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Abstract

There are considerable differences in greenhouse gas emissions across countries, with little consensus on the extent to which political regimes affect environmental outcomes. This paper shows that the incentives that resource endowments and prices generate are key to understanding the influence of political regimes on emission outcomes. We analyze the relationship between commodity windfalls and CO_2 emissions in a model of stratified political regimes, identifying the limits of democracies for environmental quality. To study the impact of international commodity prices on CO_2 emissions, we use a panel of 179 countries covering the period 1970 to 2018. We then explore democracies and autocracies as channels for the heterogeneous effects of commodity windfalls on environmental quality. Our panel fixed effects estimation strategies account for the rich dynamics of contemporaneous emissions. Our baseline results show that commodity windfalls increase CO_2 emissions in the long run. Similarly, countries with above threshold scores by measures of democratic institutions, such as executive recruitment, executive constraints, and political competition, have a significantly higher levels of CO_2 emissions than those with lower scores. These results are robust to several sensitivity checks.

JEL codes: Q56, Q33, O13, H87, H11
Keywords: Commodity windfalls, Democracy, Environmental quality, Carbon emissions

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1 Introduction

This paper studies the relationship between resource endowments and prices and greenhouse gas emissions. We explore whether this relationship heterogeneously varies depending on the types of political regimes. The supply of environmental quality policies by a government is shaped by citizens' demand and preferences for environmental accountability. Democracies offer civil society a deliberative role in policy formulation (Acemoglu and Robinson, 2006); consequently, the demand for environmental protection could help shape political leaders' preference for reforms that translates into greenhouse gas reduction (Stadelmann-Steffen, 2011; Willis et al., 2022). However, political economy models emphasize that resource booms lead to highly dysfunctional state behavior, lower the accountability of governments, and exacerbate incompetence among democratic political leaders (Robinson et al., 2006; Brollo et al., 2013). To the extent that differential CO_2 emissions may arise due to natural resource extraction rates, incentives associated with resource booms and commodity prices may differentially affect political regimes' commitment to sustainable and efficient extraction rates.

Following the existing literature, political regime types can influence the demand and supply side of environmental quality (Pellegrini and Gerlagh, 2006; Buitenzorgy and Mol, 2011; Stadelmann-Steffen, 2011; You et al., 2015; Hess, 2018; Povitkina, 2018; Haseeb and Azam, 2021; Willis et al., 2022). Similarly, there is an extensive empirical literature linking public good provision under different forms of political regimes (Deacon, 2009) to ones on the consequences of non-tax revenues to public good provision (Robinson et al., 2006; Brollo et al., 2013).

However, the implication of the more dramatic institutional differences inherent in democracies of rentier states on the supply of environmental quality have received far less attention. Political leaders in rentier democratic states are often constrained by term limits, and they tend to over-extract natural resources relative to the efficient extraction path when prices are high.

As resource exploration is an energy and greenhouse gas emissions-intensive industry (Ulrich et al., 2022), increasing global prices provide sufficient justification for the intensification of exploration, thereby lowering commitment on the part of politicians toward climate conventions, with the consequence of higher worldwide CO_2 emissions.

Against this backdrop, we test whether incentives from resource endowments and price booms are crucial to understanding if democratic political regimes influence emission outcomes. This model on the implication of natural resource windfalls for the quality of the environment can help uncover the asymmetric impact of democracies on emissions and the mechanism for understanding the heterogeneous effects across countries. We analyze the relationship between commodity windfalls and CO_2 emissions in a model of stratified political regimes to identify the limits of democracies for environmental quality.

Specifically, we investigate the political regime and environmental performance nexus through the mechanism arising from the heterogeneous impact of commodity windfalls across the political spectrums. Using a panel of 179 countries from 1970 to 2018, we estimate the effect of changes in international commodity prices on CO_2 emissions. We then uncover the channels for the heterogeneous effects of commodity windfalls on CO_2 via political regime types. To do this, we separate countries by scores of democracies and autocracies and by component measures of institutionalized democracy, including executive recruitment, executive constraints, and political competition.

The estimation of the causal effects of commodity windfalls on CO_2 emissions under the political economy model of environmental policy faces several challenges. First, the quest for comparability across the broad geographical and different economic landscapes means sacrificing these measures' ability to capture the context-specific features of democracy. If historical democratic capital matters for environmental quality, are contemporary differences in democracy scores transient over sufficiently long-time horizons? Similar concerns about "democracy" have been expressed in previous literature (Persson and Tabellini, 2006; Acemoglu et al., 2019).[1]

Second, the imbalance between greenhouse gas emissions and the ability of the natural processes to absorb those emissions implies a contemporaneous effect, leading to spurious changes in emissions that might not responsively correspond to real changes in commodity windfalls. Because emissions decay slowly over time, current concentrations of greenhouse gases in the atmosphere result from emissions accumulated over time (Neumayer, 2000; Allen et al., 2009; Matthews et al., 2009). While this property does not invalidate the anthropogenic effect of any particular year, not including historical levels is tantamount to ignoring the effect of physical laws on global outcomes of CO_2 emissions. Year-on-year fluctuations in CO_2 may depend not only on the differences in commodity export prices but may be constrained by cumulative anthropogenic greenhouse gas emissions from CO_2 concentrations in previous years (Wei et al., 2012; Meinshausen et al., 2017; Walker et al., 2021).

We circumvent the above concerns by building stratified political regimes that classify countries based on an index, summarising different dimensions of political regimes to allow for flexibility and comparisons. This measure adapts the Polity2 index classification of political regimes, which ranges from –10 (strongly autocratic) to +10 (strongly democratic). Based on the Polity2 scores, our classifications are Democracy, Autocracy, Strong Executive Recruitment, Weak Executive Recruitment, Strong Executive Constraints, Weak Executive Constraints, Strong Political Competition, and Weak Political Competition.

We implement different strategies, which reassuringly all give similar results. Our econometric contribution uses a linear panel model, including country fixed effects and auto-regressive dynamics. As in Acemoglu et al. (2019), the underlying assumption is conditional on the lags of CO_2 and commodity windfalls, as well as country and year fixed effects. Thus, countries are not on a differential trend with respect to commodity windfalls. We implement difference GMM (Arellano and Bond, 1991) and system GMM (Blundell and Bond, 1998) estimators. The sys-

[1]That is, democracy being too blunt a concept and whether it can be isolated using a specification that reflects cross-country differences.

tem GMM because we suspect the endogeneity is very persistent, making the Arellano-Bond's difference GMM poorly suited (Arellano and Bond, 1991; Roodman, 2009). We adjust emissions by population and account for dynamics with CO_2 accumulation, which permits more robust comparisons of estimates across political regimes.

Our baseline results show that commodity windfalls increase CO_2 emissions, and the effect is significant and sizeable. Consistent with our prediction, we then find that the effect of commodity windfalls on CO_2 is higher and more significant in democracies than autocracies. Similarly, we show that countries with above threshold scores by component measures of democratic institutions, such as executive recruitment, executive constraints, and political competition, pollute more vis-à-vis commodity outflows than those with lower scores. Likewise, these more democratic countries have a significantly higher carbon emission levels than those with lower scores. These results suggest that we need to rethink how strengthening and enhancing democracy, especially among many resource-rich countries close to the democracy-autocracy threshold, is put forward as an essential ingredient in response to the rising environmental challenge.

