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LINKAGE BETWEEN POLLUTION AND GROWTH: THE ROLE OF INEQUALITY

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Abstract

This paper investigates whether inequality plays a role in the relationship between CO₂ emissions and GDP on a panel dataset of European NMS (New Member States) over the period 1990-2021. For the analysis, we employ Common Correlated Effects Estimator-Mean Group for error-correction model estimation method based on Chudik and Pesaran (2015) and Pesaran (2006) which allows for slope heterogeneity in the short and long run. The results indicate that: (i) on short-run per capita income and also financial development increase CO₂ emissions, (ii) on the long-run GDP also increase pollution, but there is relative decoupling present and for positive economic growth and decreased inequality the effect on pollution is more pronounced, (iii) the impact of renewable energy consumption on CO₂ emissions is significantly negative in the long run, but not in the short run. The main result is that countries cannot simultaneously improve environmental quality (reduce CO₂ emissions), maintain economic growth and increase equality. These results contribute to the field of explaining the evolution of environmental quality in the context of the type of growth-inequality relationship.

Keyword: CO₂ Emissions; Inequality; Panel Data Analysis.

JEL Classification: C21, C52, Q56

1. Introduction

The European Union is the one of the leading drivers in term of environment legislation with the aim of curbing pollutants in order to reduce the global rise in temperature. Its strong commitment to the environment is encompass by its goal, set by the 2019 Green Deal, to make Europe the first climate neutral continent in the world. Since carbon capture technologies although progressing, due to their limitations in terms of costs and efficiency, are not likely, in the near future, to offer the instrument for cleaning the air, efforts should be made in the direction of reducing, if not stopping the future emissions.

The challenge is reducing pollution simultaneously with maintaining economic growth as high as possible, since the relationship between the two is positive. There are studies that question the possibility of reversing the sign of the relationship claiming that it is not possible to decouple

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economic growth from pollution and others that argue that even if countries could decouple their economic growth the extent of decoupling would not be sufficient to achieve climate neutrality.

Another core value of the EU is to achieve equality for its citizens. Equality is a broad concept, which covers many aspects including equality of gender, anti-discrimination, disability, de-favoured minorities, but a way to achieve these goals is through inclusive growth.

In our paper we are interested to study the relationship between pollution and economic growth and the effect that inequality has on the relationship. We are interested to find whether a positive growth rate which is associated with a decrease in inequality is inhibiting or aiding the efforts to reduce pollution. We test the hypothesis using data for the European New Member States. The paper is an extension of recent papers (Pauna & Saman, 2023; Saman & Pauna, 2023).

2. Literature review

The analysis of the relationship between economic growth and pollution has received a lot of attention in the literature, especially since there is a growing literature that claims that it is improbable that countries would achieve absolute decoupling between the two, and relative decoupling it's not sufficient to achieve the goals of the Paris Agreement of less than 2 degrees Celsius increase in the average temperature.

To study of the relationship between economic growth and the environment authors typically construct a model in which the dependent variable, some form of pollution either CO₂, or GHG emissions, is explained by GDP. The consensus since the article of Grossman & Krueger (1991) is that the relationship between the two variables is not linear but has an inverted U shape. According to this, countries have three stages of economic development, in the first stage when growth is associated with increasing pollution, followed by the turning point when pollution does not increase at the same rate as income followed by the later stages of economic development when the process of decoupling of the two variables occurs, this later stage is associated with cleaner energy production and environmentally friendly technologies.

Mikayilov, Hasanov, & Galeotti (2018) investigated the EKC between CO₂ and GDP for a time interval starting in 1861 and ending in 2015 for 12 European countries. The length of time that the study covers means that the authors have information only on GDP, emissions and population. Because of the length of the data series the authors employed a time varying coefficients cointegration methodology. The authors found that all income elasticities of emissions were positive, therefore found no evidence of absolute decoupling for the entire interval and countries studied. In the case of four countries Austria, Denmark, the Netherlands and Switzerland the authors found an elasticity higher than one which suggest that no decoupling occurred for these countries.

