Programming with application to SDG - Project

Does democracy favor green growth?

A reassessment of the Environmental Kuznets Curve through the lens of institutional freedom

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Abstract : This paper reassesses the Environmental Kuznets Curve (EKC) by considering the role of political regimes. Using World Bank and Polity V data for 2000-2018, we estimate two-way fixed effects models for subsamples on democracies, anocracies and autocracies. The regressions include GDP per capita, its square, the rule of law, renewable energy and industry. The EKC appears globally and in autocracies, but only a few countries reach the turning point, mostly very rich states or oil exporters. In democracies and anocracies, the coefficients are significants and indicate concavity, but the turning point lies beyond observed income levels. Renewable energy reduces emissions across all regimes, with the strongest effect in autocracies. The rule of law decreases emissions globally and in democracies but has the opposite effect in authoritarian contexts. Finally, an increase in the industrial production leads to an increase in CO2 emissions globally, for anocracies and for autocracies. Robustness checks underline the importance of period and sample. After 2015, an EKC emerges more clearly in anocracies, likely due to international pressure and the search for legitimacy after 2015 Paris agreements. Overall, growth does not secure lower emissions and the typology of countries achieving the decoupling prevents us from observing an existing EKC, especially when we consider the type of regimes.

Keywords: Environmental Kuznets Curve, Ecology, Democracy, Economic growth, autocracy, decoupling, institutions

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We considered SDGs 13 "Climate Action" and 16 "Peace, Justice and Strong Institutions" for this work.

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1 Introduction

Since the industrial revolution the growth of GDP has been considered the cornerstone of economic progress and the goal of every economic policy. It has enabled swathes of people around the globe to escape poverty by driving up living standards and creating a vertuous cycle of prosperity, driving down prices while increasing corporate profits and state revenues. It nonetheless carries a number of drawbacks as its benefits may not be evenly distributed. This drew the attention of economists, among whom Simon Kuznets, who discovered that as inequality grows in the early stages of economic development, it starts to decline after a certain level of GDP per capita, following a inverse U relationship, now widely known as the Kuznets curve.

However, in the early 1970s a more pressing challenge facing economic growth was discovered : climate change (Meadows, 1972). The emissions of Co2 resulting from human activity would inevitably lead to an irreversible rise in global temperatures, deteriorating not only the conditions of economic activity, through extreme weather events and increased tension on resources, but eventually posing a threat to the survival of mankind. There rises a dilemma : growth is necessary for our prosperity in the short-term, but simultaneously detrimental in the (not so much anymore) long-term. Policy makers have since tried to promote a kind of economic growth that would not harm the environment, "green growth".

The problem could indeed be solved if the evolution of GDP could be made independent of Co2 emissions, a problem known in the literature as "decoupling". In 1995, Grossman and Krueger, taking data from 28 countries, found an inverse U relationship between GDP per capita and environmental quality, a result since described in the literature as the Environmental Kuznets Curve (EKC). This suggests that after a given level of income, decoupling would "automatically" happen (a statement however nuanced by the authors). This "good news" can seem suspicious as the several IPCC reports over the past few years suggest that despite the commitments and efforts taken by governments, the 1.5° C degree target of the 2015 Paris agreement will almost surely not be met (Hickel and Kallis, 2019). The questions thus boils down to the capacity of governments to implement green growth. Paradoxically, some important advances in green technologies like solar panels and emission trading schemes are starting to come from non-democratic countries such as China. One could also consider that since individuals favor short term welfare to longer term goals when left the choice, democracies would lack the capacity to implement needed drastic changes to curb climate change whereas autocracies, less constrained by public opinion, would benefit from larger capacity to implement them. This would contradict the academic consensus that considers that democratic institutions are best suited to guarantee long term economic prosperity, as it is unclear whether they also favor the efficient climate policies that would enable green growth.

We thus test the EKC hypotheses while taking into account the relationship between democracy and the environment.

To investigate this question, we construct a dataset combining the World Bank's World Development Indicators with the polity2 score from the Polity Project of the Center for Systemic Peace (https://www.systemicpeace.org/polityproject.html). This enables us to measure economic performance, environmental outcomes, and institutional quality within a unified framework. Our empirical strategy is to estimate quadratic regressions of CO_2 emissions per capita on GDP per capita, following the Environmental Kuznets Curve approach, and to compare results across subsamples of countries defined by their level of political freedom. This design enables us to assess whether the shape and turning points of the income–emissions relationship differ systematically across political regimes.

Our main findings show a nuanced picture. For the global sample, and more clearly for autocracies, the income–emissions relationship takes a concave form, consistent with the EKC framework. Yet only a few very particular countries, often high–income or resource–based economies, actually reach the turning point. By contrast, in democracies and in hybrid regimes, the coefficients also point toward concavity, but the implied turning points lie well above observed income levels, meaning that growth continues to be associated with rising emissions for most cases. The analysis further shows that these results are sensitive to the period of observation and to the choice of controls. For instance, after 2015 the EKC appears more realistic for anocracies, possibly reflecting the combined effect of international climate commitments and legitimacy pressures. Taken together, these results suggest that the EKC cannot be treated as a general law of development.

In the following pages, we first offer a review of the literature on the relationships between GDP, environmental degradation and democracy. Then, after presenting the data, we present our econometric framework and report the main results of our analyses. Finally, we discuss the implications of those results and end with concluding remarks.

2 Literature Review

Economic growth and the environment. The relationship between economic growth and environmental degradation has long been studied in the economic literature. In the last decades, it has particularly been analyzed through the lens of the so-called Environmental Kuznets Curve (EKC). The EKC, drawn from the notorious Kuznets Curve, suggests that environmental degradation first increases with national income but decreases afer a certain point. A country may indeed emit more CO_2 in the early stages of its development through industrialization before reducing its emissions as its economy shifts toward the tertiary sector. The work considered to be the starting point of the literature on the EKC is that of Grossman and Krueger (1994). The authors analyze several environmental indicators such as urban air pollution and river contamination to find that environmental quality does not decrease monotonically with income. Instead, for most indicators, there is an initial phase where pollution increases before decreasing after a given threshold. The authors find that this turning point generally occurs at a GDP per capita of 8000 $ (in 1985 USD) for most pollution indicators.