Contribution. Our results provide a new understanding of the implications of variations in commodity prices for environmental quality. This interpretation is shaped by the literature documenting constraints imposed by term limits under democracies (Barro, 1973), the carrier-concerned political leadership in resource rich countries in Robinson et al. (2006) and Brollo et al. (2013), and the effect of natural resource windfalls on political instability in democracies (Caselli and Tesei, 2016). Benefits from environmental reforms usually come in the long term; however, due to term limits, democratic rulers are often myopic and are likely to trade off long-term benefits from environmental reforms for short-term benefits from business interests (Hanusch, 2017).

Moreover, we contribute to the political internalization model of environmental externalities (Aidt, 1998). In the spirit of Aidt (1998), the central idea rests on the political internalization of environmental externalities à la Coasian (Coase, 1960) and Pigouvian (Baumol and Oates, 1988).

That is, commodity windfalls create a political distortion that allows self-interested agents to ignore commitment to environmental policy and makes the policymaker trade off the general welfare of the voters as windfalls increase. Under certain conditions where competition between lobby groups can cause them to internalize externalities, rent seekers (lobby groups) can adjust their environmental protection objectives and trade-off efficiency considerations for inefficient and unsustainable exploitation given high commodity windfalls. Consequently, politicians in resource-dependent countries are also likely to extract more natural resources when commodity prices are high.

Another interpretation follows the Becker-Olson approach–the state, as an aggregator of pressure from interest groups, works, in part, to support powerful lobby groups to evade environmental regulations in many ways. Under democracies, power bureaucratization may facilitate rent-seeking behavior by individuals with a strong aversion to environmental reforms (Pellegrini and Gerlagh, 2006). On the other hand, autocracies legitimize the claim to political office through indoctrination, passivity, and performance and by implementing pseudo-democratic protocols (Dukalskis and Gerschewski, 2017). Therefore, they are relatively not term-restricted and may be better placed to sustain long-term commitments to environmental reforms.

From a global climate policy perspective, our analysis also contributes to understanding the difficulties inherent in why climate treaties (e.g., the race towards net zero emissions) are challenging and complex for many countries to implement. However, a growing coalition of nations has been pledging toward net zero emissions. For instance, since the mid-1990s, the Conferences of the Parties (COP) have been involved in cutting greenhouse gas emissions. The COP operates within the collective decision-making framework, where member states are engaged in negotiations and decide on relevant compromises toward achieving meaningful progress in relation to climate policies, actions, and outcomes.

Nonetheless, the 'emissions gap,' a measure of a government's mitigation actions and pledges towards emissions' reductions, necessary to limit global warming to below 2°C, is still vast and is a major contributor to trends in global greenhouse gas emissions (Olhoff and Christensen, 2018). The COP is often a complex exercise and pledges made by national governments are not legally binding. Besides, tracking emission reduction goals are not entirely transparent, and it is often difficult to ascertain which countries are responsible and which are to be compensated. These knotty issues limit the extent to which commitments translate into outcomes. We highlight a possible benefit that commodity windfalls provide that reduces the commitment of political leaders to climate change treaties.

Literature. Our paper is related to substantial literature in economics, political science, and development studies that investigate the empirical linkages between democracy and environmental quality, on the one hand, and the link between natural resource abundance and environmental quality, on the other. On the first literature, our results contribute to understanding the impact of political regimes (democracy vs. autocracy) on the environment (Pellegrini and Gerlagh, 2006; Buitenzorgy and Mol, 2011; You et al., 2015; Povitkina, 2018; Haseeb and Azam, 2021).

An extensive literature shows that democracies provide opportunities for strengthening collective actions and socio-economic transformations; mobilization by social movements and civil societies; and class alliances, which could deepen commitments to climate conventions (Stadelmann-Steffen, 2011; Hess, 2018; Willis et al., 2022). Historical experiences with democracy, and democratic capital, have also been shown to shape current climate change policies (Fredriksson and Neumayer, 2013). Similarly, the diffusion of democratic values through globalization and political solidarity among countries can deepen collective action for climate change policy aggregation across comparable democratic regimes (Petherick, 2014; Hanusch, 2017). At the same time, Burnell (2012), Povitkina (2018), and Clulow and Reiner (2022) underscore the complexity associated with democracy and climate change. A crucial element in mapping and explaining the potency, or otherwise, of democracy has been the need to distinguish between policy outputs (verbal commitments by governments) and the true reduction in greenhouse gas emissions (Bättig and Bernauer, 2009).

In certain instances, increases in democratic competition can create political economy obstacles that aggravate collective action problems and the tendency for private interest capture to increase. Hence, a democratic transition may intensify, rather than mitigate, carbon emissions (Mao, 2018). Similarly, case studies of countries show little indication of the positive impact of democracies on environmental quality. For example, Escher and Walter-Rogg (2020) provide evidence that some weak democracies (e.g., China) have been adopting measures to reduce air pollution and support international climate cooperation, thereby having better environmental-friendly outcomes than many strongly democratic economies.

Previous studies rely on cross-country regression analyses and estimate positive effects using panel data techniques, except for Acheampong et al. (2022). These authors employed dynamic and static econometric techniques to explore the effect of democracy on the environment for 46 Sub-Saharan African (SSA) countries. In contrast, other papers do not systematically control for the dynamics of CO_2 accumulation nor address the endogeneity of political regimes. Our methodological approach extends and improves on extant econometric techniques by adjusting emissions per population, controlling for the dynamics of CO_2 accumulation, and allowing for a robust set of fixed effects. Stratifying countries by the level of democracy and employing different panel fixed effect strategies (OLS, difference GMM, and system GMM) permit more robust comparisons of results.

On the second strand of literature, it is now recognized that substantial greenhouse gas emissions come from energy production and consumption. Energy consumption and economic progress are complementary to a sustainable environment. Therefore, the associated environmental problems are worsened through heavy subsidies on petroleum products, which encourage excessive and inefficient use of non-renewable fuels, such as fossil energy (Farzanegan and Markwardt, 2018; Adams and Acheampong, 2019). Although high energy prices should improve the development of cheap and cleaner energy sources, inefficiencies may arise in resourceexporting countries if higher revenue allows excessive subsidies that promote inefficient energy use. Farzanegan and Markwardt (2018) observe the high energy intensity of production and wasteful consumption of fossil fuels in Middle East and North African (MENA) countries. Using panel data on the income-emissions-democracy nexus in 17 MENA countries from 1980 to 2005, they find that increasing the quality of democratic institutions can moderate local pollution (SO_2) but not global pollution (CO_2). The literature indicates a substantial gap in the environmental impact of democracies on emission types, but the limited sample size (17 countries) and region-centric observation justify additional studies on the premise of divergent outcomes.

The remainder of the paper is done in four sections. Section 2 outlines the data, describes the main variables, and presents summary statistics. We state the estimating equation and discuss the different econometric strategies employed for estimation in Section 3. In Section 4, we report our main results and an array of robustness tests. Section 5 ends the paper with concluding remarks.

2 Data and descriptive statistics

This section discusses the main variables (and their alternatives) that come into the baseline and robustness analyses: environmental quality, commodity windfalls, and political regimes. For brevity, the description of other variables used in this paper have been resigned to when they come up in our analysis.