There are numerous studies covering the effect of EU legislation on emissions. An example is Papiez, Smiech, & Frodyma (2022), where all the EU countries were investigated, but grouping separately the new member states. They found an ambiguous influence of the EU legislation, there was some progress in the long run decoupling for EU-15 and NMS in the case of production-based emissions and emissions covered by the ETS, but in the case of consumption based emissions there was no discernable progress. They observe large discrepancies between the NMS in comparison to the rest of the EU

The decoupling of production emissions and economic growth is a necessary but not sufficient conditions when analyzing a country's impact on the environment. Some countries achieve decoupling of production-based emissions via importing goods that are carbon intensive from countries whose environment legislation is more relaxed. Hubacek, Chen, Feng, Wiedmann, & Shan (2021) acknowledge in their paper the necessity to account for a country's global emissions by studying the consumption-based emissions instead of only production-based ones for 116

countries. They found that a large number of mostly developed countries (32) achieved absolute decoupling of the production-based emissions, 23 countries achieved absolute decoupling of the consumption-based emissions and 14 countries achieved decoupling of both production and consumption-based emissions. They also observed that the decoupling trend can reverse back to increasing emissions, so the effort to diminish emissions is an ongoing process.

Most authors include other variables besides GDP, when studying the dependence between the two variables. Population or variables per capita appear in most articles, as well as total energy consumption or fossil fuel energy consumption (Jiang, Rahman, Zhang, & Islam, 2022; Hasan, Wieloch, Ali, Zikovic, & Uddin, 2023). Other variables that can appear are financial development, globalization, industrialization, innovation, especially green innovation, investment domestic or FDI. For a comprehensive literature review see Aller, Ductor, & Grechyna (2021).

While most studies include only GDP or GDP per capita as a measure of the nations' income distribution, some authors recognized the need to include other measures of the distribution as well, and have included inequality among the independent variables. Dorn, Maxand, & Kneib, (2024) showed in their paper the fact that the relationship between pollution and inequality depends on the development level of the country.

In the literature there are several theories that explain the relationship between inequality and pollution, but in the end the relationship can be positive and therefore there is synergy between the two because decreasing inequality helps to decrease pollution, or negative, which means a trade off between the two if the reverse is true.

The findings in the literature are mixed (Jorgenson, Schor, & Huang, 2017; Dorn, Maxand, & Kneib, 2024) found no relationship between inequality and pollution, (Kusumawardani & Dewi, 2020) (Grunewald, Klasen, Martínez-Zarzoso, & Muris, Income Inequality and Carbon Emissions, 2011) found a negative relationship between inequality and emissions.

3. Data and methodology

We apply the panel methodology on data for the European NMS (New Member States). The data for most countries starts from 1990 and ends in 2021 but in some cases, for newly created countries there is no data available prior to 1995. Most of our data comes from the online database Our World in Data (<https://ourworldindata.org/>), and the GINI indicator is extracted from the Standardized World Inequality Database (SWIID), which is a database developed and described by Frederick Solt (2020).

Table 1. The variables

Variable	Notation	Unit of measurement	Data source
Carbon dioxide emissions	CO ₂	Kilo tonnes (kt)	World Bank
Gross domestic product per capita	GDPct_pc	constant 2015 US \$/cap	World Bank
Index of financial development	FD	Index	The Heritage Foundation
Green patents	pat_green_pr	% of total patents	Our World in Data
Foreign direct investment	rpFDI	% of GDP stock	World Bank
Renewable energy consumption	En_r_cons	% of total final energy consumption	Our World in Data

Variable	Notation	Unit of measurement	Data source
GINI indicator	<i>gini_disp</i>	Index	SWIID Version 9.6, December 2023

Source: own synthesis

The environmental impact is measured by the dependent variable, which is per capita consumption based CO2 emissions, because it better reflects the emission propensity of the country. We would prefer GHG emissions but the data series for the consumption based GHG emissions are not available, however CO2 is the main component of GHG.

