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Commodity windfalls, political regimes, and environmental quality

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ABSTRACT

Despite concerted global efforts to curb environmental degradation (proxied by greenhouse gas emissions), climate change mitigation policies appear to be failing in reducing carbon emissions, with considerable differences in the levels and rates of emissions across countries. To bridge the gap between the observed national commitments to climate targets and the reality of rising greenhouse gas emissions, this paper examines how the incentives generated by resource endowments and commodity windfalls (proxied by international commodity price booms or fluctuations) are critical for our understanding. Using a significantly larger and more representative international sample than extant research, we document, applying both static and dynamic econometric techniques to a panel of 179 countries during the period 1970-2018, that a rise in commodity windfalls has a positive and significant effect on carbon emissions. We then explore classification of countries into democracies and autocracies as potential channels for the heterogeneous effects of commodity windfalls on environmental quality, finding that a rise in international prices of exported commodities significantly leads to an increase in carbon emissions in democratic countries, with no significant effect on carbon emissions in autocratic countries. These results are robust to various sensitivity checks.

1. Introduction

A major global threat of immense public concern is that posed by escalating climate change (Stern, 2008; Dell et al., 2012; Kalkuhl and Wenz, 2020; Kahn et al., 2021). Owing to this, there exists a preponderance of academic literature investigating the determinants of climate change. Within this literature are studies illuminating the income-pollution nexus (Grossman and Krueger, 1995, 1996; Binder and Neumayer, 2005; Farzanegan and Markwardt, 2018; Lægreid and Povitkina, 2018). The general insight is that the association between economic growth and environmental quality is non-linear. Other studies have, amongst other factors, focused on either the direct or indirect effects of financial development (Acheampong, 2019; De Haas and Popov, 2023), trade openness (Managi et al., 2009; Aller et al., 2015; Cherniwchan et al., 2017), urbanisation (Martínez-Zarzoso and Maruotti, 2011; Sadorsky, 2014; Adams et al., 2020), and political environment (Li and Reuveny, 2006; Lægreid and Povitkina, 2018; Acheampong et al., 2022).[1] Evidence on the effect of international prices of exported commodities on rising greenhouse gas emissions, however, remains scant.

To provide a first rigorous and systematic evidence on how international prices of exported commodities affect environmental quality, we ask: Are variations in the international prices of exported commodities bad for the Sustainable Development Goal (SDG) of combating climate calamity and improving environmental quality (SDG 13)? Further, when world leaders and international stakeholders gather at various climate change summits (e.g., the 2022 Sharm el-Sheikh Climate Change Conference (COP27) in Egypt), it is important to acknowledge that the extents of commitment to and implementation of any agreed climate targets are impacted by differences in political ideologies and constraints of the *sending* nations. Therefore, we also ask: Do environmental pollution trajectories between democracies and non-democracies bifurcate as commodity prices change? We shed light on these important questions by studying the relationship between commodity windfalls (i.e., price booms of resource endowments) and greenhouse gas emissions (captured primarily using carbon dioxide (CO_2) emissions). Our paper's main contribution is identifying that this relationship between commodity windfalls and environmental quality varies heterogeneously by types of political regime.

The supply of environmental quality policies and their execution by a government is shaped by citizens' demands and preferences for

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[1] See Aller et al. (2021) for a study on robust determinants of carbon emissions.