2.1 Greenhouse gas (GHG) emissions

Following conventional wisdom, the main GHG utilized in our paper is CO_2 emissions. The CO_2 emissions dataset is derived from the Emissions Database for Global Atmospheric Research (EDGAR) of the European Commission's Joint Research Centre (EC-JRC)/Netherlands Environmental Assessment Agency (PBL).[2] This dataset, released in September 2022, provides

[2]See Crippa et al. (2021) for a complete description of the 7th edition of this dataset.

grid maps for monthly emissions in *kton* substance for all land areas in the world at 0.1deg x 0.1deg (approximately 11 km x 11 km across the equator) from January 1970 to December 2021.[3] EDGAR documents CO_2 emissions from fossil sources, such as fossil fuel combustion and non-metallic mineral processes (e.g., cement production), and non-fossil sources.[4]

We exploit this feature in our analysis to further investigate heterogeneity. Using spatial tools, we aggregate the CO_2 emissions data to country-year level by overlaying a world polygon with country boundaries on the total CO_2 emissions for each grid cell. Thereafter, we report each country's average CO_2 emissions by taking a simple average across all grid cells per country. We also present results using an alternative GHG dataset (N_2O) in a robustness analysis.[5]

2.2 Commodity windfalls

To measure commodity windfalls, we follow related studies (Deaton and Miller, 1996; Arezki and Brückner, 2012; Collier and Goderis, 2012; Caselli and Tesei, 2016) in using country-specific international commodity export price index. Our measure, constructed by Gruss and Kebhaj (2019),[6] is the most widely available, covering the largest number of countries (182 economies) and years (1962-2018), as well as containing a large set of commodities (40 commodities grouped under four broad headings: energy, metals, food and beverages, and agricultural raw materials).[7] Gruss and Kebhaj (2019) employ data on international prices of individual commodities, using information mainly from the IMF Primary Commodity Prices database, but supplemented these with information from Global Economic Monitor (World Bank) and the US Energy Information Administration databases for few commodities (barley, coal, iron ore, and natural gas).[8] They

[3]Data can be accessed via https://edgar.jrc.ec.europa.eu/dataset-*ghg*70.

[4]It is important to state that large scale biomass burning with Savannah burning, forest fires, and sources and sinks from land-use, land-use change, and forestry (LULUCF) are excluded from our dataset.

[5]N_2O dataset comes from the same source as the CO_2 dataset and is calculated analogously.

[6]Data can be accessed via https://www.imf.org/en/Publications/WP/Issues/2019/01/24/Commodity-Terms-of-Trade-A-New-Database-46522.

[7]See Gruss and Kebhaj (2019) for a complete description of the methodology used in constructing the database.

[8]The commodities included in the calculation of the annual database are aluminum, bananas, barley, beef, coal, cocoa, coffee, copper, corn, cotton, crude oil, fish, fish meal, groundnuts, hard logs, hard sawn wood, hides, iron ore, lamb, lead, natural gas, natural rubber, nickel, oranges, palm oil, poultry, rice, shrimp, soft logs, soft sawn wood, soybean meal, soybean oil, sugar, sunflower seed oil, swine meat, tea, tin, wheat, wool, and zinc.

then combine the international commodity export price data with country-year-commodity level trade data from the United Nations Comtrade database, which they utilized in constructing weights for individual commodities. Further, IMF's unit value index for manufacturing exports was employed to convert the nominal commodity prices to their real counterparts.

Formally, the international commodity export price index, X, for each country is computed as:

$$X_{i,t} = \sum_{j=1}^{J} CommodityPrice_{j,t} \Phi_{i,j,t} \tag{1}$$

where i stands for country, t for year, and j for commodity; $CommodityPrice_{j,t}$ is the international price of commodity j in year t, and $\Phi_{i,j,t}$ is the time-invariant weight, taken to be the value of exports of commodity j as a share of total commodity traded by country i in year $t = \tau$. Mathematically, $\Phi_{i,j,t} = x_{i,j,\tau} / \sum_{j=1}^{J} x_{i,j,\tau}$, where x stands for the value of exports of a representative commodity. As already shown in extant literature (Deaton and Miller, 1996; Arezki and Brückner, 2012; Collier and Goderis, 2012; Caselli and Tesei, 2016; Gruss and Kebhaj, 2019), the strategic benefit of using the international commodity export price index constructed from this approach to capture commodity windfalls is that the resulting index can be treated as exogenous to domestic developments in individual countries. For a robustness test, we have also considered an alternative weighting, which uses total output; this can be represented mathematically as $\Phi_{i,j,t} = x_{i,j,\tau}/GDP_{i,\tau}$.

2.3 Democracy

We use several variables to capture the level of democratization around the world. Our main democracy variables is taken from the Polity5 database (Marshall and Gurr, 2018).[9]. Polity5 dataset, an extension of the Polity IV dataset, covers all major, independent states (i.e., nation-states with a total population of 500,000 or more in the most recent year) in the global system

[9]The Polity2 score has been widely used in the political economy literature to capture democratization and to explain various socio-economic conditions and financial market topics; see, e.g., Jensen and Wantchekon (2004), Persson and Tabellini (2006), Acemoglu et al. (2008), Arezki and Brückner (2012), Caselli and Tesei (2016), Duong et al. (2022), and Oyekola (2020, 2023).

over the period 1800-2018.[10] The revised combined Polity score (Polity2) captures each regime authority spectrum on a 21-point scale ranging from -10 (hereditary monarchy) to +10 (consolidated democracy).[11] In interpreting the scores, increasing values indicate greater levels of democratic freedom over time within a country and between nations.

To further ensure that our research is consistent with extant studies, we also relied on the dichotomous democracy index developed in Acemoglu et al. (2019), which we have extended to 2018.[12] This index combines information from two main democracy datasets: Freedom House and Polity IV. It assigns a democratic status to a country if that country is adjudged to be at least "partially free" by Freedom House and has a positive score in Polity IV; otherwise, a country is deemed not to be a democracy. In the event of a shortfall in any of the two datasets, they double-checked the democracy status of the country from Cheibub et al. (2010) or Boix et al. (2013).

We further investigate the dimensions of democracy at play by focusing on the three components of Polity2: competitiveness of executive recruitment, constraints on the executive, and political competition. Specifically, competitiveness of executive recruitment is a measure of the extent that prevailing modes of advancement give subordinates equal opportunities to become super-ordinates, while constraint on executive is a measure of the extent of institutionalized constraints on the decision-making powers of chief executives, whether individuals or collectivities. Finally, political competition measures the extent to which alternative preferences for policy and leadership can be pursued in the political arena.

[10]Dataset can be accessed via https://www.systemicpeace.org/inscrdata.html.

[11]Using the unrevised Polity2, the scores can also be converted into regime categories in a suggested three-part categorization of "autocracies" (-10 to -6), "anocracies" (-5 to +5 and three special values: -66, -77 and -88), and "democracies" (+6 to +10).

[12]Acemoglu et al. (2019) modified the popular dichotomous democracy measure of Papaioannou and Siourounis (2008).

Table 1: Summary statistics – main variables.

	CO_2 emissions			Commodity windfalls			Democracy		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
FS	168.4	691.62	4.1	78.91	36.5	0.5	1.54	7.3	4.7
EAP	613.4	1,816.82	3	93.82	42.3	0.5	3.12	6.7	2.13
ECA	134.7	277.86	2.1	68.23	24.2	0.4	1.27	7.1	5.53
LAC	61.67	157.7	2.6	78.47	29.8	0.4	4.41	5.9	1.33
MENA	79.62	112.33	1.4	61.23	30.8	0.5	-4.17	6.4	-1.5
WENA	444.8	1137.46	2.6	76.48	30.8	0.4	9.62	2.1	0.22
SA	272.9	664.63	2.4	99.94	53.4	0.5	1.12	6.8	6.06
SSA	30.88	79.89	2.6	87.26	40.6	0.5	-1.33	6.1	-4.5

Notes: SD and CV indicate standard deviation and coefficients of variation (standard deviation-to-mean ratio), respectively. FS: Full sample; EAP: East Asia & the Pacific; ECA: Eastern Europe & South-East Asia; LAC: Latin America & the Caribbean; MENA: Middle East & North Africa; WENA: Western Europe & North America; SA: South Asia; SSA: Sub-Saharan Africa.