The EKC has been backed by various studies in the context of developing countries. As an example, Narayan and Kumar (2010) test the EKC can be tested by comparing the short and long-run income elasticities of CO2 emissions. Their results, based on a sample of 43 developing countries, show that for 35% of the sample emissions declined in the long run, suggesting that GDP per capita growth might lead to environmental improvement. Their panel data analysis indicates that the inverse U-shaped correlation exists at the regional level, only within the Middle East and South Asia subsamples.

However, the EKC hypothesis remains criticized among economists. Stern (2004) raised doubts over its validity by highlighting the statistical weaknesses of various EKC studies. Indeed, his argument was that some developing countries have adopted environmental standards at a quicker rate than wealthier ones. This suggests inconsistency among country income groups. The author thus suggests the use of alternative analytical frameworks in order to better understand the dynamics between economic development and the preservation of the environment.

In contrast, more recent research by Fu (2023) finds a consistent positive correlation between GDP growth and CO2 emissions. The study suggests that economic expansion is still closely tied to rising emissions, indicating ongoing tension between growth and sustainability. However, their findings do not seem to confirm the existence of an inverse U-shaped function but more of a slightly concave relationship. Further research categorized nations into the World Bank's income classifications (Almeida et al., 2024). Regressions carried out on such subsamples allow us to distinguish environmental-economic dynamics across different income groups. The different pathways nations follow shed light on the ongoing issue of sustainable development for emerging economies, as only high-income countries show a decoupling of economic growth from CO2 emissions.

Taken together, the literature reveals mixed evidence regarding the compatibility of economic growth and environmental preservation. As some findings support the decoupling of CO2 emissions from GDP per capita in higher stages of development, others show persistent links between growth and environmental degradation, as the Meadows report argued (Meadows, 1972).

Economic growth and democracy. The relationship between democracy and economic growth has long been debated in economics. Upon evaluating the correlation between economic development and democracy (Évelyne Huber et al., 1993), early contributions often doubted the direct economic benefits of democratic institutions . As an example, Barro (1996), using cross-country analysis, argued that political rights had no significant effect on growth, as democracy could slow down development. He observed that once variables on the rule of law, free markets, small government consumption and human capital are held constant, a non-linear relationship between democracy and growth appears. Indeed, an increase in freedom could benefit growth for countries with a low level of political freedom, but reduce it above a certain threshold - a hypothesis we will test in this paper. These findings argue in favor "enlightened despotism" - the idea that an authoritarian regime could avoid political instability and thus ensure faster growth. Papaioannou and Siourounis (2008) find similar results, showing that democracy's effects are negligible, at least in the short run, before stabilizing at long-term. However, these authors used new tools to measure democracy, overcoming those proposed by Przeworski (2004). These authors define democracy through the election of an executive and legislature combined with contestability of power. However, these works often failed to distinguish temporary GDP drops when a regime change from a long-term growth dynamic.

A second literature highlighted the importance of incorporating transition shocks when investigating the democracy–growth relationship. The example of the Arab Spring shows that democratization is commonly preceded by episodes of social panic, which can cause a transitory fall in GDP per capita. This raises methodological obstacles as short-term falls associated with political transitions may hide the long-run benefits of institutional change. As a response, later studies used other econometrics techniques such as lag structures and dynamic panels with error correction terms to isolate causal effects. They also refined the indicators used to define a democracy by integrating dimensions such as freedom of press, political education, and repression of opponents. Within this field, Nobel Prize economists Daron Acemoglu and James A. Robinson published a breakthrough article (Acemoğlu et al., 2019). By combining extensive data, using indicators of democracy such as the ones proposed by Freedom House and Polity V, they analyzed a dataset of 175 countries between 1960 and 2010. They used dynamic panel models, country fixed effects, and instrumental variables to address endogeneity and omitted variable bias. Their findings suggest that an increase in the level of democracy allows a substantial increase in GDP per capita in the long run but a decline in the short run due to the political instability created by the coup. Indeed, democracy might lead to greater investments in human capital, health expenditures, infrastructure building, trade openness and more efficient rents (Brough and Kimenyi, 1986).

As a whole, the literature reveals an evolution from doubts about the benefits of democracy for growth to a more nuanced opinion. By highlighting long-term institutional advantages, it provides stronger evidence that political institutions play a role in economic development. However, by promoting economic growth and thereby strengthening the diktat of the present (Hardin, 1968), democracy could lead to an increase in CO_2 emissions.

Democracy and the environment. Various works aim to link democratic institutions to environmental outcomes. Carayannis et al. (2021), using descriptive statistics, document a statistically significant positive correlation between political freedom and environmental performance across 156 countries in 2016. Moreover, Farzin and Bond (2006) show that democracy favors decreases in CO_2 emissions as civil and political liberties enable voters to express their preferences toward more sustainable economic policies. They also note that education, demographics and urbanization could either amplify or slow down this effect. Thus, the addition of control variables seems to mix the results found. In order to address this issue, Bromley et al. (2025) explored possible omitted variables that reduce the caused endogeneity. They found that education appears to be a key moderator. Indeed, democracy only remains associated with lower CO2 emissions if average education levels are high. Finally, Tsur (2025) look after the democratic components that affect greenhouse gas emissions. He finds that while direct popular voting reduces it, greater emphasis on individual political liberties reduces the effectiveness of economic policies to decrease emissions by interfering with government intervention and regulations.

Economic growth, democracy and the environment. Several studies aimed to modelize the relationship between CO2, GDP and democracy. By using a large cross-section dataset for 2014, focusing on 78 high-income and 53 low-income countries, Kim et al. (2019) used a simple OLS regression to look after this relationship. They found that, in rich countries, most democratic dimensions are linked with an improve in the environmental quality. However, in poorer countries, emissions of CO2 are only affected by the effectivity of the government, meaning its ability to maintain the rule of law to reach the intended economic policies. Moreover, the income level only seems to matter for richer countries whereas poorer should only reinforce their institutional governance to decreases their CO2 emissions.