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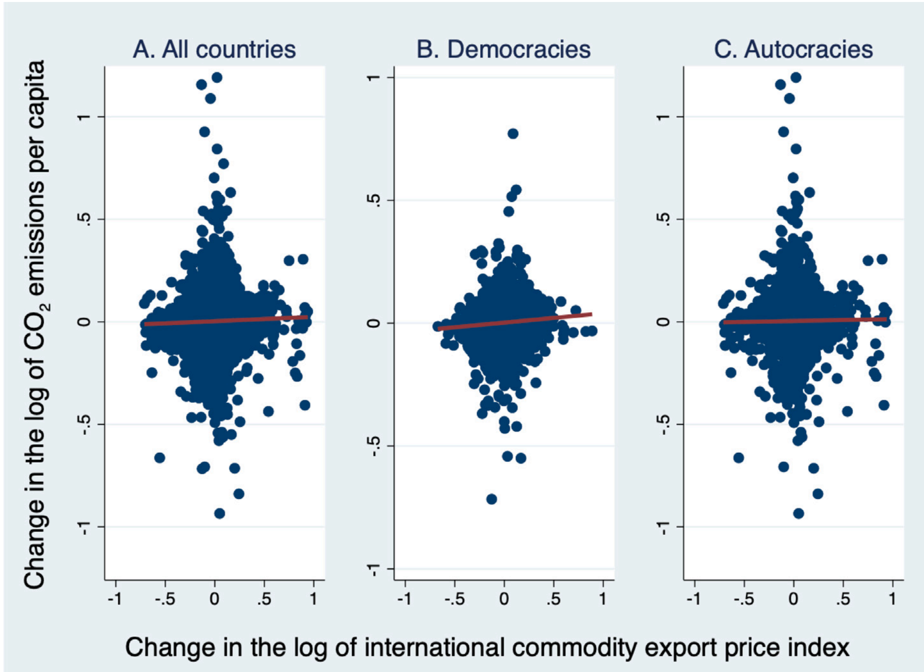

Fig. 1. Relation between international commodity export price and CO_2 emissions.
Notes: This figure shows scatter plots of CO_2 emissions per capita plotted against the international commodity export price index. Panel A combines all countries in our sample, while panels B and C distinguish between democratic and autocratic countries, respectively. The red line represents the linear regression fitted line of a change in the log of CO_2 emissions per capita on the change in the log of international commodity export price index.

environmental accountability. Because democracies offer civil society a deliberative role in policy formulation (Acemoglu and Robinson, 2006), the demand for environmental protection could help shape political leaders' preferences for reforms that translate into greenhouse gas reduction (Stadelmann-Steffen, 2011; Willis et al., 2022). However, political economy models emphasise that resource booms can lead to highly dysfunctional state behaviour, 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 commodity price changes may differentially affect political regimes' commitment to sustainable and efficient extraction rates.

According to extant literature, political regime types can influence the demand and supply sides 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 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 has received far less attention. Moreover, 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 towards climate conventions, with the consequence of higher worldwide CO_2 emissions.

Fig. 1 gives a first impression that the relation between international commodity export prices and CO_2 emissions are not necessarily the same in democracies and autocracies, compared to the aggregate sample. Panel A displays the correlation of commodity windfalls with CO_2 emissions for all countries in our sample over the period 1970–2018, while panels B and C show the correlations between the same variables for the split samples of countries into democracy and autocracy, respectively.[2] As illustrated, the fitted line in panel A indicates a positive association between the growth rate of CO_2 emissions per capita and the growth rate of international commodity export prices for all countries. However, panel B, which consisted of democratic countries, displays a steeper positive slope for the fitted line than that seen in panel C, which comprised of autocratic nations.

Against this backdrop, we test whether incentives from resource endowments and price booms are crucial to understanding if democratic political regimes, relative to autocratic political regimes, have different emission outcomes. Specifically, we investigate the heterogeneous impact of commodity windfalls on environmental performance of countries by focusing on their political regimes. To do this, we analyse 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. Based on a significantly larger and more representative international sample of 179 countries for the period 1970–2018, 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 emissions via political regime types around the world. In doing this, we provide a rigorous assessment of whether the influence of commodity windfalls on CO_2 emissions vary systematically between democracies and autocracies. Our identification approach borrows from Arezki and Brückner (2012) in separating countries by scores of democracies and autocracies and by component measures of institutionalised democracy, including executive recruitment, executive constraints, and political competition.

Estimating 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

[2] Detailed description of these variables are provided in the next section.

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).[3]

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. Thus, year-on-year fluctuations in CO_2 levels may depend not only on the differences in international 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. These measures adapt the Polity2 index classification of political regimes, which ranges from −10 (hereditary monarchy) to +10 (consolidated democracy). 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 various static and dynamic econometric strategies, which reassuringly produce similar results. Specifically, we employ OLS with and without fixed effects, difference GMM (Arellano and Bond, 1991), and system GMM (Blundell and Bond, 1998) estimators. The system 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. Similar to Acemoglu et al. (2019), the underlying assumption is conditional on the lags of CO_2 emissions and commodity windfalls, as well as country and year fixed effects. Thus, countries are not on a differential trend with respect to commodity windfalls.

