990s with the introduction of Environmental Kuznets Curve (EKC) hypothesis[2] (Grossman & Krueger, 1991) and the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) framework[3] (Dietz & Rosa, 1994, 1997). These two popular theoretical backgrounds taken separately or together, respecified or mixed with other theoretical and/or empirical foundations, have been the starting grid for numerous empirical and theoretical works that have targeted the drivers (especially economic growth) of environmental degradation. Besides, since their genesis several other theoretical studies (see e.g. Xepapadeas, 2005; Brock & Taylor, 2010; Kijima et al., 2010; Ordás Carido et al., 2011) have provided various insights with respect to pollution-growth nexus, adding to the general understanding of this seemingly simplistic relationship which, eventually, turned out to be much more complex. Also, this rapidly expanding literature has been the starting point for many surveys, criticisms, and recommendations, both in terms of the underlying economic theory, and econometric and statistical aspects (see e.g. Stern et al., 1996; Borghesi, 1999; Lieb, 2003; Stern, 2004; He, 2007; Wagner, 2008; Aslanidis, 2009; Vollebergh et al., 2009; Carson, 2009; Stern, 2010; Bo, 2011; Pasten & Figueroa, 2012; Kaika & Zervas, 2013a, b; Bernard et al., 2014; Hervieux & Mahieu, 2014; Stern, 2015; Sen et al., 2016; Stern et al., 2017; Tiba & Omri, 2017). However, in the light of those mentioned above, most studies have mainly focused on developed countries, while specific groups of states such as developing and transition ones have not received such great attention. Lately, the literature has started to develop in this direction, but the empirical evidence can still be considered scarce.

Building on these facts and in consonance with the UN Sustainable Development Goals (SDGs), we exploit the peculiarities of transition and developing economies (e.g. the liberalization and globalization process, energy transition and its efficiency, sectoral structure, environmental prospects, among others) to pinpoint the impact of economic

[2] According to traditional EKC, the relationship between economic growth and environmental degradation follows a bell-shaped pattern.
[3] The STIRPAT framework represents the stochastic counterpart of IPAT identity proposed by Ehrlich & Holden (1971, 1972), based on which the human pressures on the environment are computed as a product between three terms: population, affluence, and technology.

development—through its three dimensions namely, economic, social and political—on environmental degradation as effectively as possible. More specifically, depending upon the context, along with the commonly acknowledged determinant of environmental pollution, namely the economic growth (see e.g. the peioneering works of Shafik & Bandyopadhyay, 1992; Panayotou, 1993; Shafik, 1994; Stern et al., 1996; Panayotou, 1997; Dasgupta et al., 2002; Coondoo & Dinda, 2002; Stern, 2003, 2004; Martinez-Zarzoso & Bengochea-Morancho, 2004; and the more recent studies of Kasman & Duman, 2015; Yang et al., 2015; Hanifa & Gago-de-Santos, 2017; Ozokcu & Ozdemir, 2017; Alvarado et al., 2018; Albulescu et al., 2019; Awad, 2019; Destek & Sarkodie, 2019; among others), we explore the potential impact of other key aspects of economic development process, which are more related to its social and political dimensions, namely the urbanization (see e.g. Poumanyvong & Kaneko, 2010; Martínez-Zarzoso & Maruotti, 2011; Zhu et al., 2012; Liddle, 2013; Sadorsky, 2014a; Wang et al., 2015; Wang et al., 2016; Chen et al., 2019; Xie & Liu, 2019; among others), and political stability, respectively (see e.g. Desai, 1998; López & Mitra, 2000; Welsch, 2004; Cole, 2007; Leitão, 2010; Gani, 2012; Halkos & Tzeremes, 2013; Zhang et al., 2016; Joshi & Beck 2018; among others).[4]

Consequently, this thesis contributes to the nascent literature on economic development's effects on environmental quality in transition and developing countries. In this vein, aiming to broaden the knowledge in the field, we provide four genuine essays, one literature survey, and three empirical essays whose objectives stem to some extent from the lessons learned following the literature survey.

2. A glimpse on thesis' data and methodology

2.1. Data

Given that the thesis aims to provide original empirical evidence and contribute to the literature on the environmental pollution-economic development nexus for transition

[4] Concerning the link between urbanization/political stability and environmental degradation, some studies control to a greater or lesser extent for their potential effects, while exploring the impact of other phenomena on environmental pollution [see e.g. Iwata & Okada (2014), Li et al. (2016), Awad & Warsame (2017), Lin & Zhu (2017), Joshi & Beck (2018) for urbanization, and Shahbaz et al. (2013), Ozturk & Al-mulali (2015), Abid (2017) Sarkodie & Adams (2018) for political stability. Furthermore, it is worth noted that regarding the political stability as a whole, most of the works investigate the effects of its different components on environmental pollution (or put in other words the political stability is proxied by various indicators related to political system) such as corruption, governance, democracy, institutional quality, among others.

and developing countries, the data collection necessary for the empirical analysis may be challenging. It is generally agreed that concerning the transition economies, the data quality and availability are relatively poor for the years that precede the fall of the Communist Bloc. The same holds for several low and lower-middle income states, whose series of macroeconomic indicators, for certain reasons, are completely missing for specific periods or display missing values.

The first chapter being a literature survey that comprises, among its specific elements, a short empirical exercise, does not require extra effort for data collection. However, we mention that for some countries included in our descriptive investigation, the series values are available only starting with 1990.

The second chapter focuses on Central and Eastern European (CEE) states, which experienced major imbalances at the beginning of the 1990s. Thus, we mitigate such instabilities by restricting our sample to start only in 1996. This period allows obtaining a relatively well-balanced sample around a critical period that triggered important structural changes, namely the mid-period of the two dates of European Union (EU) enlargement with CEE countries (2004 and 2007, with Croatia joining EU in 2013). On top of that, starting our analysis with 1996, we control for the possible hard times that these economies cross after the end of the Cold War.

Regarding the last two chapters (the third and fourth one), which target the low and lower-middle income countries, the samples' members are solely selected according to data availability. Likewise, we also set the time dimension starting point (i.e. 1992 for the third chapter and 1990 for the last one), taking into account the lack of observations for the primary indicators. Indeed, having the starting year at the beginning of the 1990s, we also avoid the distortions caused by both the Soviet Empire's collapse and/or the end of the Cold War. Besides, via the robustness checks, depending on the period examined, we drop the years before and/or following the end of the Cold War to further control for its potential detrimental effects.

Overall, the empirical studies of the thesis resort to various data sources, namely Emissions Database for Global Atmospheric Research (Janssens-Maenhout et al., 2017), World Bank Indicators, Eurostat, Heritage Foundation, KOF Swiss Economic Institute (Dreher, 2006; Gygli et al., 2019), Observatory of Economic Complexity (Haussman &

Hidalgo, 2009; Hausman et al., 2011), UN Development Programme, Global Footprint Network, European Environmental Agency, International Country Risk Guide of Political Risk Services Group, and UN Conference on Trade and Development.

2.2. Methodology

The empirical strategy employs in each chapter seeks to fit as well as possible on the characteristics of the sample, and the uni- and multi-variate properties of the variables under investigation. Consequently, in light of the progress in statistics and econometrics, we try to keep up with it as much as possible, using a series of modern statistical and econometric techniques to capture the phenomena studied with a high degree of accuracy.

In the first chapter, complementary to some classical descriptive techniques, we also use with illustrative purposes several nonparametric ones. These nonparametric methods, such as local linear, local polynomial, and lowess regression, are implemented to consolidate our judgment with respect to the potential patterns between the variables. In this regard, we proxy environmental degradation by CO2 emissions per capita and economic growth by GDP per capita and specify the following equation

$$CO2 = \phi(GDP) + \varepsilon \qquad (1)$$

The CO2 is the endogenous variable, GDP is the predictor variable and $\varepsilon \sim NID(0, \sigma^2)$ the error term. $\phi(.)$ denotes the unknown smooth continuous function, whose functional form is not specified, i.e. is estimated based on data.