In their 2008 article's, Gallagher and Thacker (2008) examined the effect of democracy on environmental quality, while considering the Environmental Kuznets Curve (EKC) framework. They used panel data from 1960 to 2001. They distinguished the current level of democracy, considering the polity2 indicator, from the long-run "stock of democracy". The former is the accumulation of democratic scores since 1960. Their results show that the current level of democracy has no significant effect on CO2. However, the stock of democracy shows a significant negative effect and thus reduces emissions in the long run. As they claimed that democratic mechanisms, such as access to information or international cooperation, require time to be important enough to generate environmental

improvements, these results appeared consistent with their initial hypothesis.
However, our study focuses from 2001 to 2019. We also chose to rely on the democracy score at year i rather than on the "stock of democracy". Indeed, we acknowledge that democracy can slowly infuse into institutions to reduce corruption or strengthen accountability over time. Nonetheless, we do not consider that these trajectories are strictly cumulative. Indeed, such institutional change follows discontinuous patterns and are the result of a coup or a major crisis. Such events can abruptly erase decades of democratic or autocratic influence, while they may also lead to new economic policies. Then, the relationship between democracy and environmental outcomes can not be treated as an arithmetic accumulation. Therefore, we will test the empirical results found by Gallagher and Thacker's by using annual democracy levels and considering additional control variables for a new time range. Indeed, the last two decades, especially since the Paris Agreement, saw an important improvement in both environmental-friendly policies and industrialization of emerging countries, as well as integration into the global market. Thus, we want to assess whether or not political regime changes can lead to an improvement in CO2 emissions.

3 Data

For the political dimension, we used the polity2 data, taken from the polity project of the Center for Systemic Peace (CSP) (Marshall and Gurr, 2020), a recognized US-based monitor of political and institutional trends. The variable accounts for the democratic character of a country based on a dozen of criteria reflecting dimensions such as the election of state executives, pressure put on power and the fact citizens can freely voice their opinions. The polity2 score taken here is in practice the difference between an "autocracy score" and a "democracy score" for each country, each score being based on different indicators of political freedom and with values on a discrete scale from 0 to 10. The polity2 score is thus an integer value on a scale from least democratic (-10) to most democratic (10). Based on its polity2 score, a regime is can be ranked one of three categories : « autocracy » from -10 to -6, « anocracy » - somewhere between an autocracy and a democracy - between -5 and 5 and « democracy » from 6 to 10.

The rest of the data is taken from the World Bank's World Development Indicators (WDI). For economic output we took annual GPD per capita in 2015 US dollars. For environmental quality, we took total annual emissions per capita of carbon dioxide (CO2), excluding land use change, land use and forestry (due to uncertainty in the corresponding fluxes). This contrasts with the original Grossman and Krueger paper where the authors consider various measures linked to environmental quality (water and air pollution indicators) but exclude CO2 emissions, which after all constitute the key driver of climate change - maybe a reflection of the lack of consciousness about this issue at the time.

We also looked at variables such at urban population (as share of total population), the size of the industrial sector (as a share of value added in GDP), renewable energy consumption (as a share of total energy consumption), oil rents (the difference between the value of crude oil production at regional prices and total costs of production, as a share of GDP), rule of law and corruption (two scores with continuous values comprised between -2.5 and 2.5, taken from the Worldwide Governance Indicators). Those variables have been chosen as they have been extensively used in the EKC literature.

After merging the two data sources and cleaning the data, we get a dataset with 3049 observations across 164 countries. In order keep the same number of data points across countries and thus limit missing values, we restrained the time period from 2000 to 2018. We consequently obtain 7 variables (excluding "country" and "Time" that serve as indices) to which we add 4 new ones consisting in algebrical transformations of existing variables.

Indeed, as the CO2 and GDP variables are both highly skewed to the left of their distributions we apply the natural logarithm transformation. After those adjustments we can clearly see the positive relationship between CO2 and GDP (**??**). It also does seem non linear, and even concave, conforting us in the relevance of estimating the EKC. We observe some outliers at the bottom of the graph, that will disappear as we split the dataset with the polity2 variable, an operation later described in this section. Furthermore, in order to prepare for our model specification, we compute the squared and cubic transformation of the log of GDP. As will be reminded later, we won't use the cubic term since it turns out to be non-significant.

In order to have a more comprehensive view of all the relationships between the variables in our dataset we can have a look at the correlation matrix (Figure 1). As industry and oil are strongly correlated together (0.8), we will drop the oil variable in our specification. Similarly, we drop corruption because of its strong correlation with the rule of law (0.9) and urban population because of its strong correlation with the log of GDP (0.8). We can also see here that the log of CO2 is very strongly correlated with the log of GDP alone (0.9).

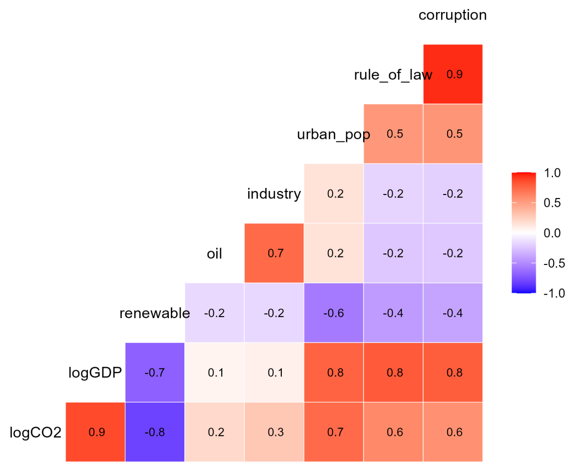
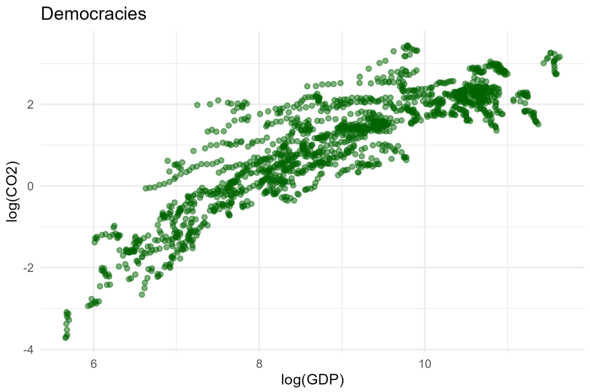
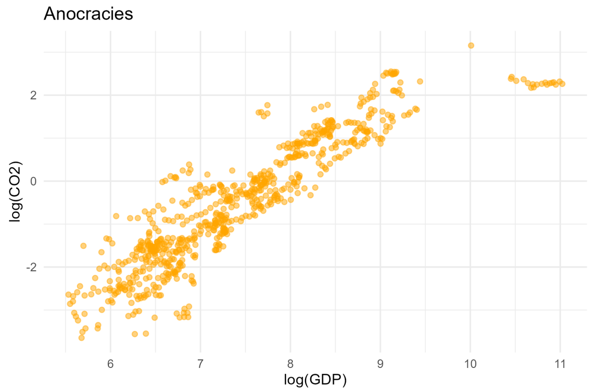