Among the independent variables we use per capita GDP, in order to control for country's population. A second variable is inequality measured by the GINI coefficient of disposable income.

We are interested to check the hypothesis that beside the coefficient of GDP per capita that asses the environmental decoupling, the type of growth the country enjoys is important as well in terms of its effect on pollution. In our model we defined two possible types of growth: inequality increasing growth and inequality decreasing growth. We constructed dummy variables which capture the interaction between change in the GDP growth (either increase and decrease), and change in inequality.

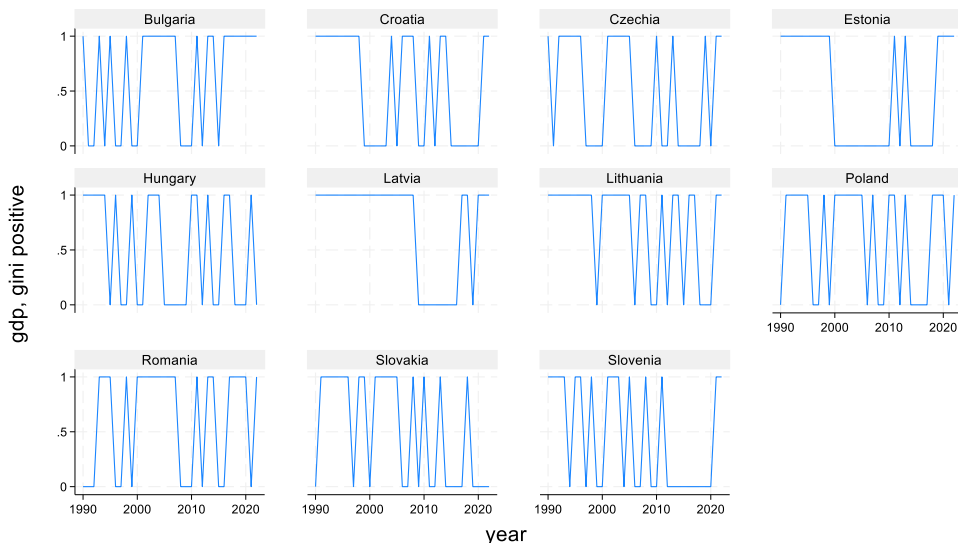
Table 2. Number of observations of GDP and inequality

	Freq.	Percent	Cum.
Increase in GDP, increase in inequality	207	57.02	57.02
Decrease in GDP, increase in inequality	49	13.5	70.52
Decrease in GDP, decrease in inequality	26	7.16	77.69
Increase in GDP, decrease in inequality	81	22.31	100
Total	363	100	

Source: Authors' computations.