Next, the econometric modeling in the second chapter relies on three estimators, namely the Mean Group (MG) (Pesaran & Smith, 1995), the Mean Group Fully Modified Least Squared (MG-FMOLS) (Pedroni, 2000, 2001), and the Augmented Mean Group estimator (AMG) (Eberhardt & Teal, 2008, 2010; Eberhardt & Bond, 2009), which have good small sample properties and deals with the variables' nonstationary and cointegration. Moreover, these estimators are designed for heterogeneous slope coefficients panel data models, where cross-sectional dependence (the AMG approach) may be at work. As well, the A(MG) techniques allow the estimation of country-specific regressions, while they are also robust to a different order of variables' integration.

Starting from a simple fixed-effects slope-heterogeneity panel regression

$$y_{it} = \alpha_i + \beta_i x_{it} + u_{it}, \tag{2}$$

Pesaran & Smith (1995) coined the MG estimator that deals with parameters' heterogeneity by averaging the individual slopes obtained from individual OLS regressions for each member of the panel. Formally, the MG estimator can be written (see Hsiao & Pesaran, 2004)

$$\beta_{MG} = \frac{1}{N}\sum_{i=1}^{N}\beta_i, \tag{3a}$$

with its variance defined as

$$Var(\beta_{MG}) = \frac{1}{N(N-1)}\sum_{i=1}^{N}\left(\beta_{i_i} - \bar{\beta}\right)^2. \tag{3b}$$

Moreover, we draw upon Pedroni (2000, 2001), to write the MG-FMOLS estimator as

$$\beta_{MG-FMOLS} = \frac{1}{N}\sum_{i=1}^{N}\left[\left(\sum_{t=1}^{T}(x_{it} - \bar{x}_i)^2\right)^{-1}\left(\sum_{t=1}^{T}(x_{it} - \bar{x}_i)y_{it}^{*} - T\gamma_i\right)\right], \tag{4a}$$

with

$$y_{it}^{*} = (y_{it} - \bar{y}_i) - \left(\frac{\Omega_{21,i}}{\Omega_{22,i}}\right)\Delta x_{it} \tag{4b}$$

and

$$\gamma_i = \Gamma_{21,i} + \Omega_{21,i}^{0} + \left(\frac{\Omega_{21,i}}{\Omega_{22,i}}\right)\left(\Gamma_{21,i} + \Omega_{22,i}\right), \tag{4c}$$

with

$$\Omega_i = \lim_{T\to\infty} E\left[\left(T^{-1}\sum_{t=1}^{T} z_{it}\right)\left(T^{-1}\sum_{t=1}^{T} z'_{it}\right)'\right] \tag{4d}$$

the long-run covariance of the stationary vector $z_{it} = (u_{it}, \Delta x_{it})'$, which can be written as the sum between the contemporaneous covariance Ω_i^0 and Γ_i the weighted sum of autocovariances, namely:

$$\Omega_i = \Omega_i^0 + \Gamma_i + \Gamma_i'. \tag{4e}$$

Finally, more recently, Eberhardt & Teal (2008, 2010), Eberhardt & Bond (2009), and Eberhardt (2012) developed the AMG estimator that accounts for both parameters heterogeneity and cross-sectional dependence. Having in mind the traditional panel model, the potential presence of cross-sectional dependence is captured by the structure of both unobservables and observables, namely

$$u_{it} = \varphi_i + \lambda_i f_t + \varepsilon_{it} \tag{5a}$$

and

$$x_{it} = \xi_i + \lambda_i f_t + \gamma_i g_t + v_{it}, \tag{5b}$$

with φ_i and ξ_i group fixed effects, f_t and g_t common factors with heterogeneous factor loadings λ_i, and ε_{it} and v_{it} white noises. The merit of this method is to move away from other estimation techniques for heterogeneous panels (e.g. Common Correlated Effects Mean Group estimator–CCEMG; Pesaran, 2006) that consider the unobservable common factors as a nuisance, by modeling them as a common dynamic process, namely

$$y_{it} = \alpha_i + \beta_i x_{it} + \eta_i t + d_i \phi_t + e_{it}, \tag{5c}$$

with ϕ_t the dynamic process variable constructed from a regression in first differences

$$\Delta y_{it} = \beta \Delta x_{it} + \sum_{t=2}^{T} \phi_t \Delta D_t + e_{it} \tag{5d}$$

and $\eta_i t$ a linear trend.

As a result, the AMG estimator is

$$\beta_{AMG} = \frac{1}{N} \sum_i \beta_i. \tag{5e}$$

In the second chapter, we draw upon these estimators to analyze the relationship between GDP and CO2 in our panel of CEE countries.

To answer the third chapter's research questions from a methodological standpoint, we employ the panel vector autoregression (VAR) analysis. In this manner, bearing in mind the sample's features, we specify a generalized method of moments (GMM) panel VAR model in the spirit of Love & Zicchino (2006) and Abrigo & Love (2016). This quite appealing empirical strategy allows us to further compute, based on the model's estimations, the important impulse response functions (IRFs), and forecast-error variance decompositions (FEVDs), which help us shape the conclusion regarding the study's main objective.

The specification of a homogeneous panel VAR with individual fixed effects can be written as follows

$$Y_{it} = W^{\bullet} + Y_{it-1} W_1 + Y_{it-2} W_2 + \cdots + Y_{it-p} W_p + \nu_i + \varepsilon_{it}, \tag{6a}$$

or considering its reduced-form

$$Y_{it} = W^{\bullet} + W(L) Y_{it} + \nu_i + \varepsilon_{it}, \tag{6b}$$

with $i \in \{1, 2, \dots, N\}$ and $t \in \{1, 2, \dots, T\}$.

In equations (6a)-(6b), Y_{it} represents the vector of our four stationary endogenous variables (i.e. GDP, URB, EINT, RENG, and CO2). $W(L)$ stands for associated matrix polynomial in the lag operator (i.e. the autoregressive structure), while $W^{\bullet}$ is the vector of constants. Likewise, ν_i and ε_{it} denotes the vector of unobservables country-specific characteristics and idiosyncratic errors, respectively. The unobservables may capture the cultural, institutional, and historical individual country characteristics that are time-invariant. As in Abrigo & Love (2016), we assume that the vector of idiosyncratic errors ε_{it} possesses the following features: $E[\varepsilon_{it}] = 0$, $E[\varepsilon_{it}'\varepsilon_{it}] = \sum$ and $E[\varepsilon_{it}'\varepsilon_{is}] = 0$, $\forall\, t > s$. Put differently, the innovations have zero first moment values, constant variances, and do not exhibit individual serial and cross-sectional correlation.

In the last chapter, we model the nexus between variables using the Panel Autoregressive Distributed Lag (ARDL) approach. In this regard, given the cointegration presence, we employ the Panel Vector Error Correction Model (PVECM) version of the ARDL technique, which enables us to retrieve both the long-run elasticities and short-run dynamics between variables. Specifically, in line with the assumed hypotheses, we center our analysis around the technique preferred by the data, namely the Pool Mean Group (PMG) estimator coined by Pesaran et al. (1999). Furthermore, to control for the correlation across countries, in the robustness section we employ a set of four much novel techniques, namely the Cross-Section Augmented ARDL (CS-ARDL) (Chudik et al., 2013), the Cross-Section Augmented Distributed Lag (CS-DL) (Chudik et al., 2013; Chudik et al., 2016), the Common Correlated Effects (CCE) (Pesaran, 2006; Chudik & Pesaran, 2015) and the AMG approach (Eberhardt & Teal, 2008, 2010; Eberhardt & Bond, 2009). It is also worth mentioning that depending on the technique, we employ its error correction counterpart, relax the long-run slope coefficients poolability assumption, and specify a static or dynamic model. The mathematical expressions of the previously mentioned estimators are illustrated below.