Figure 1: Correlation matrix for the whole sample

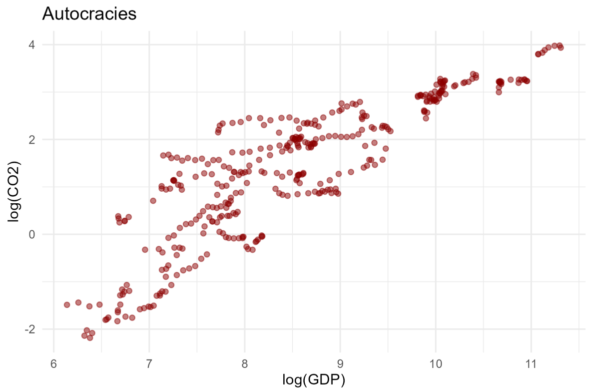
The "democratic" dimension, embodied in the polity2 score explained at the beginning of this section, is used to split the dataset into three subsets according to the regime a country belongs to : democracy, anocracy and autocracy. This operation is key as it will enable us to compare all our analyses across the 3 regimes. In order to have a glance at their respective idiosyncraties, one can look at the CO2 vs GDP scatter plot previously displayed for the whole dataset and now split by regime (Figure 2).



(a) Democracy



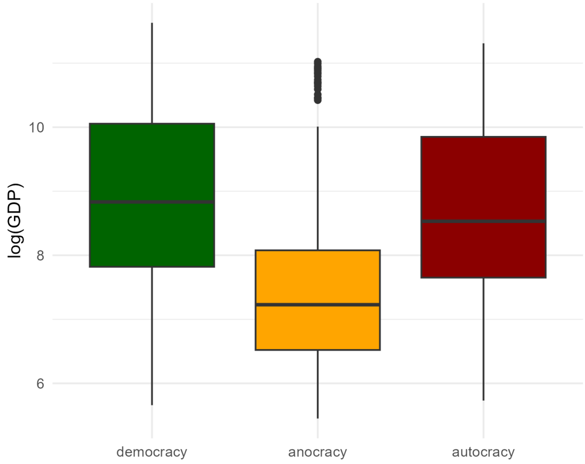
(b) Anocracy



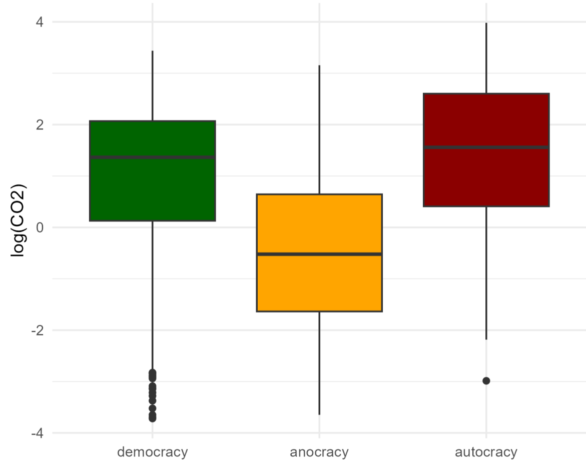
(c) Autocracy

Figure 2: CO2 versus GDP by regime

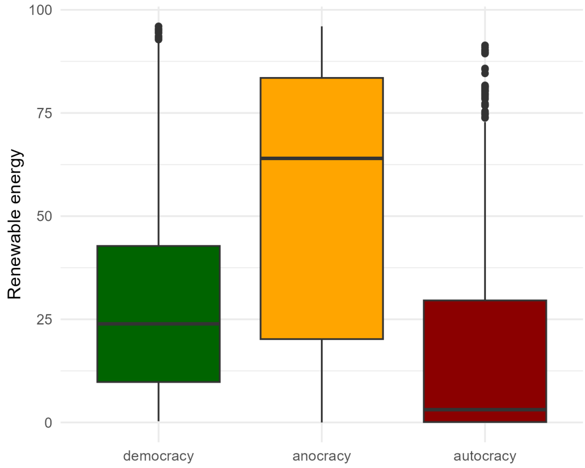
It is also of interest to look at the differences in the distribution of variables across the regimes, as illustrated in the boxplots below (Figure 3). We can see that for GDP and CO2, democracies and autocracies are at comparable levels while anocracies are clearly behind. Anocracies also denote in terms of the value range : wider than the other two regimes for renewables, narrower for rule of law. Finally, we observe that the less democratic the regime, the higher the share of industry of GDP. This might be explained notably by the fact that a similar trend occurs with oil, highly correlated to industry.



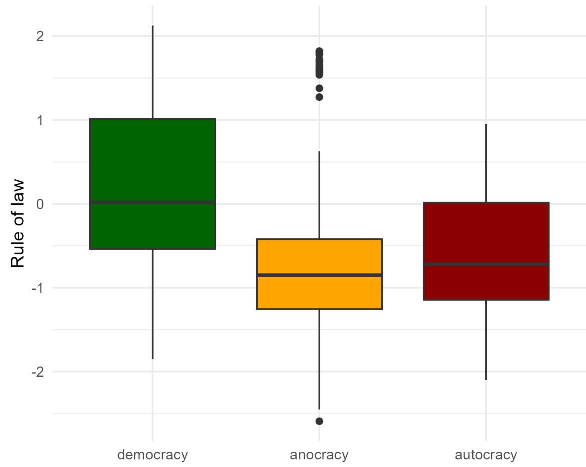
(a) log(GDP per capita)



(b) log(CO2 per capita)



(c) Renewable energy (% of total)



(d) Rule of law

Figure 3: Distribution of key variables by regime type

Consequently, we build on the results of the exploratory data analysis to build our econometric model of the EKC.