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 emissions is higher and more significant in democracies than in 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-Ã -vis commodity outflows 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.

1.1. Contribution

Our results provide a new understanding of the implications of commodity price fluctuations for environmental quality, where our interpretation is shaped by extant literature on constraints imposed by term limits under democracies (Barro, 1973), career-concerned political leadership in resource rich countries (Robinson et al., 2006; Brollo et al., 2013), and the effect of natural resource windfalls on political instability in democracies versus autocracies (Caselli and Tesei, 2016). Benefits from environmental reforms usually come in the long term. However, due to term limits, democratic political leaders are often myopic and are likely to trade off long-term benefits from environmental reforms for short-term benefits from business interests.

Moreover, we contribute to the political internalisation model of environmental externalities (Coase, 1960; Baumol and Oates, 1988; Aidt, 1998). In line with Aidt (1998), the central idea is that commodity windfalls create a political distortion that allows self-interested agents to ignore commitment to environmental policy, making the policymaker trade-off the general welfare of voters as windfalls increase. Under certain conditions, where competition between lobby groups can cause them to internalise 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 bureaucratisation may facilitate rent-seeking behaviour by individuals with a strong aversion to environmental reforms (Pellegrini and Gerlagh, 2006). On the other hand, autocracies legitimise the claim to political office by indoctrination, passivity, and performance through the implementation of pseudo-democratic protocols (Dukalskis and Gerschewski, 2017). As such, 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 towards 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 towards 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 remains 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 is 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 actions. We highlight a possible benefit that commodity windfalls provide that reduces the commitment of political leaders to climate change treaties, offering policy guidance for national governments on becoming more environmentally active.

1.2. Literature

Our paper is related to a large literature in political science, economics, and development studies assessing the empirical relationship between democracy and environmental quality, as well as the association between natural resource abundance and environmental quality. On the first literature, our results contribute to understanding the impact of political regimes (democracy versus autocracy) on environmental outcomes (Pellegrini and Gerlagh, 2006; Buitenzorgy and

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

Mol, 2011; You et al., 2015; Farzanegan and Markwardt, 2018; Lægreid and Povitkina, 2018; Povitkina, 2018; Haseeb and Azam, 2021; Acheampong et al., 2022). This body of work has shown that democracy provides opportunities for strengthening collective actions and socio-economic transformations, mobilising social movements in civil societies, and forging class alliances, which could deepen commitments to climate conventions (Stadelmann-Steffen, 2011; Hess, 2018; Willis et al., 2022).

Further, democratic capital, accumulated through experiences of democracy, has a robust positive effect on national and multi-lateral policies addressing climate change (Fredriksson and Neumayer, 2013). Similarly, the diffusion of democratic values through globalisation and political solidarity among countries can deepen collective action for climate change policy aggregation across comparable democratic regimes (Petherick, 2014). At the same time, Burnell (2012), Povitkina (2018), and Clulow and Reiner (2022) underscore the complexity associated with democracy and climate change. For example, Povitkina (2018) argues that the gains from democracy for climate change mitigation are moderated in the presence of widespread corruption by reducing the capacity of democratic governments to reach climate targets and reduce CO_2 emissions.

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). Besides, 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, as demonstrated in 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 environment-friendly outcomes than many strongly democratic countries.

On the second strand of literature, it is now recognised that substantial greenhouse gas emissions come from energy production and consumption. Consequently, 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 resource-exporting countries if higher revenue allows excessive subsidies that promote inefficient energy use.

Within the above literature, our work is most closely related to two recent empirical contributions by Farzanegan and Markwardt (2018) and Acheampong et al. (2022). Having observed the high energy intensity of production and wasteful consumption of fossil fuels in the Middle East and North Africa (MENA), Farzanegan and Markwardt (2018) analyse the link between democracy, development, and greenhouse gas emissions, using panel data for 17 MENA countries during the period 1980–2005. They find that increasing the quality of democratic institutions can moderate local pollution (SO_2), but not global pollution (CO_2). In their work, Acheampong et al. (2022) explore the effect of democracy on environmental quality in 46 Sub-Saharan African (SSA) countries, finding that higher levels of democracy simultaneously drive environmental degradation and moderate GDP per capita in SSA. Our paper complements this literature in that we study the effect of commodity price fluctuations on environmental quality across different political regimes.