2.4 Summary statistics

We present the descriptive statistics of the main variables used in the study for the full sample and along regional lines in Table 1. Average CO_2 emissions measured in *kton* are highest in East Asia and the Pacific (EAP) region, followed by the average value reported for Western Europe and North American (WENA) countries. The main countries driving this growth in carbon emissions, as shown in Figure 1, are China and the US. On the other hand, Sub-Saharan African (SSA) countries have the lowest average CO_2 emissions for the period under consideration.

Regarding commodity windfalls, countries in Asia (South Asia (SA) and East Asia and the Pacific (EAP)) and in Sub-Saharan Africa (SSA) enjoy, on average, the most commodity windfalls over our sample period. Unsurprisingly, Middle East and North African (MENA) countries receive the least commodity windfalls over the same period given the low volume of inter-regional exports within MENA economies. Figure 2 illustrates the average sample distribution of the commodity windfalls.

On the democracy score, the Western Europe and North America (WENA) countries lead the way, having the highest average Polity2 score, followed by Latin America and the Caribbean

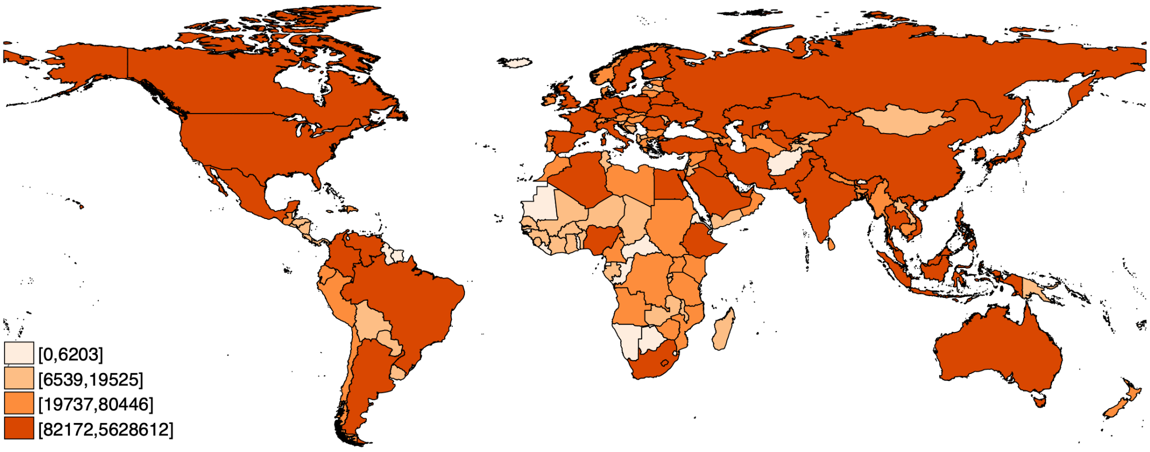

Figure 1: Map of CO_2 emissions around the world, 1980-2018

Notes: The figure shows the quintile distributions of carbon dioxide emissions for our sample of countries. Higher values (greater CO_2 emissions) are indicated by darker regions.

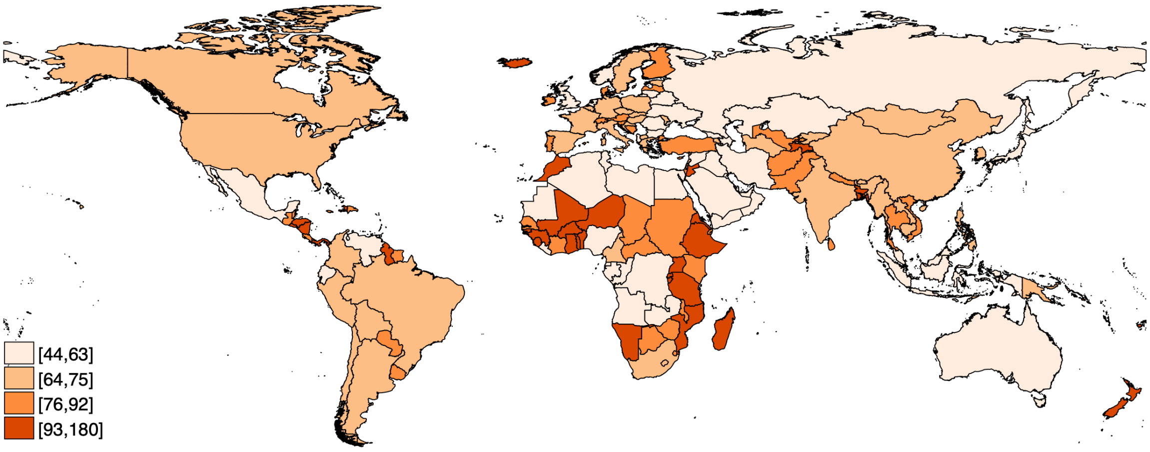

Figure 2: Map of commodity windfalls around the world, 1980-2018

Notes: The figure shows the quintile distributions of commodity windfalls for our sample of countries. Higher values (larger commodity windfalls) are indicated by darker regions.

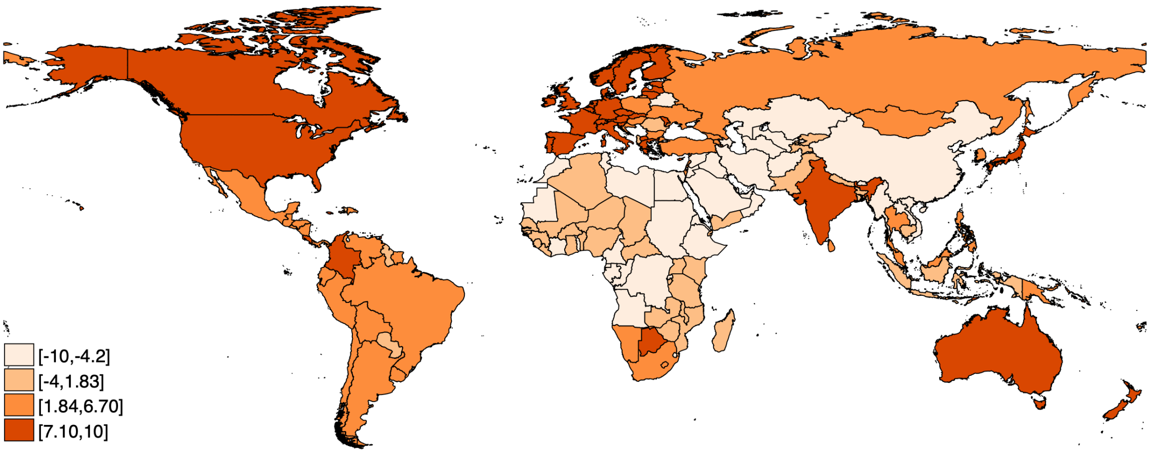

Figure 3: Map of political regimes around the world, 1980-2018

Notes: The figure shows the quintile distributions of the polity scores for our sample of countries. Higher values (more democratic countries) are indicated by darker regions.

(LAC) and East Asia and the Pacific (EAP), respectively. Apart from a few countries in the Southern African sub-region, MENA and SSA regions are mainly made up of countries that are, on average, non-democracies, as shown in Figure 3. An important pattern from the descriptive statistics is that democratic regions pollute more.