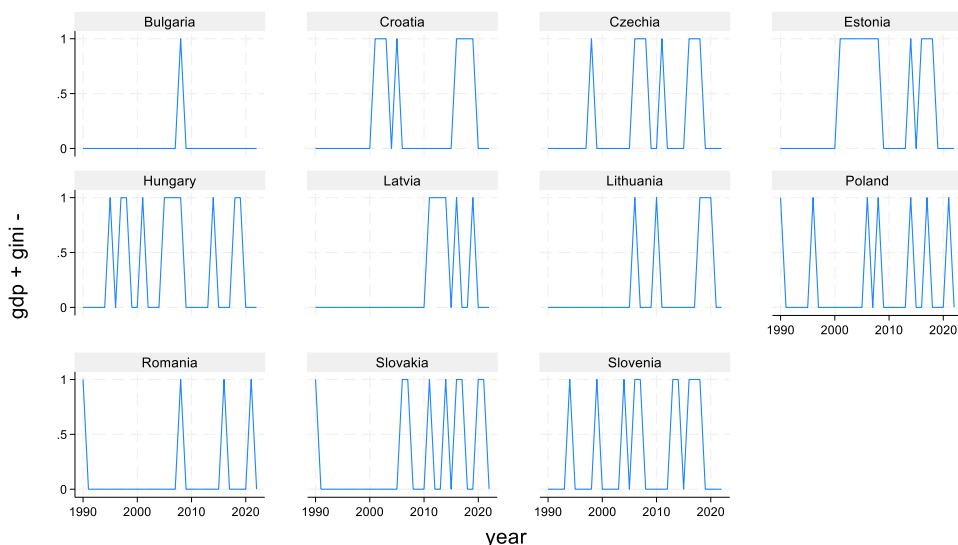
Table 2 shows that over half of the observations are a combination of increasing growth and increasing inequality, followed by less than a quarter of increasing growth and decreasing inequality. So we will not be able to test all four situations due to lack of observations. The next figures (1-4) show the great heterogeneity of countries regarding the type of growth-inequality binomial that is present in the data set. The combination of GDP growth and increased inequality is the most frequent outcome for the analysed countries in the examined interval so inequality of income is associated with higher levels of growth in the most cases (figure 1). Some countries (Bulgaria, Lithuania for the whole period and Croatia, Slovenia, with a few minor exceptions) experience no declines in both growth and inequality, while others (Latvia entirely and Estonia with some exceptions) do not experience declines in growth and increases in inequality.

Figure 1. Increase in both growth and inequality (I11)



Graphs by country

Figure 2. Increase in growth and decrease in inequality (I21)



Graphs by country



Figure 3. Decrease in growth and increase in inequality (I12)

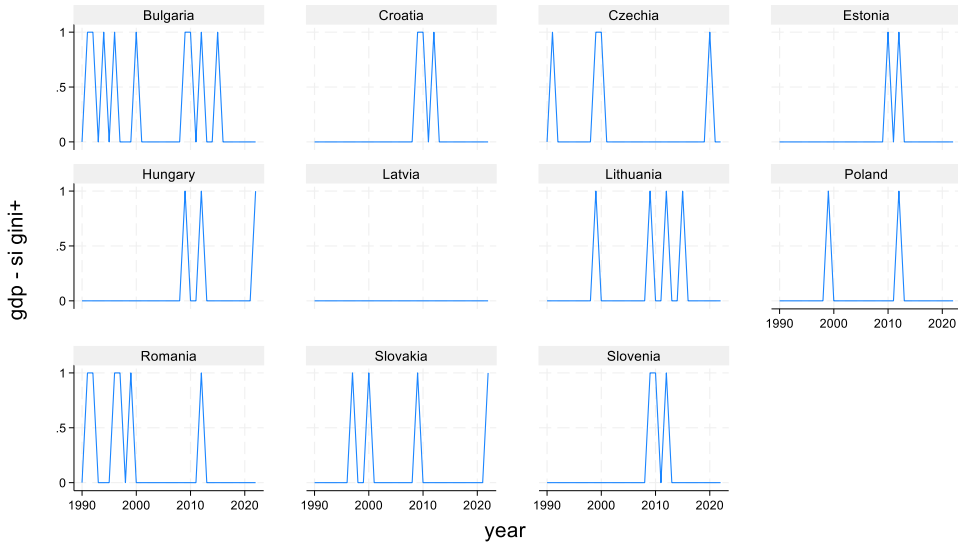
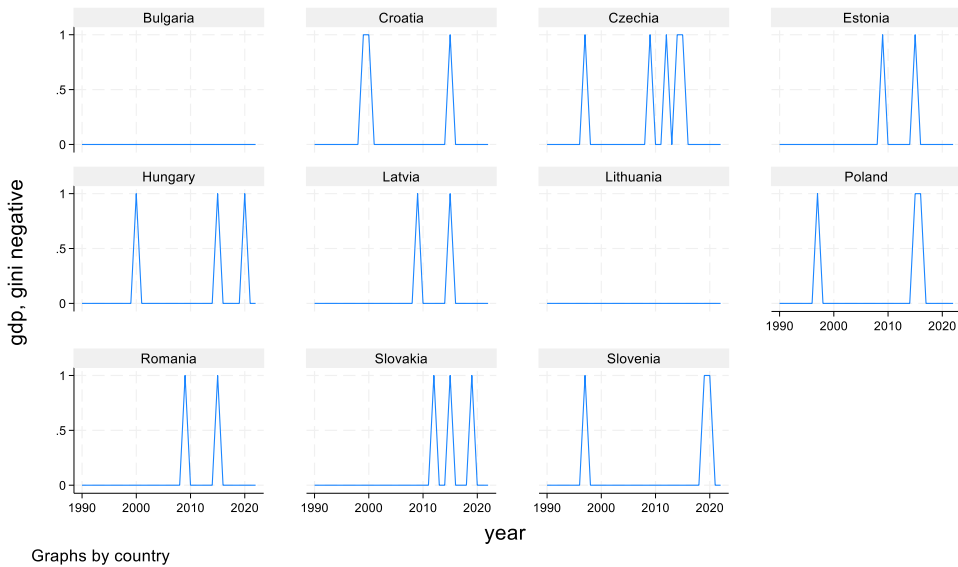