4 Econometric framework

In this part, we will specify the econometric framework used throughout our analysis. As mentioned earlier, we aim to determine whether the Environmental Kuznets Curve exists and differs across the three different types of political regimes. Considering Gallagher and Thacker's first econometric specification, we will use the following relationship :

$$\log(CO_2/P)_{it} = \alpha_i + \gamma_t + \beta_1 \log(GDP/P)_{it} + \beta_2 \Big[\log(GDP/P)\Big]^2_{it} + X_{it} + \varepsilon_{it} \quad (1)$$

We include the tonnes of emitted CO2 per capita (CO2/P), the GDP per capita in constant 2015 US dollars (GDP/P) and control variables (X_{it}). We choose to differ from Grossman and Krueger's and Gallagher and Thacker's second specification by removing the $(log(GDP/P))^3_{it}$ term, as it appears non-significant in our estimation results and increases the global multicollinearity level. Indeed, this could inflate the standard errors for very few gains regarding the short 20-year time period.

Similarly, we removed the $\bar{G}_{it}$ term, corresponding to the average GDP per capita over the prior three years. Indeed, we found articles, such as Gallagher et al.'s one, which do not use this averaging technique. Moreover, this reduces the number of degree of freedom while being non-necessary as the fixed-effect specification allows for smoothing such variations. As distributed lags were tried and found non-significant, we will address issues through robust estimators.

Finally, we considered our cross-correlation analysis (displayed in the previous part), to address multicollinearity issues. It seems that three regressors suffer from a high level of correlation: urban pop, renewable and oil. Then, we removed the oil rent indicators. Indeed, descriptive statistics show us that the oil variable is positive in the raw data for nearly exclusively autocracy, while being unsignificant for the latter. Thus, this would not bring new information to our analysis while increasing the standard error size. We also removed the urban population variable. In fact, we noticed a very high correlation between the part of the population living in an urban area and the log(GDP/P). We then choose to remove it to avoid violating the 4th Gauss-Markov condition.

We also had to make choose whether or not removing the variable corresponding to the part of the electricity produced from a renewable source. Indeed, it presents a very high correlation with GDP and CO2. However, using a renewable source of energy could heavily reduce CO2 emissions as a country does not have to rely on fossil energy for its industrial production. Therefore, removing the "renewable" would lead to a major loss of information and will even change major interpretations. Indeed, the EKC exists for autocracy if and only if "renewable" is removed. This appears as a classical omitted variable bias and thus keeping this indicator might reduce the endogeneity. So as to check whether or not we can keep it, we performed a VIF test for multicollinearity. On a "naive" simple pooled OLS regression, the VIF is about 11 points for "renewable" indicating that we should remove it. Nonetheless, we can perform it on a panel, with fixed effect, regression, to assess if the multicollinearity is within or across countries.

Table 1: Variance Inflation Factors (Within estimator)

Variable	**VIF (Within)**
logGDP	30.27
logGDP^2	28.13
renewable	1.26
industry	1.55
rule_of_law	1.14

As we can see here, when we perform a "within country" VIF test, it appears that there is no such collinearity across countries (except for logGDP and logGDP^2 which is normal), meaning that our fixed effect panel regression will deal with this issue. We also checked it by comparing the within and between correlations. We will discuss below the other tests which lead us to perform a fixed effect panel regression instead of a pooled naive one.

Before pursuing, we checked the robustness of the model concerning the Gauss-Markov conditions through a Breusch-Pagan test for homoscedasticity, a Breusch-Godfrey's one for autocorrelation and a Jarque-Bera for normality of the residuals. We failed to reject H0 for all of the three tests, implying that our model presents heteroskedasticity, auto-correlation of the residuals and a non-normal distribution of the latter. These results, in addition to the multicollinearity issues will lead us to move toward a non-pooled panel regression. Indeed, this might reduce all of the issues mentioned above.

So as to choose between a random effects (RE) and a two-way fixed effects (FE) one, we performed a Hausman test. Allowing to reject H0 at all usual levels, this test leads us toward a fixed effect model. However, our goal is to track how a country's CO2 emissions change when that same country's covariates change over time. Fixed effects fit this goal: they focus on within–country variation and remove all time-invariant factors as geography or cultural habits. In fact, domestic travel in a country as large as the United States clearly implies a higher use of domestic flights instead of buses or trains due to the long difference in travel time. A two-way fixed effects model is also more robust to violations of random effects assumptions. Indeed, random effects mix within and between variation and rely on the strong assumption that unit effects are uncorrelated with the regressors. Even when a Hausman test points to RE, that result can be fragile under heteroskedasticity, serial or spatial correlation, or slope heterogeneity. In practice, RE

estimates may reflect cross-sectional differences more than the dynamic response we care about. For clarity and robustness, we therefore use FE as our main specification.
Finally, we performed a Wald test to check if the creation of subsamples according to the type of regimes is consistent. We found a p-value of 0.0807, meaning that H0 is rejected at 10% : coefficients differ significantly when considering the type of regimes.

In conclusion, our final model will be

$$\begin{aligned}\log(CO_2/P)_{it} &= \beta_1 \log(GDP/P)_{it} + \beta_2 \Big[\log(GDP/P)_{it}\Big]^2 \\ &\quad + \beta_3\,\text{Renewable}_{it} + \beta_4\,\text{Rule-of-law}_{it} + \beta_5 \text{industry}_{it} \\ &\quad + \alpha_i + \gamma_t + \varepsilon_{it}.\end{aligned} \tag{2}$$

In the next section, we will discuss the results obtained by performing a two-ways fixed effect panel regression on the three different subsamples : democracy, anocracy and autocracy with the previous econometric specification.

5 Main results

In this section, we will analyze the main results of our cross-country analysis.