3 Econometric model

Our interest is to estimate the effect of commodity windfalls on carbon emissions across countries at different levels of democracy. To do this, we employ panel data models at the country-year level to first estimate the effect of commodity windfalls on CO_2 emissions. After that, we seek to understand the interplay of a country's political environment in the established nexus by re-analyzing the primary model by level of democratization. Thus, our estimating equation takes the form:

$$\Delta y_{i,t} = \rho y_{i,t-1} + \gamma \Delta X_{i,t} + \delta \Delta X_{i,t-1} + \alpha_i + \beta_t + \varepsilon_{i,t} \tag{2}$$

where Δ stands for the first-difference operator, i for country, and t for year. The dependent variable, y, is the log of CO_2 emissions per capita. However, we also show in the Appendix that our results are qualitatively similar with CO_2 emissions in levels (see Table A.1). The main explanatory variable, X, is the log of international commodity export price index defined in equation (1). As in Arezki and Brückner (2012) and Caselli and Tesei (2016), our specification involves regressing the first-differenced log of the outcome variables of interest on first-differenced log international commodity export price index.

Our econometric specification is augmented with country fixed effects, α_i, to account for time-invariant country-specific unobserved heterogeneity (e.g., geography, ethnicity, religion, or culture); these variables may jointly affect carbon emissions, commodity windfalls, and democracy, such that the inclusion of α_i aids in lowering omitted variables bias. Besides, we add year fixed effects, β_t, to account for common global shocks and time trends in carbon emissions (e.g., war occurrences, pandemics, etc.).[13] $\varepsilon_{i,t}$ are idiosyncratic errors, which we cluster at the country-level to account for possible correlations of the standard errors within a country. Other elements in the model are parameters to be estimated.

Our estimation is carried out by applying three different (dynamic) panel estimators: OLS, difference GMM, and system GMM. Kotschy and Sunde (2017) stipulate the logic for engaging various estimation approaches in this type of context, one of which is that one can assess "the bounds of the true coefficient" (p. 216), given that the different estimators are operated on varying sets of identification assumptions; see also Fortunato and Panizza (2015). Hence, we are able to validate our coefficient estimates from the different methods, thereby assuaging the concerns that presenting results from any single estimator may impose.

Due to methodological issues surrounding the use of OLS estimator (e.g., endogeneity concerns in the face of lagged dependent variable), we rely on the GMM estimator to obtain consistent estimates while resolving the endogeneity issue associated with the dynamic panel. Specifically, we adopt the difference GMM of Arellano and Bond (1991) and the system GMM of Blundell and Bond (1998) and Arellano and Bover (1995), both of which demand weaker exogeneity assumptions compared to the fixed effect OLS model. Importantly, the difference and system GMM estimators can identify δ and other parameters in equation (2), using the lagged values of the relevant right-hand side variables.

For difference GMM, the use of lagged values as instruments may be weakly correlated once country fixed effects are expunged from the model, and especially with a highly persistent left-hand side variable. Under this scenario, the estimate of ρ will be inconsistent, similarly to the fixed effect OLS estimator. On the contrary, the system GMM estimator does not run into this problem, which is achieved by including both the lags and levels of the relevant differenced variables as instruments. Besides, the system GMM permits the inclusion of time-invariant

[13] Note that we have not included additional controls in our baseline regressions due to established reasons in extant literature. For example, important physical factors such as distance to border are fixed over time and cannot be distinguished from country-specific effects. Moreso, we do not add other controls to avoid the "bad control" scenario (Angrist and Pischke, 2008; Emediegwu and Nnadozie, 2023; Emediegwu and Ubabukoh, 2023).

predictors in the level regressions. Then, to ensure that the instrument count does not explode, we collapse instruments into smaller sets following Beck and Levine (2004), Roodman (2009), and Caselli and Tesei (2016). In light of the foregone discussion, we present estimates from the three methods for the baseline results, after which we mainly show the results for system GMM.

4 Empirical results

4.1 Commodity windfalls and CO_2 emissions

We start by showing the relationship between international commodity export price index and CO_2 emissions in Table 2. The estimated coefficients are based on fixed effect OLS in columns (1)-(2), difference GMM in columns (3)-(4), and system GMM in columns (5)-(6), with the latter two methodologies employed to account for the dynamics in the even columns. The reported country-based clustered standard errors are robust against heteroscedasticity. Also, the dependent variables in these regressions are represented in per capita terms, and both the commodity export price index and CO_2 emissions are expressed in first-differenced log form.

Table 2: Commodity windfalls and environmental quality.

Dependent variable:	ΔCO_2 emissions per capita					
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS		Difference GMM		System GMM	
ΔCommodity export price index$_t$	-0.013	-0.011	-0.016	-0.012	-0.011	-0.010
	(0.218)	(0.254)	(0.135)	(0.196)	(0.270)	(0.306)
ΔCommodity export price index$_{t-1}$	0.0279^b	0.029^b	0.024^c	0.028^b	0.030^b	0.031^b
	(0.022)	(0.016)	(0.053)	(0.020)	(0.015)	(0.012)
CO_2 emissions per capita$_{t-1}$		-0.067^a		-0.122^a		-0.044
		(0.000)		(0.002)		(0.164)
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.020	0.060				
AR(1) p-value			0.000	0.000	0.000	0.000
AR(2) p-value			0.350	0.356	0.353	0.353
Observations	7510	7510	7330	7330	7510	7510
Countries	179	179	179	179	179	179

Notes: ^{a}, ^{b}, and ^{c} imply significantly different from 0 at 99%, 95%, and 90%, respectively. The dependent variable is the first-differenced log of CO_2 emissions per capita. The estimation methods are fixed effect OLS in columns (1)-(2), difference GMM in columns (3)-(4), and system GMM in columns (5)-(6). The base sample is a yearly panel of 179 countries, spanning the period 1970-2018. Standard errors are heteroscedasticity-robust and are clustered at the country level. Values in parentheses are p-values.

In columns (1), (3), and (5), which present estimates from the static model, we find a positive and statistically significant effect of lagged commodity export price index on CO_2 emissions per capita. These estimates imply that increasing international commodity export prices raises carbon dioxide emissions. These results align with recent studies (Wang et al., 2020; Gyamfi et al., 2022; Liu et al., 2022) examining the combined influence of commodity prices and natural resource rents on environmental quality. Economic development, natural resources, and value-added agricultural activities are positively connected to CO_2 emissions. Positive changes in international commodity prices are associated with increased economic growth, translating into higher demand for agriculture, livestock, minerals, and hydrocarbon products. This chain of events results in further emissions of greenhouse gases. More interestingly, because the short-term benefits of commodity windfalls outweigh the long-run costs of pollution, small positive changes in prices can lead to more than proportionate changes in CO_2 emissions. Meanwhile, the contemporary international commodity export price index has no significant effect on CO_2 emissions.

To account for cumulative anthropogenic greenhouse gas emissions from CO_2 concentrations in previous years and carbon cycle feedback, as well as the net response of commodity windfalls on CO_2 emissions, we add a lag of CO_2 emissions per capita to the model and report the results in columns (2), (4), and (6). As noted in the previous section, the OLS estimator is inconsistent in a dynamic panel model. To account for the associated endogeneity concerns, we present the difference GMM and system GMM estimators in columns (4) and (6), respectively. We find similar results across the three estimation approaches. Specifically, we obtain a positive and statistically significant relationship between commodity price index and CO_2 emissions. These estimates indicate that such a positive change in commodity windfalls increases CO_2 emissions with a coefficient of 0.03, conditional on the lag value of CO_2 emissions per capita. The bottom rows in columns (3)–(6) report the p-value of a test for serial correlation in the residuals. This is a test for AR(2) correlation in the first-differenced residuals, the absence of which is required for consistent estimation. The p-values for this test indicate that we reject the assumption of no serial correlation in the residuals when we adequately control for the dynamics of CO_2 emissions per capita.