First, following the work of Pesaran et al. (1999), the mathematical specification of the autoregressive distributed lag $[ARDL(p, q_1 \dots q_k)]$ dynamic panel model can be written as

$$CO2_{it} = \sum_{j=1}^{p} \partial_{ij} CO2_{it-j} + \sum_{j=0}^{q} \gamma_{ij}' x_{it-j} + \mu_i + \varepsilon_{it}. \quad (7)$$

In the above equation the subscript $i = \overline{1,N}$ represents the panel members (countries) and $t = \overline{1,T}$ designates the periods (number of years); CO2 is our dependent variable, the log of CO2 emissions per capita, and $x_{it} = (PS_{it},\ GDP_{it},\ RENG_{it}, EINT_{it})'$ $(k \times 1)$ is the vector of explanatory variables, with $\gamma_{ij}(k \times 1)$ associated coefficients vector; μ_i denotes the country-specific fixed effects, while ε_{it} represents the error term. We also note that the lag order of the dependent variable, p, and independent factors, q, should be set such that the error term, ε_{it}, does not exhibit serial correlation across panel members, i.

Furthermore, the individual mean level coefficient estimates based on the ARDL approach are computed as

$$\hat{\beta}_{ARDL,i} = \frac{\sum_{j=0}^{q} \hat{\gamma}_{ij}}{1 - \sum_{j=1}^{p} \hat{\partial}_{ij}}. \tag{8}$$

Therefore, the mean long-term estimates are given by the following expression: $N^{-1} \sum_{i=1}^{N} \hat{\beta}_{ARDL}$. In addition, we note that $\hat{\partial}_{ij}$ and $\hat{\gamma}_{ij}$ represent the short-run estimates from equation (7).

Assuming that variables are nonstationary and cointegrated, the above equation [(7)] can be rewritten into a PVECM. Thus, the equation that incorporates along with long-term coefficients both the short-run elasticities and the error correction term (ECT) has the following form

$$\Delta CO2_{it} = \phi_i (CO2_{it-1} - \lambda_i' x_{it}) + \sum_{j=1}^{p-1} \partial_{ij}^{*} \Delta CO2_{it-j} + \sum_{j=0}^{q-1} \gamma_{ij}'^{*} \Delta x_{it-j} + \mu_i + \varepsilon_{it}, \tag{9}$$

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

Second, in line with the work of Chudik et al. (2013), we write the equation of CS-ARDL as follows

$$CO2_{it} = \sum_{j=1}^{p} \partial_{ij} CO2_{it-j} + \sum_{j=0}^{q} \gamma_{ij}' x_{it-j} + \sum_{j=0}^{\pi} \omega_{ij}' \bar{z}_{t-j} + \mu_i + u_{it}, \tag{10}$$

where the new terms $\bar{z}_{t-j} = \left(\overline{CO2}_{t-j}, \bar{x}'_{t-j}\right)'$, $\bar{z}_t = N^{-1}\sum_{i=1}^{N} z_t$, while π stands for the number of cross-sectional averages' lags.

In addition, taking into account the nonstationary and cointegration features of the variables, we can rewrite the above equation into the following ECM

$$\Delta CO2_{it} = \phi_i(CO2_{it-1} - \theta'_i x_{it}) + \sum_{j=1}^{p-1} \delta_{ij}\,\Delta CO2_{it-j} + \sum_{j=0}^{q-1} \varphi'_{ij}\,\Delta x_{it-j} + $$

$$+ \sum_{j=0}^{\pi} \omega'_{ij}\bar{z}_{t-j} + \mu_i + u_{it}, \quad (11)$$

Third, in the spirit of Chudik et al. (2013) and Chudik et al. (2016), we can write the equation of CS-DL in the below form

$$CO2_{it} = \tau'_i x_{it} + \sum_{j=0}^{q-1} \sigma'_{ij}\Delta x_{it-j} + \psi_{ico2}\overline{CO2}_t + \sum_{j=0}^{\pi} \psi'_{ixj}\bar{x}_{t-j} + \eta_i + e_{it}, \quad (12)$$

where $\bar{x}_t = N^{-1}\sum_{i=1}^{N} x_{it}$, $\overline{CO2}_t = N^{-1}\sum_{i=1}^{N} CO2_{it}$, $e_{it} = A_i(L)^{-1}u_{it}$, $\eta_i = A_i(L)^{-1}u_{it}$, $\tau_i = A_i(L)^{-1}\sum_{j=0}^{q}\gamma_{ij}$, $\sigma_i = A_i(L)^{-1}\nu_{ij}$, $\nu_{ij} = -\sum_{k=j+1}^{q}\gamma_{ik}\ for\ j = 1, \dots, p-1$. ψ_{ico2} and ψ_{ixj} are the factor loadings which also comprise $A_i(L)^{-1}$, compared to ω_{ij} from equation (10), while L denotes the lag operator.

Fourth, in the context of our analysis, adding as additional regressors the cross-sectional averages of both dependent and independent variables would yield to the mathematical expression of static CCE estimator as follows

$$CO2_{it} = \gamma'_i x_{it} + \omega'_i\bar{z}_t + \mu_i + u_{it}, \quad (13)$$

where $\bar{z}_t = (\overline{CO2}_t, \bar{x}'_t)'$ and $\bar{z}_t = N^{-1}\sum_{i=1}^{N} z_t$.

Fifth, following Chudik & Pesaran's (2015a) work, to control for the potential persistence in the dependent variable, we employ the CEE estimator in its dynamic form (i.e. DCCE). The mathematical expression of the dynamic model is written as

$$CO2_{it} = \partial_i CO2_{it-1} + \gamma'_i x_{it} + \sum_{j=0}^{\pi} \omega'_{ij}\bar{z}_{t-j} + \mu_i + u_{it}, \quad (14)$$

where $CO2_{it-1}$ is the lagged value of $CO2_{it}$, π denotes the number cross-sectional averages' lags of dependent and independent factors, and the remaining terms are defined as in the previous equations.

Finally, we also employ the novel Augmented Mean Group (AMG) estimator [describe by equations (5c)-(5d)-(5e) above] robust in the presence of cross-sectional dependence introduced in Bond & Eberhardt (2009) and Eberhardt and Teal (2010).

In sum, this thesis's methodology falls within the one specific to the panel time-series data models, where the nonstationarity, cointegration, slopes heterogeneity, and cross-sectional dependence may be considered a concern—all together or mixtures between them.

3. Thesis outline

The ongoing societal transformations place the relationship between economic development and environmental quality among the central and most debatable topics in economics and many other related areas.

Although the strand of literature regarding the effects of economic development on environmental degradation has a history of several decades, the complexity of the link and the empirical and theoretical findings that do not provide a solid consensus seems to instigate even more the flourishing of the research in the field. However, many aspects still need to be elucidated and understood in more depth, especially with respect to transition and developing economies, whereas the dynamics of economic phenomena make this mission much challenging. Indeed, a deeper understanding of the implications that the relationship between economic development and environmental pollution has on society as a whole is a topic of interest not only for academia but also for decision-making bodies responsible for designing, implementing, and monitoring the sustainable development policies.

This thesis explores the link between economic development and environmental quality by looking holistically at the effects of economic development, in terms of its economic, social, and political dimensions, on the environmental pollution for developing and transition economies. It comprises four chapters, first corresponding to a literature survey, and each of the next three provides an empirical essay, which addresses different aspects of the potential impact of economic development on environmental quality.

Chapter I *«New Insights into the Environmental Kuznets Curve Hypothesis in Developing and Transition Economies: A Literature Survey»*[5] gives a fresh look on the literature concerned with examining the pollution-growth nexus via the EKC hypothesis in developing and transition economies. Overall, the previous related works have provided mixed empirical findings regarding the EKC validity, while, during the years, several theories that have tried to explain the potential bell-shaped pattern between environmental degradation and economic growth have emerged in the literature. Our study brings together into an integrated setup, both the most well-known economic reasonings behind the EKC incidence and a significant number of empirical papers published in the last decade in various top journals in the field. Indeed, on the one hand, focusing on a more homogeneous group of countries such as developing and transition economies, which possess a series of particularities compared to developed nations, we can obtain specific insights and better understand the well-debatable relationship between pollution and growth. On the other hand, we certainly could not deny that the advance in statistical and econometric techniques and the increase in data availability/quality have changed how researchers address the EKC hypothesis. Thus, we expect to observe some improvements in its prediction and the associated threshold value.