Figure 4. Decrease in growth and inequality (I22)



Using the above dummies we construct interaction variables between them and GDP, the variables have the GDP per capita value when the corresponding dummy variable is one and zero in the rest. Including this variables in the model together with the GDP variable we will be able to test if the type of growth (inequality increasing or decreasing) is important as well in the relationship between pollution and GDP.

We found dependence across countries (cross-section units) and modelled it as a common factor structure part of error term as it is unobservable. Also the coefficients proved to be heterogeneous, so we considered an ARDL(p,q) panel model as in Chudik and Pesaran (2015), which approximate the common factors as cross-section averages:

$$y_{it} = \sum_{l=0}^p \alpha_{il} y_{it-l} + \sum_{l=0}^q \beta'_{il} x_{it-l} + u_{it} \tag{1}$$

$$u_{it} = \gamma'_{i} f_t + e_{it}$$

Where i is the cross-section, t is time, f_t is a vector of unobserved common factors approximate as cross-section averages of the variables, u_{it} is a serially uncorrelated across i .

The estimation methodology is error correction approach of Common Correlated Effects Estimator-Mean Group (CS-ECM) to be able to see both the long-run and the short run relationship between variables. The Mean Group (MG) estimator (Pesaran, 2006; Chudik and Pesaran, 2019) estimates the mean of cross-section individual regression coefficients. In other studies Pooled Mean Group (PMG) estimator is used instead of mean group estimator (Frank, 2005; Martinez-Zarzoso and Bengochea-Moranco, 2004), which put a constrain on the long-run relationship to be homogeneous across cross-sections. The hypothesis of this restriction could be tested empirically and also a Hasman test could be used to test the appropriate model between these two. However, in a dynamic model the pooled estimator is biased (Ditzen, 2019).

The ECM representation of the model (1) is:

$$\Delta y_{it} = \phi_i (y_{it-1} - \theta_{1,i} - \theta'_{2,i} x_{it-1}) + \sum_{l=0}^{p-1} \alpha_{il} \Delta y_{it-l} + \sum_{l=0}^{q-1} \beta'_{il} \Delta x_{it-l} + \sum_{l=0}^t \gamma'_{il} f_{it-l} + e_{it} \tag{2}$$

4. Results and conclusions

The selected specification has the following explanatory variables: on short term the GDP per capita, the renewable energy consumption, and alternatively one of the three variables: the rate of the foreign direct investment, the financial development, and the rate of green patents. On long term we add the interaction terms between GDP per capita and the two dummies which describe the inequality increasing or reducing type of growth. The models included only two out of the four dummies because the lack of cases in the dataset (of decrease GDP combined with either increase inequality or decrease inequality) generated multicollinearity for some countries.