4.2 Commodity windfalls, political regimes, and CO_2 emissions

In this section, we use our design to explore the potential mechanisms via political regimes. One possible way of exploring the potential mechanism through political regimes is to include a measure of democracy on the right-hand side; however, it would seem to be subject to certain limitations. From an econometric identification perspective, the stylized evidence using this political economy model of environmental policy has two possible limitations. The first is about convergence, and the second concern hinges on the appropriateness of "democracy," i.e., whether it can be isolated using a specification that reflects cross-country differences (Persson and Tabellini, 2006; Acemoglu et al., 2019).

We circumvent this by building stratified political regimes that classify countries based on a synthetic index summarizing different governance dimensions to allow for flexibility and comparisons. This measure adapts the Polity2 index classification of political regimes, which ranges from –10 (strongly autocratic) to +10 (strongly democratic). It reflects the degree of competitiveness in political participation, the openness and competitiveness in the selection of the chief executive, and the constitutional constraints on executive powers. Our classifications, based on this polity score, are Democracy, Autocracy, Strong Executive Recruitment (SER), Weak Executive Recruitment (WER), Strong Executive Constraints (SEC), Weak Executive Constraints (WEC), Strong Political Competition (SPC), and Weak Political Competition (WPC).

For each regime type, we investigate the effect of lagged commodity export price index on CO_2 emissions and compare the coefficients estimated across political regimes in Table 3. Because the contemporaneous commodity export price index does not exert any statistically significant effect on CO_2 emissions in Table 2, we omit it in the rest of our analysis. Panel A of

Table 3 reports the fixed effect OLS results, panel B the difference GMM estimates, and panel C the system GMM coefficients. Across the three panels, the main result is that the effect of commodity export price index is positive and significantly pronounced under democracy, strong executive recruitment, strong executive constraints, and strong political competition.

An extensive empirical literature supports the role of democratic institutions on environmental outcomes (Bernauer and Koubi, 2009; Bhattacharya et al., 2017). Democracies offer civil society a deliberative role in policy formulation (Acemoglu and Robinson, 2006); consequently, the demand for environmental protection could help shape political leaders' preference for reforms that translate into greenhouse gas reductions. Nevertheless, the evidence of a positive effect provided by our analysis relies on several mechanisms. First, interest groups must agree on environmental legislation. Second, they must also determine how to implement it. Our explanation in this paper explores a situation where the assumption of coercive interest groups with similar priorities for environmental policy is violated. Consequently, we investigate whether the incentives offered by commodity windfalls cause a wide divergence amongst interest groups, which can sometimes make it difficult to reconcile under democratic values in ways that generate a reduction in CO_2 emissions.

Now, democratic political structures are about compromise amongst competing interest groups. Higher commodity prices indicate additional revenues that can lower the compromise thresholds, thereby allowing political leaders to satisfy rent-seeking interest groups and the electorate to secure a re-election to office (Robinson et al., 2006). Similarly, term limits impose high political constraints, which implies a rejection of extant policy structures and processes that systematically lower rents irrespective of the implication for environmental risks and degradation.

Further, because democracy involves participatory deliberation, reaching a consensus among citizens over which environmental quality matters can be challenging under democracies (Chenoweth, 2010; Hendrix and Haggard, 2015). Conversely, citizens do not have a substantive contribution

Table 3: Commodity windfalls, political regimes, and environmental quality.

Dependent variable:	ΔCO_2 emissions per capita							
	(1) DEM	(2) AUT	(3) SER	(4) WER	(5) SEC	(6) WEC	(7) SPC	(8) WPC
	Panel A. Fixed effect OLS							
ΔCommodity export price index$_{t-1}$	0.036^a	0.020	0.031^a	0.023	0.041^a	0.018	0.041^a	0.021
	(0.001)	(0.33)	(0.007)	(0.264)	(0.002)	(0.347)	(0.004)	(0.245)
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.044	0.025	0.049	0.023	0.055	0.022	0.046	0.023
Observations	3859	2806	3634	3031	3307	3358	3381	3284
Countries	93	65	87	71	80	78	82	76
	Panel B. Difference GMM							
ΔCommodity export price index$_{t-1}$	0.023^b	0.021	0.020^b	0.022	0.025^b	0.018	0.027^b	0.021
	(0.023)	(0.334)	(0.050)	(0.306)	(0.031)	(0.340)	(0.040)	(0.279)
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AR(1) p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AR(2) p-value	0.176	0.705	0.089	0.59	0.045	0.480	0.360	0.876
Observations	3766	2740	3547	2959	3227	3279	3299	3207
Countries	93	65	87	71	80	78	82	76
	Panel C. System GMM							
ΔCommodity export price index$_{t-1}$	0.035^a	0.025	0.030^a	0.028	0.038^a	0.024	0.039^a	0.026
	(0.001)	(0.243)	(0.005)	(0.193)	(0.002)	(0.226)	(0.004)	(0.163)
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AR(1) p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AR(2) p-value	0.176	0.705	0.089	0.590	0.046	0.479	0.362	0.878
Observations	3859	2806	3634	3031	3307	3358	3381	3284
Countries	93	65	87	71	80	78	82	76

Notes: ^{a}, ^{b}, and ^{c} imply significantly different from 0 at 99%, 95%, and 90%, respectively. The dependent variable is the first-differenced log of CO_2 emissions per capita. The estimation methods are fixed effect OLS in panel A, difference GMM in panel B, and system GMM in panel C. The base sample is a yearly panel of 179 countries, spanning the period 1970-2018. DEM (AUT) is democracy (autocracy) and comprises of countries that have a strictly positive (negative) Polity score. SER: Strong Executive Recruitment (WER: Weak Executive Recruitment) comprises of countries that have an above (below) mean score of executive recruitment in the sample. SEC: Strong Executive Constraints (WEC: Weak Executive Constraints) comprises of countries that have an above (below) mean score of executive constraints in the sample. SPC: Strong Political Competition (WPC: Weak Political Competition) comprises of countries that have an above (below) mean score of political competition in the sample. All political regime stratifications are based on Polity5 database. Standard errors are heteroscedasticity-robust and are clustered at the country level. Values in parentheses are p-values.

to policy development in a less democratic nation, meaning that, by extension, they have little input on environmental issues as well. Besides, implementing any environmental reform will require radical changes in the mold of authoritarian environmentalism through government mandates, which limit some rights and individual liberties (Beeson, 2010). This authoritarian approach to policy implementation presents autocracies with limited political economy obstacles, thereby placing them in a more favorable position to implement environmental policies.

4.3 Robustness checks

Accounting for cumulative anthropogenic greenhouse gas emissions. The critical threat to the validity of the estimates in Table 3 is the effect of cumulative anthropogenic greenhouse gas emissions from CO_2 concentrations of previous years (Wei et al., 2012; Meinshausen et al., 2017; Walker et al., 2021). To consider this, we next account for CO_2 convergence and include a lag of CO_2 emissions as part of the right-hand side variables in equation (2). Specifically, we repeat the regressions used in Table 3, augmenting them with a lag of CO_2 emissions, and document the estimated coefficients in panel A of Table 4. The results are largely similar to the estimates in Table 3.

Higher dynamics. We check to see whether our estimates are sensitive to additional lags since accumulated CO_2 emissions over time could contribute to more pollution contemporaneously, a concept known in climate econometrics literature as "harvesting" (Emediegwu et al., 2022). To check for this, we include a second lag of CO_2 emissions as part of the right-hand side variables in equation (2). The results in panel B of Table 4 validate the stability of our baseline estimates.