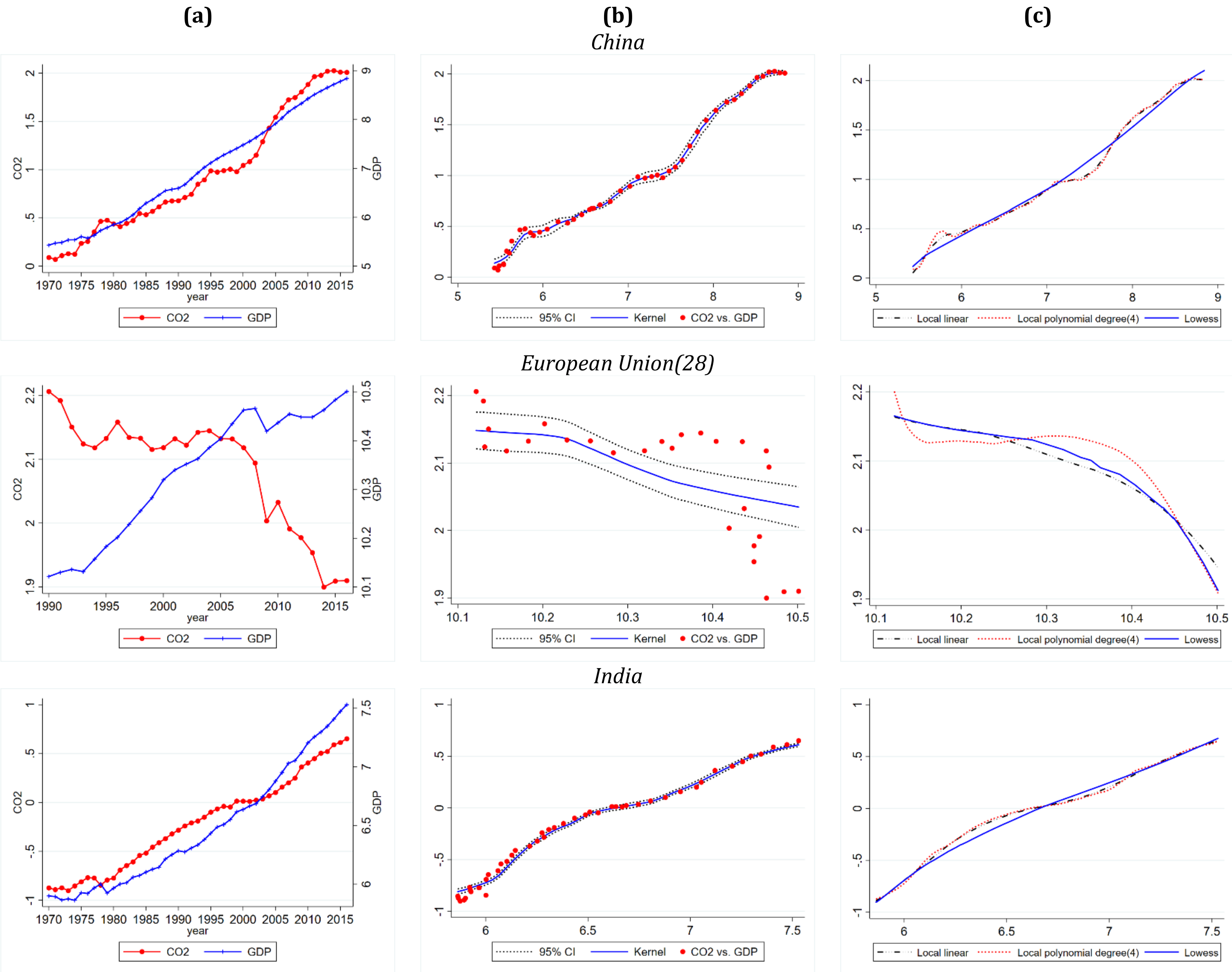
More specifically, to offer a more comprehensive picture of the pollution-growth nexus and, ultimately, distinguish whether the empirical works have managed to overcome the shortcomings suggested by the theory, we proceed as follows. First, we cover in our theoretical survey the economic rationale behind EKC and the crucial components of the research design when estimating it, namely the model specification, assumptions, econometric methodology, and identification strategy. In short, we discuss not only the economic theory behind EKC but also the advance in the econometric tools. Second, using descriptive and several nonparametric techniques, we conduct a short descriptive empirical exercise to disentangle the pollution-growth pattern for four top

[5] A version of this *Chapter* was published as Purcel, A.-A. (2020). New insights into the environmental Kuznets curve hypothesis in developing and transition economies: a literature survey. *Environmental Economics and Policy Studies*, *22*, 585-631. DOI: 10.1007/s10018-020-00272-9

global CO2 emitters (namely China, the European Union, India, and the Russian Federation), and also at the global level. Third, in the empirical survey, we differentiate between panel data and time-series studies, while we also discuss some new econometric perspectives regarding the modeling of environmental degradation-economic growth nexus.

This first essay of the thesis contributes to the literature by giving various essential insights regarding the link between economic growth and environmental pollution in developing and transition economies. On the one hand, our updated empirical survey reveals that a considerable number of papers find a long-term link between environmental degradation and economic growth. This result not only consolidates the EKC's innate nature but also may signal that the suggestions and progress put forward by the economic and econometric theory have facilitated the improvement of the related research design. On the other hand, several of these works unveil a bell-shaped pattern between indicators, indicating that the EKC hypothesis may be at work. In this direction, we can build around the intuition that industrialized economies have represented a model for developing and transition states in terms of how they have managed to cope with the potential environmental threats posed by economic growth. Certainly, having already an example in this regard, it is much easier for developing economies to address this fight against pollution and to learn from the mistakes of their predecessors to succeed in switching the increasing pollution trend in favor of the environment, even for lower income levels (Munasinghe, 1999; Dinda, 2004; Yao et al., 2019). However, some of these studies that initially reveal a bell-shaped pattern later concluded that the turning point lies outside the income range. In such cases, the identification strategy may lack rigorousness (see e.g. Bernard et al., 2014) and/or the findings may suggest that the pollution is increasing along with economic growth (see e.g. Cole et al., 1997; Stern & Common, 2001; Lieb, 2003). Indeed, either of the two emerges, demands a reassessment of the research design (e.g. model specification, assumptions, econometric methodology, identification strategy) to detect and correct the potential weaknesses and/or ambiguities. Besides, our short illustrative empirical exercise (see Figure 3 below) points out the importance of employing complementary techniques, even the simplest, to ensure the findings' robustness.

Figure 3: CO2-GDP nexus graphs



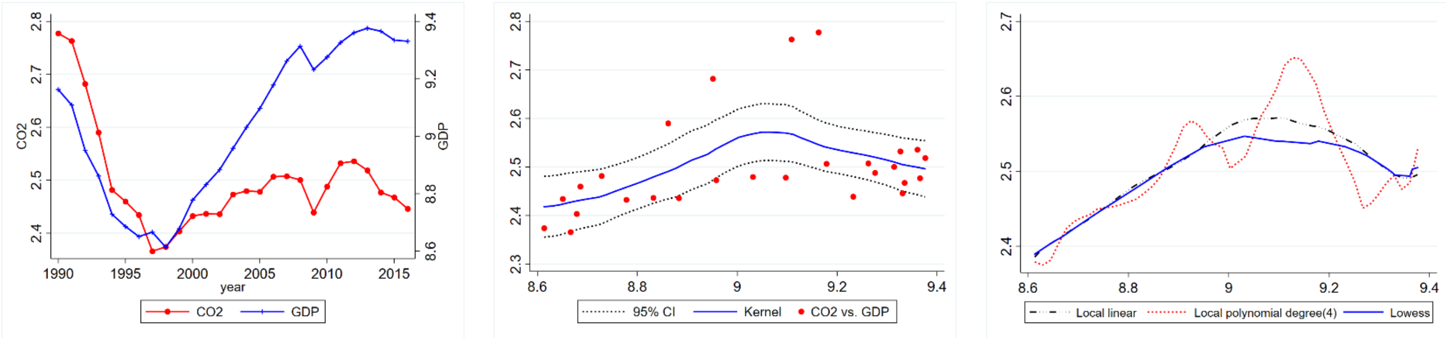
Notes: Column (a) shows the evolution of CO2 emissions and GDP per capita during the period analyzed. In column (b), along with the scatterplot, we fitted a local constant kernel regression with 95% confidence bands. In column (c), we performed a local linear, local polynomial of degree(4) and lowess regression. For the kernel, local linear, and local polynomial, we specify the default Epanechnikov function and (0.1) bandwidth. The default bandwidth option is used for lowess regression.