We estimated three panel CS-ECM models with heterogeneous slopes and common factors to address the cross-sectional dependencies named after the variable we considered from the three specified above. The CD test statistic rejects the hypothesis of weak cross-sectional dependence in all cases, showing that we can confidently say that no cross-section dependence left in the models.

Table 3. Estimation results

	Pat_green	FDI	FD
Short Run Estimates			
D.IEn_r_cons	0.107	0.107	0.143
	(1.63)	(1.24)	(1.64)

	Pat_green	FDI	FD
L2D.pat_green_pr	0.285		
	(1.42)		
LD.rpFDI		-0.0022	
		(-1.15)	
D.FD			0.409*
			(1.86)
D.IGDPct_pc	0.400*	0.285*	0.311*
	(1.88)	(1.8)	(1.76)
Adjust. Term	-0.457***	-0.466***	-0.515***
	(-3.85)	(-3.78)	(-4.49)
Long Run Estimates			
Mean Group			
IGDPct_pc	0.330**	0.791	0.435***
	(2.18)	(1.21)	(3.26)
lgdpct_pc_l11	0.00876*	0.0146*	0.00569**
	(1.91)	(1.68)	(2.55)
lgdpct_pc_l21	0.012*	0.00646*	0.0103
	(1.71)	(1.88)	(1.58)
lEn_r_cons	-0.296**	-0.553	-0.394***
	(-2.7)	(-1.8)	(-3.4)
L2.pat_green_pr	-0.109		
	(-0.15)		
L.rpFDI		-0.0136	
		(-0.66)	
FD			-0.619
			(-1.13)
N	292	287	292
CD Statistic	-0.193	-0.422	-1.015
CD p-value	0.847	0.673	0.31

Note: *t* statistics in parentheses. * means $p_value < 0.10$, ** $p < 0.05$, *** $p < 0.01$
 Variables that are in logarithm are denoted with the prefix *l*.
 D and L are the difference and lag operator respectively.
 Test for weak cross-sectional dependence (CSD) is the CD test (Pesaran, 2015)

Source: Authors' computations.

On short run all models shows significant and positive effect of GDP per capita on CO2 emissions and financial development (FD), which has also an increasing impact on pollution.

The error-speed of correction is displayed as adjustment term, which is negative, below one and highly significant as it should be to validate an error correction model shows that there is an adjustment towards the equilibrium.

On the long run per capita income and the consumption of renewable energy have the right sign and are highly significant for models with green patent (*pat_green_pr*) and financial development (FD) variables. The renewable energy consumption reduced the CO2 emissions in the long run, but not in the short run.

The decoupling of GDP from pollution is evaluated through the GDP coefficient in the models. It shows that there is no absolute decoupling of emission and economic growth in the NMS, but the value of the coefficient is smaller than one showing that there is relative decoupling. This result is in line with global evaluation based on consumption-based approaches (Wiedmann and Lenzen, 2018; Schandl, et al., 2018). However, empirical studies found mixed results for different countries in different income groups (Liobikiene et al., 2016, Wang et al., 2022).

Among the two variables which capture the type of growth only one of them is significant in the FD model, the one for positive economic growth and increased inequality. The coefficient is small, but suggests that growth associated with increase inequality is detrimental for NMS in their efforts to reduce emissions in comparison to growth combined with decreased inequality. For the other two models both interaction variables are positive and significant.

The model with the maximum p-value for the CD statistics is the one which include the rate of green patent in total patents so this is the preferred model. It shows that growth with decrease in inequality is more detrimental than the growth with increasing inequality. This is in line with Grunewald et al. (2017) that show that in upper middle-income and high-income economies, higher inequality is associated with higher emissions.