The influence of outliers. Next, we check if our results are driven by outlier countries. We carry out this exercise in two distinct steps. First, we exclude countries based on Cook's distance higher than a standard rule-of-thumb threshold.[14] The results from the remaining

[14] This is usually defined as: $4/N$, where N is the number of observations.

Table 4: Commodity windfalls, political regimes, and environmental quality–accounting for CO_2 dynamics

Dependent variable:	ΔCO_2 emissions per capita							
	(1) DEM	(2) AUT	(3) SER	(4) WER	(5) SEC	(6) WEC	(7) SPC	(8) WPC
	Panel A: Convergence dynamics							
ΔCommodity export price index$_{t-1}$	0.0328^a	0.0255	0.0284^a	0.0291	0.0333^a	0.0231	0.0352^a	0.0274
	(0.0016)	(0.2436)	(0.0078)	(0.1846)	(0.0047)	(0.2470)	(0.0089)	(0.1550)
CO_2 per capita$_{t-1}$	-0.0773^c	0.0252	-0.0822^b	0.0193	-0.0897^b	0.0429	-0.1071^a	0.0145
	(0.0530)	(0.5818)	(0.0286)	(0.6690)	(0.0251)	(0.3442)	(0.0016)	(0.7689)
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AR(1) p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AR(2) p-value	0.1694	0.7111	0.0837	0.5966	0.0405	0.4908	0.3634	0.8791
Observations	3859	2806	3634	3031	3307	3358	3381	3284
Countries	93	65	87	71	80	78	82	76
	Panel B: Higher dynamics							
ΔCommodity export price index$_{t-1}$	0.0325^a	0.0235	0.0291^a	0.0278	0.0350^a	0.0222	0.0351^a	0.0263
	(0.0013)	(0.2724)	(0.0063)	(0.1945)	(0.0028)	(0.2474)	(0.0062)	(0.1601)
CO_2 per capita$_{t-1}$	-0.0226	0.0281	-0.0312	0.0222	-0.0372	0.0323	-0.0316	0.0166
	(0.5398)	(0.3684)	(0.3895)	(0.4982)	(0.3353)	(0.2900)	(0.1970)	(0.6379)
CO_2 per capita$_{t-2}$	-0.0537	-0.0952a	-0.0216	-0.1143^a	-0.0334	-0.1026^a	-0.0572	-0.0962^a
	(0.2005)	(0.0090)	(0.6086)	(0.0017)	(0.4273)	(0.0030)	(0.1773)	(0.0089)
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AR(1) p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AR(2) p-value	0.0204	0.3844	0.0288	0.3070	0.0081	0.4998	0.0676	0.2095
Observations	3852	2798	3628	3022	3301	3349	3376	3274
Countries	93	65	87	71	80	78	82	76

Notes: ^{a}, ^{b}, and ^{c} imply significantly different from 0 at 99%, 95%, and 90%, respectively. The dependent variable is the first-differenced log of CO_2 emissions per capita. The estimation method is system GMM in both panels. The base sample is a yearly panel of 179 countries, spanning the period 1970-2018. DEM (AUT) is democracy (autocracy) and comprises of countries that have a strictly positive (negative) Polity score. SER: Strong Executive Recruitment (WER: Weak Executive Recruitment) comprises of countries that have an above (below) mean score of executive recruitment in the sample. SEC: Strong Executive Constraints (WEC: Weak Executive Constraints) comprises of countries that have an above (below) mean score of executive constraints in the sample. SPC: Strong Political Competition (WPC: Weak Political Competition) comprises of countries that have an above (below) mean score of political competition in the sample. All political regime stratifications are based on Polity5 database. Standard errors are heteroscedasticity-robust and are clustered at the country level. Values in parentheses are p-values.

Table 5: Commodity windfalls, political regimes, and environmental quality–excluding outliers

Dependent variable:	ΔCO_2 emissions per capita							
	(1) DEM	(2) AUT	(3) SER	(4) WER	(5) SEC	(6) WEC	(7) SPC	(8) WPC
	Panel A: Excluding outliers based on Cook's distance							
ΔCommodity export price index$_{t-1}$	0.0381a	0.0139	0.0311a	0.0192	0.0417a	0.0137	0.0344a	0.0144
	(0.0004)	(0.5330)	(0.0022)	(0.4033)	(0.0007)	(0.4941)	(0.0033)	(0.4700)
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AR(1) p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AR(2) p-value	0.7485	0.8071	0.8494	0.6301	0.6416	0.4960	0.8390	0.6125
Observations	3758	2658	3549	2867	3218	3198	3297	3119
Countries	93	65	87	71	80	78	82	76
	Panel B: Excluding China and the US							
ΔCommodity export price index$_{t-1}$	0.0327a	0.0266	0.0283a	0.0302	0.0330a	0.0239	0.0351a	0.0282
	(0.0018)	(0.2237)	(0.0082)	(0.1700)	(0.0052)	(0.2320)	(0.0095)	(0.1434)
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AR(1) p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AR(2) p-value	0.0204	0.3844	0.0288	0.3070	0.0081	0.4998	0.0676	0.2095
Observations	3852	2798	3628	3022	3301	3349	3376	3274
Countries	93	65	87	71	80	78	82	76

Notes: ^{a}, ^{b}, and ^{c} imply significantly different from 0 at 99%, 95%, and 90%, respectively. The dependent variable is the first-differenced log of CO_2 emissions per capita. The estimation method is system GMM in both panels. The base sample is a yearly panel of 179 countries, spanning the period 1970-2018. DEM (AUT) is democracy (autocracy) and comprises of countries that have a strictly positive (negative) Polity score. SER: Strong Executive Recruitment (WER: Weak Executive Recruitment) comprises of countries that have an above (below) mean score of executive recruitment in the sample. SEC: Strong Executive Constraints (WEC: Weak Executive Constraints) comprises of countries that have an above (below) mean score of executive constraints in the sample. SPC: Strong Political Competition (WPC: Weak Political Competition) comprises of countries that have an above (below) mean score of political competition in the sample. All political regime stratifications are based on Polity5 database. Standard errors are heteroscedasticity-robust and are clustered at the country level. Values in parentheses are p-values.

countries, shown in panel A of Table 5, are strongly consistent with the baseline estimates, although with a marginal increase in the size of the estimate. Next, we exclude China and the US - the two countries with the highest CO_2 emissions per capita.[15] Besides, both countries are also heavily involved in international trade; hence, it is important to ascertain the insensitivity of our results against the influence of both countries. We present the results in panel B of Table 5, showing similar estimates as our main results, thus confirming that our results are not driven by these two important countries.

Alternative outcomes/predictors. We further show that our results are robust to using an alternative GHG. In the place of CO_2 emissions, we re-analyzed our model using N_2O emissions and got qualitatively analogous estimates, although at the cost of a reduced significance (see panel A of Table 6). We have also checked how using an alternative measure of commodity windfalls may affect our results. We conduct this exercise by replacing the international commodity export price index weighted by total commodity trade with an index weighted by a country GDP in our primary model. The results, displayed in panel B of Table 6, are not different from the baseline estimates in terms of size and significance. Moreover, we have attempted a different definition of democracy as constructed in Acemoglu et al. (2019).[16] In unreported results, we find that using this measure of democracy, in place of polity2 scores, produces similar results, albeit with lower magnitudes and significance than the baseline estimates.[17]

To sum up, the above exercises underscore the importance of our results as not driven by spurious variables and are plausibly correctly specified. Therefore, large deviations from the main estimates are unexpected.