Yet, our paper differs from both Farzanegan and Markwardt (2018) and Acheampong et al. (2022) in at least two crucial ways. First, we enrich extant literature by focusing on the implications of commodity windfalls for global greenhouse gas emissions, whereas development and democracy are the primary explanatory variables in Farzanegan and Markwardt (2018) and Acheampong et al. (2022), respectively. In this respect, our paper is closest to Farzanegan and Markwardt (2018), who fundamentally evaluated the indirect effect of democracy on environmental quality. Whilst extant literature indicates a substantial gap in the environmental impact of democracies on emission types, the limited sample size and region-centric nature of both Farzanegan and Markwardt (2018) and Acheampong et al. (2022) justify the need for additional studies,[4] which our paper fulfils.

Second, instead of having democracy enter our empirical model directly, we lower endogeneity concerns by adopting an identification strategy similar to Arezki and Brückner (2012) under which we run regressions of CO_2 emissions on commodity price fluctuations for separate samples of democracies and autocracies. Thus, the political regime dis-aggregation analysis, where we examine the environmental implications of commodity windfalls for both democracies and autocracies, is our paper's most important contribution. To our best knowledge, our study is the first to perform such dis-aggregated analysis of the effect of international prices of exported commodities on carbon emissions across political regimes.

1.3. Organisation of the paper

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 statistical analysis 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 used in the baseline and robustness analyses: environmental quality, commodity windfalls, and political regimes. For brevity, the description of other variables used in this paper has been resigned to when they come up in our analysis.

2.1. Measuring environmental quality

Following conventional wisdom, the main greenhouse gas (GHG) utilised in our paper to capture environmental quality 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).[5] This dataset, released in September 2022, provides grid maps for monthly emissions in *kton* substance for all land areas in the world at 0.1deg × 0.1deg (approximately 11 km × 11 km

[4] To put into context, the largest sample in the regression models of Farzanegan and Markwardt (2018) contains 76 observations from 17 MENA countries, while Acheampong et al. (2022) has 337 observations from 46 SSA countries. The equivalent in our largest possible sample is 7510 observations from 179 countries, whilst even our specification with the smallest sample still contained 2658 observations from 65 countries in the split regressions. An earlier work by Li and Reuveny (2006) is one of the closest to our work in terms of country coverage (143) and sample size (3833). Like Acheampong et al. (2022), however, they focus on the direct effects of democracy on environmental degradation. More recently, Lægreid and Povitkina (2018) study whether political institutions moderate the relationship between GDP and CO_2 emissions in 156 countries. Although they present results for panel data on 6166 observations for the GDP-CO_2 nexus, their results on the moderating role of political environment is based on cross-sectional data for 140 countries. Apart from this, their focus, like all these other earlier papers, is different to ours.

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

across the equator) from January 1970 to December 2021.[6] 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.[7] 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 (NO_2) in a robustness analysis.[8]

2.2. Measuring 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),[9] 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).[10] Gruss and Kebhaj (2019) employ data on international prices of individual commodities, using information mainly from the IMF Primary Commodity Prices database, but supplemented this 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).[11] They then combine the international commodity export price data with country-year-commodity level trade data from the United Nations Comtrade database, which they utilised 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. Measuring political regimes

We use several variables to capture political regimes and the levels of democratisation around the world. Our main proxy variables are from the Polity5 database (Marshall and Gurr, 2018).[12] 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) over the period 1800–2018.[13] 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).[14] In interpreting the scores, increasing values indicate greater levels of democratic freedom over time within a country and between nations.

To 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.[15] 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, the authors double-checked the democracy status of the country from Cheibub et al. (2010) or Boix et al. (2013). In an extended analysis, where we implement interaction model specifications (see Table A.12), we consider five conceptualisations of democracy (deliberative, egalitarian, liberal, participatory, and electoral) provided by the Varieties of Democracy (V-Dem) database.[16]

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[6] Data can be accessed via https://edgar.jrc.ec.europa.eu/dataset_ghg70.

[7] 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.

[8] NO_2 dataset comes from the same source as the CO_2 dataset and is calculated analogously.

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

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

[11] The commodities included in the calculation of the annual database are aluminium, 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.