Summary

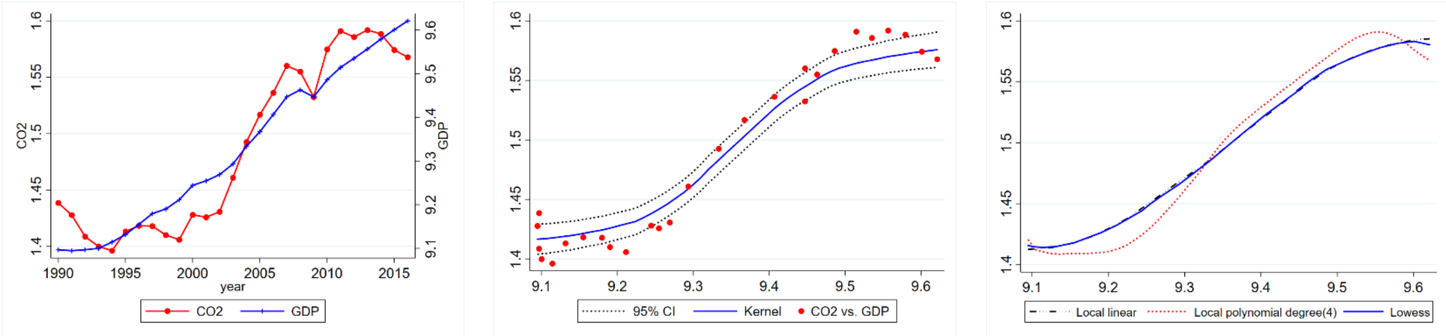
(**Figure 3:** continued)

(a) **(b)** **(c)**

Russian Federation



World



Notes: Column (a) shows the evolution of CO2 emissions and GDP per capita during the period analyzed. In column (b), along with the scatterplot, we fitted a local constant kernel regression with 95% confidence bands. In column (c), we performed a local linear, local polynomial of degree(4) and lowess regression. For the kernel, local linear, and local polynomial, we specify the default Epanechnikov function and (0.1) bandwidth. The default bandwidth option is used for lowess regression.

Overall, this chapter attempts to offer a more comprehensive and updated assessment of the evolution of the relationship between environmental quality and economic growth through EKC. Dividing our survey into three different key phases, namely (i) theoretical review, (ii) empirical exercise, and (iii) empirical review, while targeting a group of economies that have not enjoyed much attention in the literature, and with a slightly different role in terms of involvement in international climate change agreements compared to developed countries, we aim to provide new valuable insights on this subject. In addition, this review offers a solid basis for valuable information that helps us identify gaps in the literature that we address empirically in subsequent studies that shape this thesis.

Chapter II *«Pollution and Economic Growth: Evidence from Central and Eastern European Countries»*[6] examines the relationship between pollution (expressed by CO2 emissions per capita) and economic growth (expressed by GDP per capita) in eleven CEE countries. Referred as transition economies, the CEE states have undergone laborious changes on their path to liberalization (i.e. the transition from a socialist economy to a market economy) that has involved several economic, social, and political processes. By all means, these transformations have shifted in one way or another how the authorities and the population relate to the environmental issues, perceive the news about climate change, and, ultimately, react to all these aspects. In the wake of the aforementioned, in our analysis, we start from the premise that economic growth and other adjacent processes at the macroeconomic level may significantly impact environmental degradation.

Motivated by the sparse literature on this group of economies, we build our study around the intuition that these countries may have different development paths, and their economies carry the footprint associated with past communist regimes. Concerning the development paths, we consider an extended EKC where the cube of GDP is intended to capture possible differences in the stage of economic development (i.e. technological changes). Regarding the past communist regimes' common footprint, we include in the cointegrating vector, both energy consumption per capita and economic freedom.

Our econometric strategy relies on three estimators designed to capture the potential heterogeneities among countries, namely the MG, MG-FMOLS, and the more recently developed AMG approach, which accounts for cross-sectional dependence and allows a country-specific estimation. The empirical methodology reflects the data characteristics while also considers the sample's N and T dimensions. Put differently, these estimators, in addition to being part of the category of estimators specific to nonstationary panels, are also recommended when dealing with moderate macro panels in terms of both N and T dimensions.

[6] A version of this *Chapter* was published as Lazăr, D., Minea, A., & Purcel, A.-A. (2019). Pollution and economic growth: Evidence from Central and Eastern European countries. *Energy Economics, 81*, 1121-1131. DOI:10.1016/j.eneco.2019.05.011

Table 1: Aggregated estimates

Dependent variable: CO2			
	MG	**MG-FMOLS**	**AMG**
	(1)	**(2)**	**(3)**
GDP	760.968**	457.226***	525.619*
	(356.031)	(75.771)	(289.662)
GDP^2	-76.852**	-46.567***	-53.153*
	(35.910)	(7.713)	(29.465)
GDP^3	2.587**	1.580***	1.793*
	(1.207)	(0.261)	(0.999)
ENG	1.136***	1.147***	0.902***
	(0.107)	(0.042)	(0.128)
ECFR	-0.183***	-0.180**	-0.146*
	(0.061)	(0.087)	(0.086)
CDP			0.907***
			(0.219)
Observations	220	209	220
Pattern	increasing	increasing	increasing
GDP for concavity change	9.9004 ($19,938)	9.8182 ($18,365)	9.8812 ($19,559)

Notes: Reported MG coefficients are unweighted averages across countries. Long-run covariances in MG-FMOLS are estimated using Bartlett kernel with Newey-West fixed bandwidth. Common Dynamic Process (CDP) included as an additional regressor in AMG, and reported coefficients are unweighted averages across countries. Standard errors in brackets. ***, **, * denote statistical significance at the 1%, 5%, and 10% level, respectively.

On the one hand, the findings unveil an increasing nonlinear link between indicators at the aggregate level [Table 1 displays the (main) aggregated results]. Mainly, we find that the relationship changes its concavity for a computed GDP level at around 19,900 US$. Thus, in the proximity of this GDP value, the increase in CO2 remains relatively steady, while the impact's amplitude increases once we move to the right and left of this estimated value. Moreover, the results show a strongly negative significant effect of economic freedom on environmental degradation, emphasizing that the transition process from a planned towards a market economy had beneficial consequences on the environment. Opposite, not surprisingly, energy consumption is found to increase CO2 emissions. These aggregated findings remain qualitatively unchanged when we employ different estimation techniques, enlarge the cointegration vector with various exogenous factors, and substitute the environmental quality indicators. On the other hand, at the disaggregated level, the CO2-GDP nexus is described by a wide spectrum of patterns. The estimates reveal more pronounced nonlinearities in countries such as Croatia, Estonia, Poland, and Slovakia, where a third-order polynomial link is at work, followed by Bulgaria, Czech Republic, Hungary, and Latvia, which show a quadratic relationship. More precisely, an inverted-*N* (*N*) curve is found in Poland and Slovakia (Croatia and Estonia), while the pattern seems to be concave (convex) in the

Czech Republic and Hungary (Bulgaria and Latvia). Moreover, the findings unveil a linearly increasing relationship in Lithuania and the lack of a statistically significant link in Romania and Slovenia.

This chapter contributes to expanding empirical literature on pollution-growth nexus using the extended EKC hypothesis as a theoretical background. To the best of our knowledge, we are the first to investigate this relationship solely for the group of eleven CEE states. More than that, we concomitantly look at both aggregated and country-specific levels. In doing so, to capture the causal effect of GDP on CO2, we build the identification strategy trying to take into account the shortcomings that econometric theory has raised over the past recent years (especially the potential cross-sectional dependence and slopes heterogeneity). As such, we provide novel comprehensive findings that may help us further understand the complex relationship between GDP and CO2 in this particular group of economies.