A specific innovation compared to the existing literature is that, instead of focusing on the direct inequality-emissions relationship, we consider the synergistic effect between the type of economic growth and inequality on emissions. Furthermore, the estimator we use (Common Correlated Effects Estimator-Mean Group for error-correction model based on Chudik and Pesaran (2015)) deals with unobserved heterogeneity. This heterogeneity is derived from the fact that different countries, which have different challenges and opportunities adopt pollution prevention technologies at different times with different pace.

4.1. Robustness check

Another way to deal with unobserved heterogeneity of the coefficients is to apply quantile estimation, which measure the effect of the independent variables on the distribution for the dependent variable. We use the quantiles-via-moments (MM-QR) of Machado and Santos Silva (2019) which doesn't assume homogeneity on the fixed effects across all quantiles, but assumes a location-scale model.

$$y_{it} = \alpha_i + x'_{it}\beta + (\delta_i + x'_{it}\gamma)u_{it} \quad (3)$$

The τ - th quantile, $0 < \tau < 1$, of the dependent variable y is defined as:

$$Q_y(\tau|x) = \min\{\eta | P(y \leq \eta|x) \geq \tau\}$$

$\beta(\tau) = \beta + \gamma Q_u(\tau)$ are the coefficients for τ - th quantile.

Table 4. Estimation results for quantile regression

lco2_cons_pc	location	scale	qtile_15	qtile_30	qtile_45	qtile_60	qtile_75	qtile_90
lGDPct_pc	0.221 ***	0.064 **	0.135	0.175 **	0.209 ***	0.239 ***	0.273 ***	0.332 ***
	(3.02)	(2.11)	(1.54)	(2.27)	(2.84)	(3.25)	(3.61)	(3.82)
FD	0.130	-0.153 ***	0.336 ***	0.240 *	0.158	0.086	0.006	-0.135
	(0.92)	(-3.1)	(2.84)	(1.93)	(1.15)	(0.58)	(0.04)	(-0.67)
rpFDI	0.0006	0.0007 ***	-0.0004	0.0000	0.0004	0.0008	0.0011	0.0018 **
	(0.61)	(4.2)	(-0.46)	(0.05)	(0.46)	(0.81)	(1.19)	(1.86)
pat_green_pr	0.053	-0.021	0.081	0.068	0.057	0.047	0.036	0.017
	(0.36)	(-0.22)	(0.91)	(0.66)	(0.42)	(0.27)	(0.17)	(0.06)
lEn_r_cons	-0.183 ***	-0.037	-0.133	-0.156 **	-0.176 ***	-0.193 ***	-0.212 ***	-0.246 ***
	(-2.98)	(-1.42)	(-1.48)	(-2.08)	(-2.72)	(-3.4)	(-4.4)	(-5.56)
lGDPct_pc_l11	0.00520 ***	0.00090	0.00400	0.00456	0.00503 ***	0.00546 ***	0.00592 ***	0.00675 ***
	(3.03)	(0.77)	(1.45)	(2.06)	(2.77)	(3.42)	(3.78)	(3.37)
lGDPct_pc_l21	0.00484 ***	0.00023	0.00453	0.00467	0.00479 ***	0.00490 ***	0.00502 ***	0.00524 ***
	(2.97)	(0.21)	(1.52)	(2.00)	(2.65)	(3.58)	(5.16)	(5.66)

The results are obtained with MM-QR estimators with robust and clustered standard errors that computes asymptotically valid standard errors under the assumption of heteroscedasticity and misspecification. The direction and significance of the coefficients are in line with the estimation results from the main model. They suggest that the effect of the GDP per capita and the interaction term denoting the two possible types of growth (inequality increasing growth and inequality decreasing growth) are heterogeneous, being large for countries whose CO₂ emissions is high and small for countries with low pollution.

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