[12] The Polity2 score has been widely used in the political economy literature to capture democratisation 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 (2023a,b), Oyekola et al. (2023).

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

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

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

[16] The five conceptions of democracy are from the Varieties of Democracy (V-Dem) database (Coppedge et al., 2011) and are defined as follows: (1) Deliberative democracy focuses on the process by which decisions are reached in a polity. A deliberative process is one in which public reasoning focused on the common good motivates political decisions—as contrasted with emotional appeals, solidary attachments, parochial interests, or coercion. (2) Egalitarian democracy addresses the goal of political equality. An egalitarian polity is one that achieves equal participation, equal representation, equal protection, equal resources, and in which citizens enjoy equal access to political power. (3) Liberal democracy stresses the intrinsic importance of transparency, civil liberty, rule of law, horizontal accountability (effective checks on rulers), and minority rights against the tyranny of the state and/or the majority. (4) Participatory democracy underscores the relevance of active participation of by citizens in all political processes, electoral and non-electoral. (5) Electoral democracy is the idea that democracy is achieved through competition among leadership groups, which vie for the electorates approval during periodic elections before a broad electorate. Parties and elections are the crucial instruments in this largely procedural account of the democratic process. V-Dem dataset measures the extent of democracy for 178 countries from 1789 to 2019, using information on a broad array of around 400 country characteristics. Based on these indicators, each of deliberative, egalitarian, liberal, participatory, and electoral measure of democracy is constructed to range between 0 and 1. See Coppedge et al. (2011) for a fuller description.

Table 1
Summary statistics.

	Obs.	Mean	Std. Dev.	Min.	Max.
ΔCO_2 emissions per capita	7,510	0.0042	0.087	−0.93	1.19
CO_2 emissions per capita	7,510	−5.75	1.16	−13.7	−1.75
ΔNO_2 emissions per capita	7,510	−0.0023	0.068	−2.17	1.04
ΔCommodity export price index	7,510	0.0070	0.16	−0.71	0.94
Polity score	6,398	1.69	7.33	−10	10
Executive recruitment	6,398	5.78	2.34	1	8
Executive constraints	6,398	4.42	2.29	1	7
Political competition	6,398	5.82	3.56	1	10
Democracy (Acemoglu et al., 2019)	6,452	0.52	0.50	0	1
Deliberative democracy (V-Dem)	6,978	0.36	0.27	0.0060	0.89
Egalitarian democracy (V-Dem)	6,978	0.36	0.25	0.027	0.88
Liberal democracy (V-Dem)	6,949	0.36	0.28	0.0060	0.89
Participatory democracy (V-Dem)	6,978	0.29	0.22	0.0060	0.80
Electoral democracy (V-Dem)	6,978	0.46	0.29	0.012	0.92

Notes: Data description is given in the text.

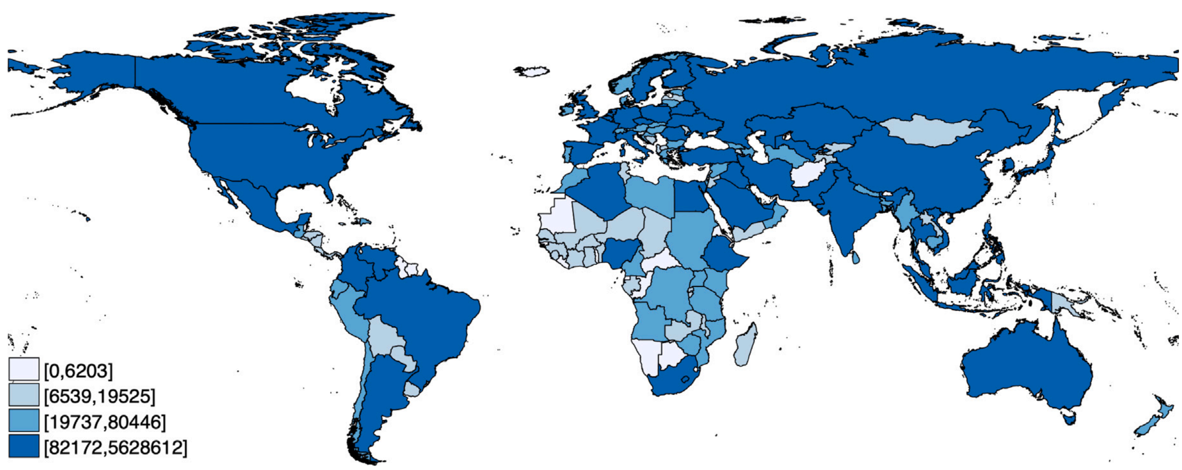

Fig. 2. Map of environmental quality around the world, 1980–2018.
Notes: The figure shows the quintile distributions of CO_2 emissions for our sample of countries. Higher values (lower environmental quality) are indicated by darker regions.