Chapter III *«Developing States and the Green Challenge. A Dynamic Approach»*[7] investigates the aggregated and sector-specific CO2 emissions' responsiveness following exogenous shocks to growth and urbanization, considering a transmission scheme that incorporates two of the widely used instruments in mitigating environmental degradation, namely the renewable energy and energy efficiency. In this regard, using the STIRPAT framework, we focus on 68 developing economies span over the period 1992-2015. Being Non-Annex parties to the Kyoto Protocol and only starting with Paris Agreement more active players in fighting climate change, developing economies distinguished from developed nations in terms of their roles concerning the international environmental agenda for climate change. Nonetheless, the CDM under the Kyoto Protocol umbrella is designed to involve both developed and developing economies in actions aimed at reducing environmental degradation. More specifically, via the green projects implemented in developing states (mostly projects related to renewable and energy efficiency), the developed ones can also meet some of their emission reduction commitments.

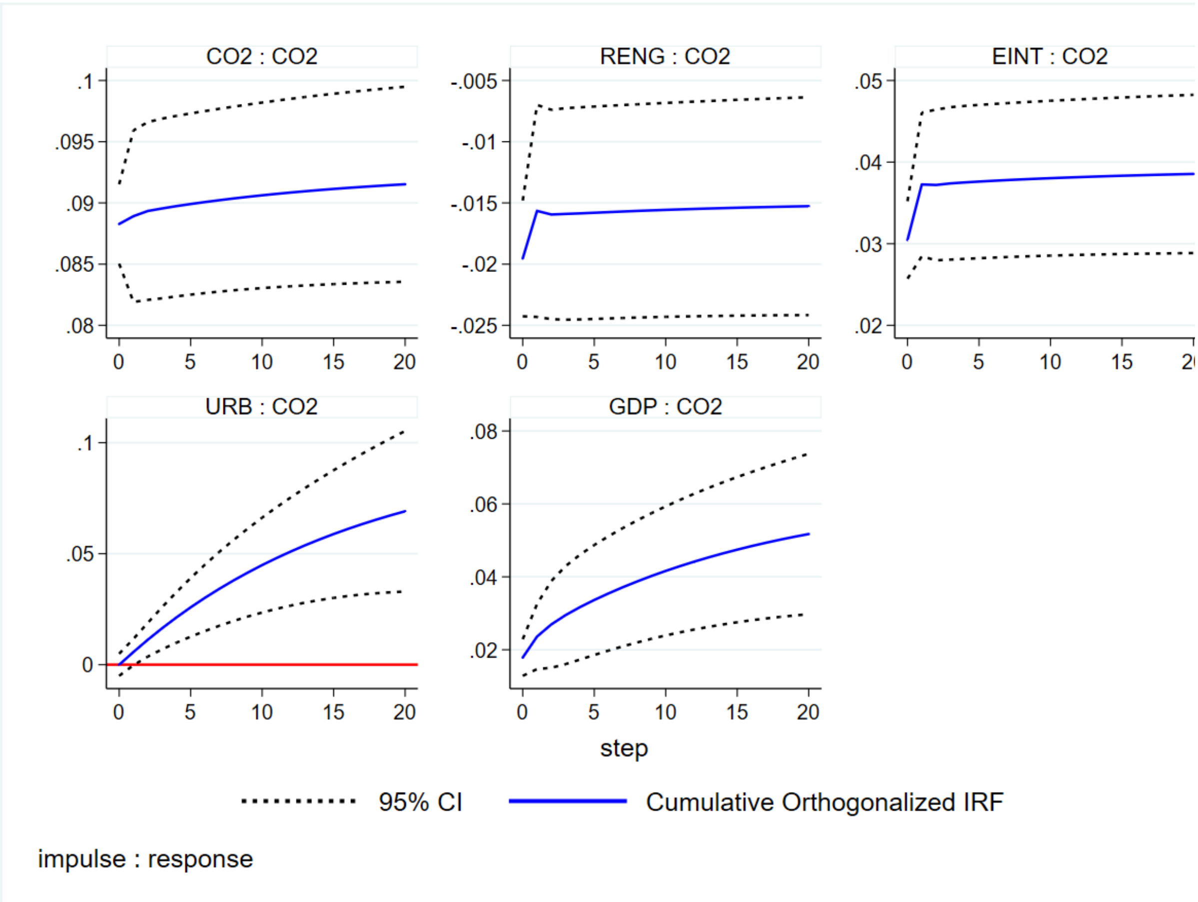
[7] A version of this *Chapter* was published as Purcel, A.-A. (2020). Developing States and the Green Challenge. A Dynamic Approach. *Romanian Journal of Economic Forecasting*, *23*, 173-193.

One the one hand, our study is motivated by these peculiarities of developing countries regarding their position to environmental issues, especially at the international level, and the ongoing structural transformation they cross in terms of economic development. Besides, it is generally acknowledged and postulated by the related literature that external disturbances have a more pronounced impact on developing economies than developed ones. Indeed, this may be easily linked to less industrialized nations' previously mentioned characteristics, which may increase, among others, their vulnerability. On the other hand, similar to the transition economies, the link between output and pollution is still not much documented, while based on the economic intuition and a large body of the previous works, several developing states did not yet achieve the GDP threshold that may trigger a decrease in pollution. Indeed, the same may hold when we bring into discussion the ongoing urbanization process that these economies have experienced on the road to foster economic development. In this fashion, we examine the effects of both growth and urbanization on CO2 in the context of the traditional and urbanization related EKC hypothesis, while we are not ruling out that the potential shocks to their dynamics may affect the share of renewables and energy intensity of the economy, which in turn may significantly impact the CO2 emissions.

Given our data's uni- and multi-variate properties, we employ the recently developed GMM-panel VAR approach of Abrigo & Love (2016). This empirical strategy not only helps us to address the potential endogeneity between variable but also allow us to have a perspective of the future effect of indicators on CO2 (this is especially of interest to see if a potential threshold effect will be at work for output and urbanization) through the computation of IRFs. Also, the approach is applied in the context of the two well-known theoretical frameworks, namely the STIRPAT model and the EKC hypothesis, allowing us to endorse the presumed transmission channel and capture the essential structural shocks.

From the aggregate perspective (Figure 4 and Table 2 show the aggregated findings), shocks to GDP, urbanization, and energy intensity trigger, both on impact and cumulated over a twenty years horizon, an increase of CO2 emissions. Particularly, concerning the long-term responsiveness of CO2 in the aftermath of output and urbanization shocks, the pattern suggests that a threshold effect compatible with traditional and urbanization-related EKC may be at work. Conversely, positive external disturbances to renewable energy lead to a decrease in current and future levels of CO2 in our group of developing economies. Likewise, as expected, the results show an inertial behavior of CO2 emissions during the period analyzed. Although the findings are robust across an extensive set of alternative specifications (i.e. different order of variables into the transmission channel, when we apply several restrictions with respect to both *N* and *T* dimensions, and include several additional exogenous factors into the model), they vary depending on the countries' level of development and their Kyoto Protocol ratification/accession status. Besides, the sectoral-specific analysis reveals that the CO2 from transport, buildings, and non-combustion sector are more likely to increase in the future, considering that external shocks to GDP and urbanization trigger a decrease only in emissions related to power-industry and other industrial combustion sector.

Figure 4: Cumulative orthogonalized IRFs



Observations: 1428 • Groups: 68
Notes: Considering two generic variables A and B, "A: B" denotes the response of B following shocks to A. The continuous line denotes the impulse response functions. The dashed lines stand for the associated 95% confidence interval computed based on 1000 Monte Carlo simulations.

Table 2: Forecast-error variance decompositions

Response variables	Impluse variables				
	GDP	URB	EINT	RENG	CO2
GDP	99.28	0.29	0.19	0.19	0.02
URB	12.89	86.96	0.02	0.01	0.10
EINT	21.59	0.16	78.12	0.04	0.07
RENG	0.89	0.41	8.16	90.42	0.08
CO2	4.08	2.69	9.90	4.03	79.27

Notes: Considering a twenty years horizon, the numbers (in percentages) show the variation in the row variable that is explained by the column variables.