[15] Data from EDGAR indicate that both countries are responsible for more than 40% of global CO_2 emissions annually (Crippa et al., 2021).

[16] Kindly refer to subsection 2.3, where we briefly described this dataset.

[17] More specifically, we find that international commodity export price index continues to have statistically significant effect (coef: 0.0249; p-value: 0.0452) in democracies, but insignificant effect in autocracies (coef: 0.0305; p-value: 0.1654).

Table 6: Commodity windfalls, political regimes, and environmental quality–alternative outcomes/predictors

	(1) DEM	(2) AUT	(3) SER	(4) WER	(5) SEC	(6) WEC	(7) SPC	(8) WPC
	Panel A: Alternative measure of GHG emissions (DV is ΔN_2O emissions p.c.)							
ΔCommodity export price index$_{t-1}$	0.0190^b	0.0131	0.0189^b	0.0143	0.0231^b	0.013	0.0244^a	0.0121
	(0.0161)	(0.2407)	(0.0243)	(0.1884)	(0.0113)	(0.1988)	(0.007)	(0.2202)
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AR(1) p-value	0.0000	0.0275	0.0000	0.0243	0.0000	0.0206	0.0000	0.0185
AR(2) p-value	0.674	0.2444	0.6737	0.2455	0.7066	0.2492	0.4839	0.2283
Observations	3859	2806	3634	3031	3307	3358	3381	3284
Countries	93	65	87	71	80	78	82	76
	Panel B: Alternative measure of commodity windfalls (DV is ΔCO_2 emissions p.c.)							
ΔCommodity export price index$_{t-1}$	0.0328^a	0.0255	0.0284^a	0.0291	0.0333^a	0.0231	0.0352^a	0.0274
	(0.0016)	(0.2436)	(0.0078)	(0.1846)	(0.0047)	(0.2470)	(0.0089)	(0.1550)
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AR(1) p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AR(2) p-value	0.1694	0.7111	0.0837	0.5966	0.0405	0.4908	0.3634	0.8791
Observations	3859	2806	3634	3031	3307	3358	3381	3284
Countries	93	65	87	71	80	78	82	76

Notes: ^{a}, ^{b}, and ^{c} imply significantly different from 0 at 99%, 95%, and 90%, respectively. The dependent variable is the first-differenced log of N_2O emissions per capita (CO_2 emissions per capita) in panel A (panel B). Commodity export price index in panel A is the baseline version, which is weighted by the total exports of commodities by a country, whilst the alternative measure used in panel B is weighted by GDP. The estimation method is system GMM in both panels. The base sample is a yearly panel of 179 countries, spanning the period 1970-2018. DEM (AUT) is democracy (autocracy) and comprises of countries that have a strictly positive (negative) Polity score. SER: Strong Executive Recruitment (WER: Weak Executive Recruitment) comprises of countries that have an above (below) mean score of executive recruitment in the sample. SEC: Strong Executive Constraints (WEC: Weak Executive Constraints) comprises of countries that have an above (below) mean score of executive constraints in the sample. SPC: Strong Political Competition (WPC: Weak Political Competition) comprises of countries that have an above (below) mean score of political competition in the sample. All political regime stratifications are based on Polity5 database. Standard errors are heteroscedasticity-robust and are clustered at the country level. Values in parentheses are p-values.

5 Conclusions

This paper investigates whether carbon emissions respond differently to commodity windfalls in democracies and non-democracies. Despite substantial policy attention towards climate change and significant increase in adopting democracies around the world, evidence is inconclusive on how economic incentives from polluting activities shape emissions' outcomes under democracies and non-democracies. We highlight the implication of commodity windfalls for political distortion by allowing self-interested policymaker to trade off the general welfare of voters as windfalls rise. As the environmental crisis worsens, calls for eco-authoritarianism, i.e., a more radical approach that lowers the political economy obstacles evident under democracy for greenhouse gas abatement, may be needed.

The empirical analysis in this paper supports the claim that increasing commodity windfalls lead to higher CO_2 emissions. Moreover, commodity windfalls significantly lead to higher CO_2 emissions under democracies than autocracies. Although democracies offer civil society a deliberative role in policy formulation, this however becomes problematic when there are several competing interest groups, such that policymakers can trade off the demand for environmental protection for short-term benefits from business interests. Conversely, autocracies legitimise claims to political offices through indoctrination, passivity, and by implementing pseudo-democratic protocols. Besides, autocratic rulers are relatively not term restricted. They are therefore in a position likely to sustain long-term commitments to environmental reforms, albeit we do not find commodity windfalls to offer any meaningful influence on environmental quality in this type of political environment.

Nonetheless, the relationship between commodity windfalls and CO_2 emissions is not easily quantifiable; some hidden mechanisms may not be fully explored. Consequently, our results do not imply that democracy is unimportant. Instead, we emphasise that to reach their full potential in influencing reductions in CO_2 emissions, governments under democratic institutions should be guided on the potential implications of higher commodity windfalls and encourage them to invest in more sustainable abatement technologies, as revenues generated from non-tax sources increase.

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Table A.1: Commodity windfalls, political regimes, and environmental quality–further robustness

	(1) DEM	(2) AUT	(3) SER	(4) WER	(5) SEC	(6) WEC	(7) SPC	(8) WPC
	Panel A: Alternative model specification							
Dependent variable:	CO2 emissions per capita							
ΔCommodity export price index$_{t-1}$	0.0328a	0.0255	0.0284a	0.0291	0.0333a	0.0231	0.0352a	0.0274
	(0.0016)	(0.2436)	(0.0078)	(0.1846)	(0.0047)	(0.247)	(0.0089)	(0.155)
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AR(1) p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AR(2) p-value	0.1694	0.7111	0.0837	0.5966	0.0405	0.4908	0.3634	0.8791
Observations	3859	2806	3634	3031	3307	3358	3381	3284
Countries	93	65	87	71	80	78	82	76
	Panel B: Sample split by time-varying Polity scores							
Dependent variable:	ΔCO_2 emissions per capita							
ΔCommodity export price index$_{t-1}$	0.0371a	0.0262	0.0324b	0.028	0.0333b	0.0306	0.0379a	0.0213
	(0.009)	(0.2219)	(0.0169)	(0.1894)	(0.0218)	(0.1388)	(0.0026)	(0.335)
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AR(1) p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AR(2) p-value	0.7324	0.875	0.6911	0.7934	0.6416	0.9059	0.475	0.7784
Observations	3631	2767	3629	2769	3407	2991	3866	2532
Countries	129	110	128	110	123	113	138	112

Notes: ^{a}, ^{b}, and ^{c} imply significantly different from 0 at 99%, 95%, and 90%, respectively. The dependent variable is log of CO_2 emissions per capita (the first-differenced log of CO_2 emissions per capita) in panel A (panel B). The estimation method is system GMM in both panels. The base sample is a yearly panel of 179 countries, spanning the period 1970-2018. DEM (AUT) is democracy (autocracy) and comprises of countries that have a strictly positive (negative) Polity score. SER: Strong Executive Recruitment (WER: Weak Executive Recruitment) comprises of countries that have an above (below) mean score of executive recruitment in the sample. SEC: Strong Executive Constraints (WEC: Weak Executive Constraints) comprises of countries that have an above (below) mean score of executive constraints in the sample. SPC: Strong Political Competition (WPC: Weak Political Competition) comprises of countries that have an above (below) mean score of political competition in the sample. All political regime stratifications are based on Polity5 database. Standard errors are heteroscedasticity-robust and are clustered at the country level. Values in parentheses are p-values.