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, the 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 institutionalised 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.

2.4. Summary statistics

We present descriptive statistics for all variables used in this study in Table 1. For our main variables, we provide additional descriptive statistics along regional lines in Table A.1 and by country in Table A.2. Average CO_2 emissions are highest in North America (NA), followed by East Asia and the Pacific (EAP) region. The main countries driving this growth in carbon emissions, as shown in Fig. 2 and Table A.2, are the US and China. 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 SSA enjoy, on average, the most commodity windfalls over our sample period. Unsurprisingly, the 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. Fig. 3 illustrates the average sample distribution of the commodity windfalls.

On the democracy score, NA countries lead the way, having the highest average Polity2 score, followed by Europe and Central Asia (ECA) and Latin America and the Caribbean (LAC) in that order. 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 Fig. 4.

An important pattern from the descriptive statistics is that democratic regions tend to pollute more, as underscored in the introductory section (see Fig. 1). Likewise, Fig. A.1 shows that average CO_2 emissions have generally been trending upwards and that democratic economies emit more CO_2 on average than autocratic nations, despite both groups facing relatively similar international commodity export prices.

3. Econometric model

Our interest is to estimate the effect of commodity windfalls on carbon emissions across countries under different political regimes. 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 democratic environment in the established nexus by re-analysing our primary model by political regimes. Thus, our estimating equation takes the following form:

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

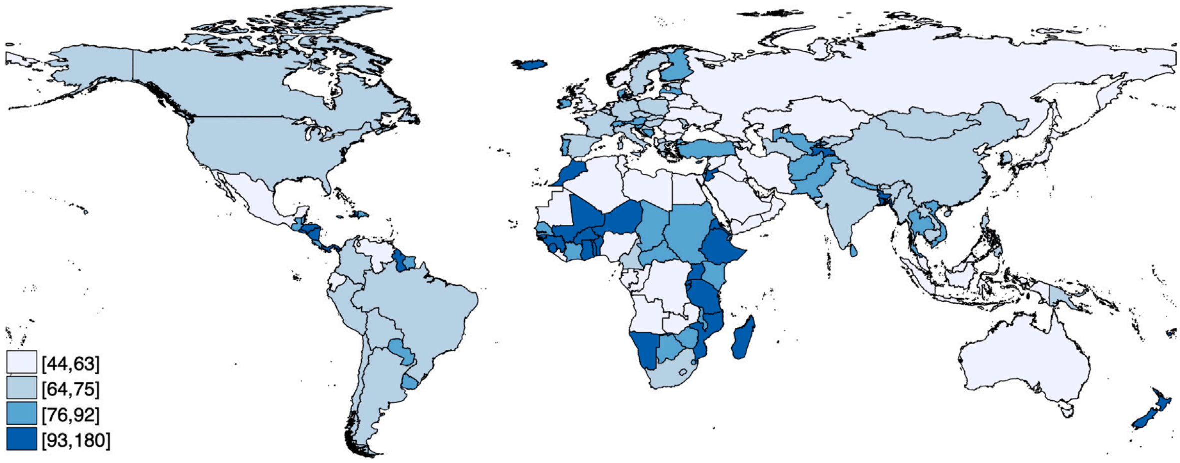

Fig. 3. Map of commodity windfalls around the world, 1980–2018.
Notes: The figure shows the quintile distributions of international commodity export price index for our sample of countries. Higher values (larger commodity windfalls) are indicated by darker regions.