Having the roots of its objectives in the lessons drawn based on the first chapter, and being seen as a complementary part of the second one, through this chapter we offer an original assessment of the current and future state of developing countries in terms of CO2 pollution (and environmental sustainability in the broad sense).

Chapter IV *«Does Political Stability Hinder Pollution? Evidence from the Developing States»*[8] explores the effects of (overall) political stability on environmental degradation in 47 low and lower-middle income economies. Jointly with the economic and social system, the political system is at the core of a nation's well-functioning, while it has tight connections with various elements of the other two. Therefore, any potential fluctuations in the overall or its subcomponents' dynamics—whether we refer here to its formal side (the governmental related subcomponents) or the informal one (non-governmental related subcomponents)—can trigger a series of chain reactions, which due to systems' interconnects may significantly impinge also on the environmental conditions. Taking a brief look at some political stability statistics, we notice that in recent decades (specifically over 2006-2016 period), the number of worldwide political conflicts has doubled, and what is even more worrying is that violent conflicts have increased the most [Global Peace report (GPI), 2017]. Moreover, historical evidence has shown that these episodes of political instability are more frequent in poorer countries.

Driven by these facts and corroborated with the specificities regarding the developing countries' status in terms of global environmental agenda (presented in the previous chapter), we consider both opportune and of interest the enrichment at the empirical level the not very extensive knowledge in this area. Consequently, in our desire

[8] Versions of this *Chapter* were published as Purcel, A.-A. (2019). Does political stability hinder pollution? Evidence from developing states. *Economic Research Guardian, 9*, 75-98 and Purcel, A.-A. (2020). Environmental degradation and political stability: A comparative study of civil and common law developing economies. *Review of Economic Studies and Research Virgil Madgearu, 13*, 93-113.
DOI: 10.24193/RVM.2020.13.54

to capture as comprehensively as possible the dimensions of political stability, we proxy it with the ICRG composite index, while environmental degradation is captured by a widely used global pollutant, namely the CO2 emissions. The other CO2 potential determinants we include in the model are chosen based on the STIRPAT and EKC literature, being also in consonance with the 2030 SDGs.

Bearing in mind the sample's features, we opt for a quite appealing empirical strategy, which allows us to retrieve both the long- and short-run coefficients, and, more importantly, to account for the potential reverse causality between variables. Besides, we go even further and apply this approach, namely the ARDL, in its classical and newly-developed version (i.e. robust to cross-sectional dependence), considering different estimators and scenarios. Likewise, we employ a series of complementary techniques and alternative specifications to check our results' stability.

First, we find that over the period 1990-2015 for a broad sample of low and lower-middle income economies, the link between indicators is characterized by a threshold effect (Table 3 displays the main aggregated threshold results). More precisely, political stability significantly reduces CO2 pollution after exceeding the threshold value of roughly 66.47, expressed in political stability index points. Thus, according to the ICRG index, this value corresponds to a moderate level of political stability. Second, this result is strongly robust when we employ a set of alternative estimation techniques, include several additional control factors, alter the sample based on various criteria, disaggregate the PS index on subcomponents, use different computation methods of the composite PS index, and provide an alternative approach in searching for a potential threshold effect. Third, these findings seem to be sensitive to various structural characteristics (i.e. the level of economic development, Kyoto Protocol ratification/accession status, and legal inheritance) and alternative global and local environmental degradation measures. Finally, the country-specific analysis reveal the complexity of the CO2-political stability nexus. Disregarding cases for which the relationship between variables is not statistically significant, one the one hand, the estimates show that political stability might increase CO2 emissions in countries such as Morocco, Mozambique, Papua New Guinea, Tunisia, Yemen (where a U-shaped curve is at work) and also Cameroon, El Salvador, Haiti, Mongolia, Nigeria, and Zambia (where a positive link is unveiled). On the other hand, a decreasing trend in CO2 along with an increase in political stability is documented for countries where the relationship follows either a bell-shaped (Angola, Bangladesh, Bolivia, Guinea-Bissau, Honduras, Madagascar, Malawi, Mali, Myanmar, Niger, Sierra Leone, Sri Lanka, Togo, Uganda, Vietnam) or a decreasing pattern (Republic of the Congo).

Table 3: CO2 emissions and political stability: threshold estimates

Dependent variable: ΔCO2	**Main estimates**		**Robustness estimates**	
	PMG		**CS-ARDL-PMG**	
	(1a)	**(1b)**	**(2a)**	**(2b)**
	Long-run estimates			
PS	4.087***	2.523***	4.796***	4.493*
	(0.758)	(0.702)	(1.774)	(2.525)
PS^2	-0.516***	-0.300***	-0.602***	-0.561*
	(0.100)	(0.092)	(0.221)	(0.320)
GDP		0.791***	0.815***	0.823***
		(0.051)	(0.267)	(0.221)
RENG		-0.069***	-0.213	-0.183
		(0.024)	(0.423)	(0.293)
EINT		0.543***	0.461**	0.471***
		(0.046)	(0.235)	(0.183)
	Short-run estimates			
ECT	**-0.192*** **	**-0.229*** **	**-0.542*** **	**-0.545*** **
	(0.031)	**(0.031)**	**(0.096)**	**(0.129)**
$\Delta CO2_{(t-1)}$			0.457***	0.454***
			(0.096)	(0.129)
ΔPS	0.719	2.726	2.377	2.222
	(4.063)	(3.456)	(3.121)	(12.718)
ΔPS^2	-0.092	-0.342	-0.300	-0.280
	(0.504)	(0.427)_	(0.391)	(1.594)
ΔGDP		0.919**	0.564*	0.593*
		(0.449)	(0.334)	(0.314)
ΔRENG		-1.376***	-0.390	-0.326
		(0.291)	(0.599)	(0.415)
ΔEINT		0.698	0.277	0.300
		(0.445)	(0.274)	(0.214)
C	-1.814***	-3.068***	-9.161	-8.322
	(0.304)	(0.431)	(6.792)	(8.497)
Log likelihood	1603.802	2078.713		
R_squared			0.57	0.58
RMSE			0.07	0.07
CD statistic			-0.39	-0.06
Groups	47	47	43	47
Observations	1158	1158	1075	1138
Hausman Chi-2 test p-value	0.4072	0.8520		
Pattern	bell-shaped	bell-shaped	bell-shaped	bell-shaped
PS turning point (Ÿ)	3.96085 (52.501 pts.)	4.19675 (66.469 pts.)	3.98411	3.9988

Notes: We use the difficult option to avoid difficulty to maximize the likelihood function when nonconcave regions appear during estimation. CD and RMSE denote the Cross-Sectional Dependence and the Root Mean Square Error, respectively. CD H0 is "errors are weakly cross sectional dependent". The value of turning point is expressed in log. Standard errors in brackets. ***, **, * denote statistical significance at the 1%, 5%, and 10% level, respectively.

In a nutshell, this last chapter offers a renewed perspective on the pollution-political stability nexus by adding to the growing literature, especially in terms of the nonlinear modeling between variables. It also highlights the importance of complementarity between aggregate and disaggregated estimates in providing the most complete as possible conclusions when studying different macroeconomic phenomena. Naturally, it can be also viewed as a continuation of previous chapters, in which we go beyond the potential nonlinearities between economic growth (urbanization) and environmental degradation postulated by the EKC (urbanization EKC), and search if such nonlinearities are also present regarding the impact of other economic development dimensions, namely the political one, on CO2 emissions.

4. Policy implications, and future research avenues

At the global level, the overall mission to foster sustainable development is also outlined through the well-known 17 Sustainable Development Goals (SDGs), the upgraded successor of the Millennium Development Goals (MDGs), both defined under the United Nations' (UN) umbrella. This comprehensive set of goals—which are planned to be achieved by 2030—revolves in a cohesive manner around the fundamental pillars of economic development, including its economic, social, and political aspects, and, more importantly, the mutuality between them. Moreover, achieving them requires all society entities' combined effort, from population to various non(governmental) organizations and associations. Thus, bearing in mind these goals and other sub- and supra-(national) related objectives, it becomes imperative to formulate environmental policies appropriate to particular contexts in order to ease the environmental quality enhancement while promoting economic development. The present thesis contributing to the augmentation of knowledge regarding economic development effects on environmental quality in developing and transition countries may provide some valuable policy recommendations in this direction.