Table 2: Estimation results of the Environmental Kuznets Curve by regime type

	Global	**Democracy**	**Anocracy**	**Autocracy**
logGDP	1.6046***	1.9987***	1.1705***	1.0023*
logGDP^2	-0.0694***	-0.0721***	-0.0512**	-0.0497·
Renewable	-0.0234***	-0.0178***	-0.0266***	-0.0453***
Rule of Law	-0.0306**	-0.0626**	-0.0165	0.1393**
Industry	0.0027***	0.0018	0.0049**	0.0084***
Adj. R^2	0.4491	0.5792	0.3632	0.5336
N	3,174	1,568	746	371

Significance codes: $^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\cdot}p < 0.1$

As displayed in the table above, we notice that the EKC holds when the entire dataset is considered. The coefficient on logGDP is positive, sizeable (1.6046), and highly significant, while the squared term is negative, small in magnitude (-0.0694), and also strongly significant. This confirms the concave shape of the curve at the global level: rising income initially leads to higher emissions, though the negative quadratic points to an eventual turning point.

For democracies, the EKC pattern is even more pronounced. The effect of logGDP is larger (1.9987) and significant at the 1% level, and the squared term is negative (-0.0721) and also significant. The stronger magnitude of both coefficients suggests that in democratic regimes, growth is more tightly linked to environmental degradation at lower income levels, but with clearer evidence of a concave relationship as income continues to rise.

For anocracies, the EKC mechanism appears weaker. The coefficient of logGDP is smaller (1.1705) but remains highly significant, while logGDP^2 is negative (-0.0512) and significant at the 5% level. The pattern still indicates concavity, though the effect of income is less pronounced compared to democracies or the global sample. The results suggest that in anocracies, growth has a more moderate impact on emissions, and the path towards a turning point is less sharp.

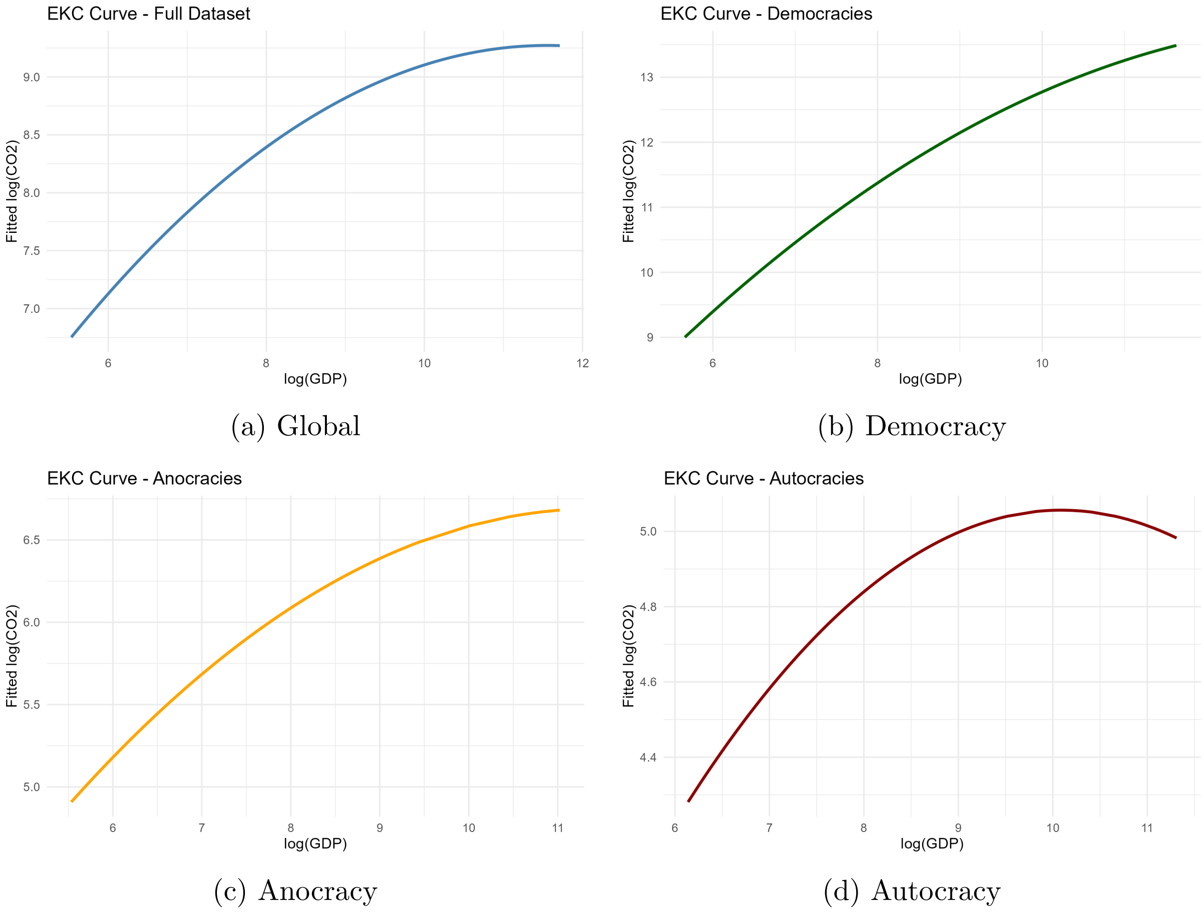
Finally, in autocracies, the EKC is present but its significance is smaller. The coefficient of logGDP is positive (1.0023) and significant at the 5% level, while the quadratic term is negative (-0.0497) and significant at the 10% level. Although being weaker in magnitude and significance compared to other regime types, these results still point to a concave relationship between income and emissions in authoritarian settings.

As we can see, the renewable estimates are negatives and highly significants for all regimes, while being higher (in absolute value) for autocracies. It means that if the part of the electricity produced using a renewable technology increases by 1%, the CO2 per capita emitted is reduced by up to 4.53% in autocracies. This stronger impact may reflect the heavier reliance on fossil fuels in authoritarian regimes, where the substitution towards renewable energy immediately replaces highly polluting energy sources such as coal or oil. Indeed, we saw that oil rents were mainly present in such regimes. Then, even a small increase in the share of renewable electricity can translate into a relatively large reduction in emissions. Moreover, autocracies often lack environmental standards and monitoring institutions. Thus, using renewable energies might capture the ecological trend of a state aiming to cut its CO2 emissions. As a result, the estimated impact appears stronger than in democracies or anocracies, where additional policies and efficiency gains already contribute to lowering emissions.