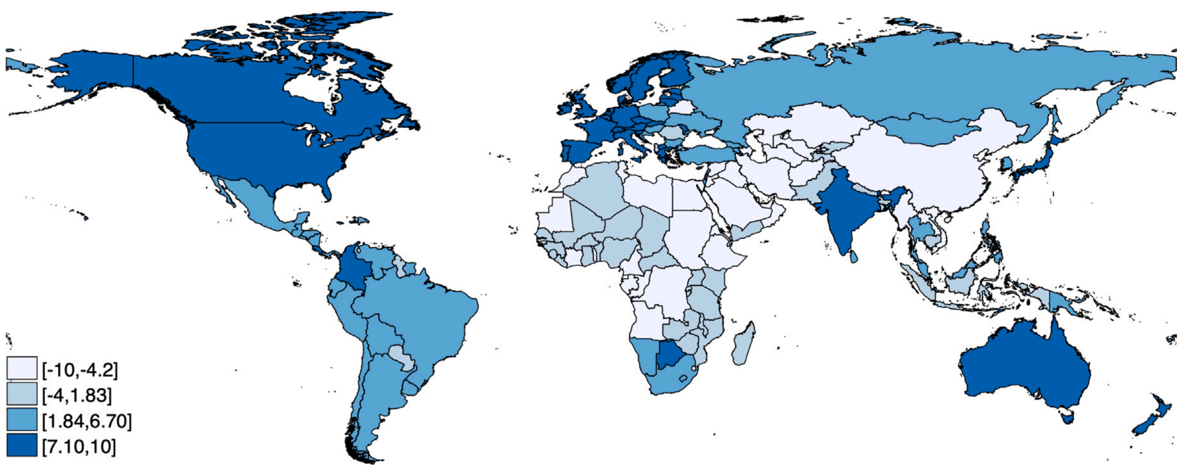

Fig. 4. Map of political regimes around the world, 1980–2018.
Notes: The figure shows the quintile distributions of the polity scores for our sample of countries. Higher values (more democratic countries) are indicated by darker regions.

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. The main explanatory variable, X, is the log of international commodity export price index defined in Eq. (1). Like 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 of 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.).[17] $\varepsilon_{i,t}$ 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 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)). As such, we are able to validate our coefficient estimates from the different methods, thereby assuaging any 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 estimators to obtain consistent estimates while resolving the endogeneity issues 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 effects OLS specification. More importantly, the difference and system GMM estimators can identify δ and other parameters in Eq. (2), using 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

[17] 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. Moreover, we do not add other controls to avoid the "bad control" scenario (Angrist and Pischke, 2008; Emediegwu and Nnadozie, 2023; Emediegwu and Ubabukoh, 2023).

Table 2
Commodity windfalls and environmental quality.

Dependent variable:	ΔCO_2 emissions per capita							
	(1) OLS	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Without Fixed effects		With Fixed effects		GMM Difference		System	
ΔCommodity export price index$_t$	−0.013	−0.010	−0.013	−0.011	−0.016	−0.012	−0.011	−0.010
	(0.240)	(0.319)	(0.218)	(0.254)	(0.135)	(0.196)	(0.270)	(0.306)
ΔCommodity export price index$_{t-1}$	0.0278[b]	0.030[b]	0.028[b]	0.029[b]	0.024[c]	0.028[b]	0.030[b]	0.031[b]
	(0.021)	(0.013)	(0.022)	(0.016)	(0.053)	(0.020)	(0.015)	(0.012)
CO_2 emissions per capita$_{t-1}$		−0.006[a]		−0.067[a]		−0.122[a]		−0.044
		(0.000)		(0.000)		(0.002)		(0.164)
Country fixed effects	No	No	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.019	0.025	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	7510	7510	7330	7330	7510	7510
Countries	179	179	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 OLS without fixed effects in columns (1)–(2), OLS with fixed effects in columns (3)–(4), difference GMM in columns (5)–(6), and system GMM in columns (7)–(8). All models include year fixed effects. 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.

the model, especially with a highly persistent left-hand side variable. Under this scenario, the estimate of ρ will be inconsistent, which is similar to the fixed effects 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, system GMM permits the inclusion of time-invariant predictors in the level regressions. Moreover, we ensure that the instrument count does not explode by collapsing 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, using variants of Eq. (2). The estimated coefficients are based on OLS without country fixed effects in columns (1)–(2), OLS with country fixed effects in columns (3)–(4), difference GMM in columns (5)–(6), and system GMM in columns (7)–(8), with the latter two methodologies employed to account for the dynamics in the even columns. All models include year fixed effects and standard errors, which are robust against heteroscedasticity, are country-clustered. Also, the dependent variables in these regressions are represented in per capita terms, and both the international commodity export price index and CO_2 emissions are expressed in first-differenced log form.