In light of Chapter I, several developing and transition economies managed to switch their increasing pollution trend in the context of ongoing economic growth. Also, some of them achieved the tipping point for a lower income level than their industrialized counterparts. Therefore, from a policy perspective, they can provide solid know-how for states which are still facing increasing environmental degradation as they move towards high industrialization. However, developed countries' strategies to cope with rising pollution following economic expansion should not be forgotten either, whether they have led to positive results or have revealed some practices less suited to different situations which require improvement. Furthermore, considering both the progress of statistics/econometrics and economic theories in the field, the policy implications should be formulated following a rigorous analysis. Thus, it becomes essential to guarantee, to a certain extent, the robustness of the results. Not to mention that it is generally acknowledged that the pollution-growth patterns [and when the relationship form allows, their computed threshold(s)] are closely related to the sample, period, empirical methodology, and variables considered. As such, ensuring the accuracy of the results, which are usually the cornerstone of adjacent policies, becomes even more crucial.

Chapter II's findings showed that despite a positive aggregated effect of economic growth on CO_2, some CEE countries succeeded in decreasing associated emissions and fostering economic growth. In this vein, two main policy recommendations could be formulated. On the one hand, judging from the aggregate standpoint, the policymakers need to focus more on the environmental conditions of CEE countries to limit the adverse effects that economic growth may have on the quality of the environment. On the other hand, tackling the country-peculiarities more in-depth may help improve environmental policies at the disaggregated level and contribute to the readjustment of those at the EU level. Indeed, with regard to the latter, more comprehensive integration of country-level heterogeneities into the overall EU environmental objectives would probably be an added value from the policy perspective. Moreover, some imminent correlations that must be interpreted prudently indicate that a future reduction in CO_2 in the context of economic expansion may be more easily attained in countries with green and significant industry sectors, where the high labor productivity upholds complex techniques.

Chapter III provided valuable insights regarding the current and future behavior of aggregated and sectoral-specific CO_2 emissions following external disturbances to output and urbanization, and, more importantly, how renewables and energy efficiency interplay in this transmission channel. Given the relatively fast industrialization and urbanization process in developing economies, it brought attention to the crucial implications they may imply on CO_2 pollution. Thus, based on our findings, the growth-promoting, and urban planning policy design need to better account for the potentially harmful consequences they may cause to the environment. Indeed, all of these, together with defining preventive measures and implementing appropriate environmental policies, may facilitate the change of the upward trend of pollution earlier and for a lower degree of urbanization and economic growth. More on this matter, while renewable energy has proven to be a vital factor in reducing pollution, the greater incentive of energy efficiency projects can provide additional benefits to environmental quality. Besides, considering that more accentuated increases in CO_2 may be encountered mostly in lower-middle income countries and those states which ratified/acceded to the Kyoto Protocol before it entered into force, their governments must pay increased attention upon environmental conditions and periodically reevaluate the associated strategies to ensure greater effectiveness. Likewise, the policy actions should be extensively directed towards the sectors with the highest propensity to increase CO_2 levels, namely the transport, buildings, and non-combustion sector.

The last chapter (Chapter IV) strived to draw attention to the implications of the political system's stance on CO_2 pollution in countries that are more likely to face political distress episodes—developing economies. First, the aggregated findings revealed that reaching a relatively moderate to a high level of political stability can help in improving environmental conditions. In this regard, effective and tight synergy among governmental and nongovernmental structures could boost political stability, which, in turn, may ease policy implementation. Accordingly, more appropriate and efficient environmental policies can be designed, while also their monitoring and adaptation can be carried out under more favorable circumstances. Second, in light of heterogeneities unveiled regarding the aggregated relationship, special attention should be paid to the group of states for which political stability has a positive effect on CO_2 (i.e. economies with a lower-middle income, civil law inheritance, and those which ratified or acceded to the Kyoto Protocol after 2005). On the one hand, in these countries, possible political unrest episodes may hamper the achievement of political stability optimum that would generate a decrease in CO_2. From a policy perspective, for example, trying to address the business environment's needs, along with those of various ethnic groups, can significantly reduce the potentially related strikes. Thus, the balance of the political framework would be less affected. On the other hand, a positive impact of political stability on CO_2 may occur following the more relaxed decision-makers' attitude that, eventually, may spur the adoption of less stringent policies. In this manner, continuous monitoring of the environmental quality can signal some potential deviations from the desired trajectory and, thus, urging the adoption of consistent decisions. Given that additional political stability seemed to exacerbate the emissions of different local and global pollutants, the above may also be applied in their case; all the more that, usually, local pollutants are also intensely regulated at the national level, and the international pressure may be lower compared to global pollutants. Third, following the country-specific analysis, political stability should be improved in some developing countries to impact environmental quality positively. While only an in-depth analysis at countries' level can help determine more accurately the specific triggers (both formal and informal ones) of political instabilities, a simple descriptive analysis—that must be treated with much caution—indicate that the industrialization process, high unemployment/globalization, limited involvement of the military in politics, and from an environmental perspective a lower forest rents share in GDP, may induce different political-related disequilibria. Therefore, by approaching these aspects more closely, one can identify possible political disturbances' sources and apply coercive measures. Concurrently, the quality of the environment may benefit following these actions.

Being unlikely to find a formula that fits all contexts, the additional results unveiled by this thesis suggest that increasing economic freedom (especially in CEE countries) and energy efficiency, together with the gradual transition to renewable energy sources, may be decisive factors in ensuring sustainable development. Moreover, the intuitions that can be derived following the overall thesis' conclusions may also indicate that (i) a fruitful international collaboration, along with (ii) implementation of appropriate policies such as environmentally-friendly measures, low-carbon growth strategies, the internalization of externalities, or the adoption of regulations against pollution-havens, could boost the environmental conditions in developing and transition countries, and provide long-term sustainability.

The present thesis offered new empirical evidence and insights on a contemporary but at the same time, controversial topic, namely, the relationship between economic development and environmental quality. However, given the phenomena' dynamism, the results should not be seen as final answers, but as efforts to understand some of the consequences that economic development has on environmental quality in developing and transition economies. Also, through our findings, we hope to smooth the path to new research in this direction.

Naturally, the first chapter could be redesigned into a meta-analysis to better assess the literature in the field and provide measurable findings regarding the sources of potential differences in the pollution-growth nexus, seen through the prism of EKC. Seeking answers that complement the conclusions drawn on the grounds of our three empirical essays, future work may emerge in several directions. First, given that the energy sector is a major contributor to CO2 pollution, exploiting the effect of more disaggregated energy sources (see e.g. Antonakakis et al., 2017; Naminse & Zhuang, 2018) on CO2 could provide valuable knowledge on those specific items that need to be adjusted in order to minimize the associated pollution. Second, regarding the environmental quality responsiveness to various (imminent) disturbances, assessing the effect of different types of crises on CO2 may enhance the comprehension of associated dynamics (see e.g. Jalles, 2019). Third, it would be quite insightful and challenging to look at more disaggregated country-specific data to discern better the heterogeneities revealed by investigating the economic development-environmental quality nexus at the aggregated (macroeconomic) level. Fourth, tackling the impact of (unexpected) changes in environmental regulation at the national level, and particularly the way firms adjust their activity to cope with such fluctuations (possibly in relation to their production factors, and particularly research and development investment, see Alam et al., 2019), could provide a clearer understanding of this area. Fifth, examining the population's awareness in relation to environmental objectives and their integration in governments' welfare function, possibly from a political economy perspective, could foster our comprehension of motivations and challenges related to the promotion of environmental-friendly economic development. Finally, regarding the econometric strategy, especially the nonlinear modeling between indicators, future research may consider employing—if conjecture allows—complementary approaches such as Panel Threshold Regression (PTR) (see Hansen, 1999) and Panel Smooth Threshold Regression (PSTR) (see Gonzalez et al., 2005) models, different semi- and non-parametric techniques, and even empirical methodologies that move beyond the classical time-domain.

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