Regarding the rule of law, meaning the ability of the State to reinforce contract rights, its estimate appears negative and significant for democracy, while being unsignificant for anocracies. It can be explained as if a state is more able to reinforce the application of voted pro-environmental laws, the latter are more able to reduce CO2 emissions. Moreover, more developed states tends to prevent corruption more efficiently. Nonetheless, fragile states as anocracy might not pass such laws, which leads to an inefficiency of the rule of laws indicator, regarding CO2 emissions. We might also notice that this indicator is highly positive and significant for autocracy. Then, as an autocracy is able to reinforce laws, it might emit more CO2. This could be explained when studying the dataset. Indeed, very strict autocracy tends to emit more CO2 and can obviously reinforce the application of laws due to the brutality of such regimes. Then, the same brutality might lead them to be isolated on the international scene and thus not be incited to respect global environmental agreements. Thus, the more brutal towards its own citizens a government is, the more able it is to reinforce the rule of laws and then the more it would be isolated on the global scene. It might then emit more CO2.

Finally, the estimates for industry present a heterogeneous pattern among regime types. At the global level, the coefficient is slightly positive (0.0027) but highly significant, which indicates that industrial activity is systematically associated with higher emissions per capita. However, this effect is not significant in democracies. It suggests that cleaner technologies, stricter environmental standards or structural change towards services mitigate the environmental cost of industrial production. In anocracies, the coefficient is small but positive and significant (0.0049). The strongest effect is found in autocracies as the coefficient is larger (0.0084) and highly significant. This highlights that in authoritarian contexts, industrial expansion is more directly linked to increased carbon emissions, possibly due to the persistence of more carbon-intensive economies in developping autocracies.

You can find below the corresponding EKC curves for each type of regimes.



(a) Global (b) Democracy

(c) Anocracy (d) Autocracy

Figure 4: Environmental Kuznets Curves (EKC): Global, Democracy, Anocracy, and Autocracy

As we can see, the EKC curve only strongly appears for the autocracy subsamples. Indeed, while coefficients being significant for the others, turning points seem to be higher than the maximum value of the logGDP per capita inside the sample. In fact, we computed the turning points, meaning the level of GDP per capita for which the CO2 emissions level is supposed to decrease as the GDP per capita increase and we compared it the maximum observation found in the data.

Table 3: Turning points and observed GDP per capita ranges

Model	**Turning point (GDP pc)**	**Observed range (GDP pc)**	**Exists in sample?**
Global	104,509	[253, 122,144]	Yes
Democracy	1,039,901	[287, 112,418]	No
Anocracy	92,006	[253, 61,250]	No
Autocracy	24,089	[463, 81,609]	Yes

Notes: “Exists in sample” = turning point lies within the observed GDP per capita range.

Thus, we can not conclude for the existence of an EKC curve, except for autocracies or globally. However, only few countries managed to reach this turning point. For the global sample, only Luxembourg and Bermuda reach it. This can be explained as Luxembourg is very wealthy and small country, with a limited industrial production and available public transportation. Thus, its banking economy allows it to decouple its economic growth from its CO2 emissions. Similarly, Bermuda is a wealthy country thanks to banking activity and tourism. Moreover, it might be more difficult to capture all emitted CO2 due to its condition of being small islands. Both of these countries also import an important part of their consumption and thus externalise their CO2 emissions, which can make us doubt about the validity and existence of a such EKC curve For the autocracies, we see that Bahrein, Koweit, Qatar, Saudi Arabia and United Arab Emirates achieve to reach this turning point. These countries are high-income oil exporters, with very large GDP per capita compared to the rest of the autocratic group. Thus, even if they produce a lot of CO2, their wealth is much more important comparing to their emissions. However, we can clearly criticize the existence of an EKC in this case as the only countries to achieve it relies on a fossil-energy oriented economy.

6 Discussion

The results of our analysis suggest that the Environmental Kuznets Curve (EKC) is not a general law. In most of our estimations, turning points appear at levels of GDP per capita that only few countries manage to reach. This means that the inverted U-shape relationship cannot be fully confirmed in our data, except for the global sample and autocracies. Even there, groups of countries actually achieving the turning point is very small and often limited to specific economic structures.

First, the global results are mainly driven by small, very rich countries such as Luxembourg and Bermuda. As saif before, these economies rely on financial services and tourism, while importing most of the goods they consume. This implies that a large share of their emissions is externalized abroad. Thus, the fact that they reach the turning point only reflects the way their economies are organized. The same criticism applies to autocracies, where only Bahrain, Kuwait, Qatar, Saudi Arabia and the United Arab Emirates achieve the turning point, as Narayan and Kumar (2010) found. Indeed, These states are wealthy oil exporters, with very high GDP per capita compared to their emissions. Their economic model remains fossil-fuel based, which raises doubts about whether the EKC is really at work or if the result only reflects exceptional levels of income generated by resource rents. This conclusion seems consistent with the fact that oil rents mainly appear among autocracies.

A key point is that the results depend strongly on the period and the data. To this extent, we made various robustness check across different time periods. For instance, when focusing only on years between 2012 and 2018, almost all autocracies drop below the turning point, with the exception of Qatar. At the same time, an EKC seems to appear globally, but the countries above the threshold are mostly financial centers or tax havens, with Norway as the only exception. Norway is the only country that managed to reach the turning point without relying exclusively on fossil rents or financial activities, which makes it an important case and is consistent with the environmental policies conducted by their government. Similarly, when extending the analysis back to the 1970s, the EKC is much less visible because many governance indicators, such as rule of law, are only available after 2000. Thus, the reduction in observations biases the estimation. However, when focusing on the period 2015–2024, the EKC clearly appears as significant for anocracies, with a turning point at around 2,621 constant 2015 USD per capita.

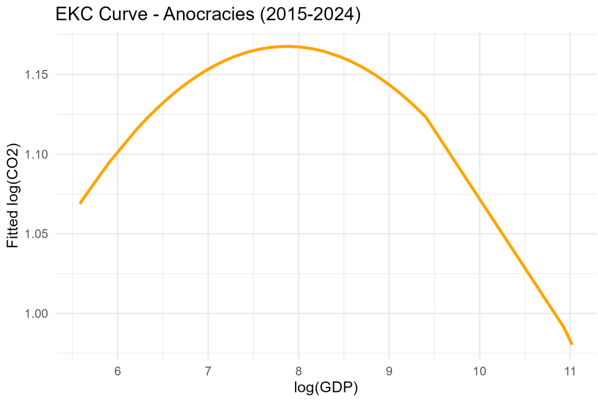


Figure 5: EKC for anocracies on the 2015-2024 subsample

Several countries are above this threshold, including Singapore, the United States, Turkey, Malaysia, Libya, Russia, Suriname, Cuba, Gabon, Thailand, Ecuador, Algeria, Jordan, Armenia, Egypt, Morocco, Angola, Bhutan and Djibouti. One possible explanation is that anocracies, which often seek legitimacy on the international stage, might have stronger incentives to reduce CO2 emissions in recent years, especially since 2015 Paris Agreements. This result is consistent with parts of the literature and gives turning points of a similar magnitude to previous studies.

Another point of comparison is with the early literature. Grossman and Krueger (1994) found a turning point at around 8,000$ in 1985 USD (equivalent to 18,000$ in 2015 USD), but we do not find this result. Indeed, pollutants considered differ: Grossman and Krueger focused on local pollutants such as sulfur dioxide, which have strong short-term health impacts. Countries are often quicker to control these pollutants once they reach a higher income level. In contrast, our study considers CO2, a global pollutant with long-term effects, for which the incentives to reduce emissions emerge later in the development process. We find different results from the 40.000$ (1995 constant US dollars - equivalent to nearly 60.000 2015 US dollars) found in Gallagher and Thacker (2008).

Overall, our results underline the importance of data choices, time periods and control variables. They suggest that the EKC should not be seen as a universal pattern, but rather as a phenomenon that can emerge in specific contexts, depending on institutional quality, economic structure and international incentives.

7 Conclusion

This paper has examined the link between income and CO2 emissions across different political regimes. Our results show that the Environmental Kuznets Curve is not a universal rule, but rather a relationship that can sometimes appear under specific conditions. For the global sample, as well as for autocracies, the estimates confirm the existence of a concave relationship between GDP per capita and emissions. However, only a handful of very particular countries actually reach the turning point, such as Luxembourg, Bermuda, or oil-rich states in the Gulf region. This suggests that the EKC should be interpreted with caution, as it might reflect special cases rather than a general process of development.

When we look at democracies and anocracies, the concavity is visible in the coefficients but the turning point is located far above the observed income levels. This means that for most countries, growth is still associated with rising emissions. Our additional tests show that the picture can change depending on the period considered, the available indicators and the chosen controls. For example, after 2015, anocracies display a much clearer EKC with more realistic turning points, probably because of stronger international pressure and the search for legitimacy for these regimes on the global stage.
Taken together, these results highlight both the strengths and the limits of the EKC approach. Indeed, it helps to illustrate how income and institutions interact in shaping environmental outcomes. However, other control variables accounting for external emissions, such as trade statistics, could be considered. Future research could therefore extend this work by considering consumption-based emissions, adding other governance indicators, and looking at the role of international agreements in shaping the trajectory of different regime types.

In the end, our study shows that the EKC can be observed in some cases, but it cannot be seen as a general law. Our first intuition was that autocracies may be more able to control their internal policies toward more sustainable ones as they are not dependent of the "dictatorship of the present". However, this assumption has not been empirically verified as the only regimes achieving decoupling are petromonarchies. Thus, their decoupling, in addition to being useless globally, is for sure not meant: environmental issues are not on the agenda of oil-based regimes.

References

Acemoğlu, D., Naidu, S., Restrepo, P., and Robinson, J. A. (2019). Democracy does cause growth. *Journal of Political Economy*.

Almeida, D., Carvalho, L., Ferreira, P., Dionísio, A., and Haq, I. U. (2024). Global dynamics of environmental kuznets curve: A cross-correlation analysis of income and co2 emissions. *Sustainability*.

Barro, R. J. (1996). Democracy and growth. *Journal of Economic Growth*.

Bromley, P., Furuta, J., and Schofer, E. (2025). The missing link: democracy, education, and carbon emissions. *Environmental Politics*.

Brough, W. T. and Kimenyi, M. S. (1986). On the inefficient extraction of rents by dictators. *Public Choice*.

Carayannis, E. G., Campbell, D. F. J., Grigoroudis, E., and Grigoroudis, E. (2021). Democracy and the environment: How political freedom is linked with environmental sustainability. *Sustainability*.

Farzin, Y. H. and Bond, C. A. (2006). Democracy and environmental quality. *Journal of Development Economics*.

Fu, X. (2023). Research on the relationship between co2 emission and gdp growth with data visualization methods. *Applied and Computational Engineering*.

Gallagher, K. P. and Thacker, S. C. (2008). Democracy, income, and environmental quality. *null*.

Grossman, G. M. and Krueger, A. B. (1994). Economic growth and the environment. *National Bureau of Economic Research*.

Hardin, G. (1968). The tragedy of the commons. *Science*.

Hickel, J. and Kallis, G. (2019). Is green growth possible. *New Political Economy*.

Kim, Y., Kim, S., Baek, J., and Heo, E. (2019). The linkages between democracy and the environment: Evidence from developed and developing countries:. *Energy Environment*.

Marshall, M. G. and Gurr, T. R. (2020). Polity v project, political regime characteristics and transitions, 1800–2018. *Center for Systemic Peace*.

Meadows, D. (1972). The limits to growth: A report for the club of rome's project on the predicament of mankind. new york: Universe books, 1972, 205 pp., 6.50(*cloth*)2.75 (paper) l.c. 73-187907. *American Behavioral Scientist*.

Narayan, P. K. and Kumar, P. (2010). Carbon dioxide emissions and economic growth: Panel data evidence from developing countries. *Energy Policy*.

Papaioannou, E. and Siourounis, G. (2008). Democratisation and growth. *The Economic Journal*.

Przeworski, A. (2004). Democracy and economic development. *null*.

Stern, D. I. (2004). The rise and fall of the environmental kuznets curve. *World Development*.

Tsur, Y. (2025). The diverse impacts of democracy on greenhouse gas emissions. *Ecological Economics*.

Évelyne Huber, Rueschemeyer, D., and Stephens, J. D. (1993). The impact of economic development on democracy. *Journal of Economic Perspectives*.