In columns (1), (3), (5), and (7), which present coefficient 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. The results align with recent studies (Wang et al., 2020; Gyamfi et al., 2022; Liu et al., 2022), examining the combined influence of commodity export 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 export 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, contemporaneous 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), (6), and (8). As noted in the previous section, the OLS estimator is inconsistent in a dynamic panel model. In dealing with the associated endogeneity concerns, we present the difference GMM and system GMM estimators in columns (6) and (8), respectively. We find similar results across the four 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 lagged value of CO_2 emissions per capita, suggesting that a 1 percentage point change in commodity export prices predicts a 3% increase in carbon emissions. The bottom rows in columns (5)–(8) report the p-value of a test for serial correlation in the residuals. This test checks for the AR(2) correlation in the first-differenced residuals and requires its absence 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 and its interaction with international commodity export price index on the right-hand side. However, from an econometric identification perspective, the stylised evidence using this political economy model of environmental policy has two possible limitations. The first relates to convergence, and the second 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).

Following Arezki and Brückner (2012), we circumvent this by building stratified political regimes that classify countries based on a synthetic index summarising different governance dimensions to allow for flexibility and comparisons. This measure adapts the Polity2 index classification of political regimes, which ranges from −10 (strongly

Table 3
Commodity windfalls, political regimes, and environmental quality – OLS.

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. Without fixed effects							
ΔCommodity export price index$_{t-1}$	0.036[a]	0.022	0.031[a]	0.026	0.041[a]	0.020	0.041[a]	0.023
	(0.001)	(0.284)	(0.006)	(0.220)	(0.001)	(0.301)	(0.003)	(0.206)
Country fixed effects	No	No	No	No	No	No	No	No
R-squared	0.042	0.025	0.047	0.021	0.055	0.021	0.045	0.022
Observations	3859	2806	3634	3031	3307	3358	3381	3284
Countries	93	65	87	71	80	78	82	76
	Panel B. With fixed effects							
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
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

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 OLS without and with fixed effects in panels A and B, respectively. All models include year fixed effects. 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.

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 (DEM), Autocracy (AUT), 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 international commodity export price index on CO_2 emissions and compare the coefficients estimated across political regimes in Tables 3 and 4. Because the concurrent 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.[18] Panel A of Table 3 reports the results of OLS without country fixed effects and panel B the results of OLS with country fixed effects. Panel A of Table 4 reports the difference GMM estimates, while panel B documents the system GMM estimates. Across both tables, the main result is that the effect of international commodity export price index on CO_2 emissions is positive and significantly pronounced under democracy, strong executive recruitment, strong executive constraints, and strong political competition. These results are in consonant with our preliminary evidence in Fig. 1.

An extensive empirical literature supports the role of democratic institutions in environmental outcomes (Bernauer and Koubi, 2009; Bhattacharya et al., 2017). Democracies offer society a deliberative role in policy formulation (Acemoglu and Robinson, 2006). Consequently, the demand for environmental protection could help shape a political leader's preference for reforms that translate into greenhouse gas reductions. Nevertheless, the evidence of a positive effect provided by our analysis relies on certain mechanisms. First, interest groups must agree on environmental legislation (Midlarsky, 1998; Li and Reuveny, 2006). Second, they must also decide on how to implement it. Thus, the results in this paper are consistent with a political economy perspective that coercive interest groups, mainly through capitalist agenda, can defeat any societal need for environmental protection (Li and Reuveny, 2006). Consequently, the results from our investigation underscore the role that laissez-faire market mechanisms play under democracy, where the incentives offered by commodity windfalls can cause a wide divergence amongst interest groups, a problem that can sometimes be difficult to reconcile under democratic values. Consequently, democracy may not generate a reduction in CO_2 emissions (Midlarsky, 1998).

Besides, 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 (Midlarsky, 1998; Robinson et al., 2006). Similarly, term limits impose high political constraints, which may imply 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 (Midlarsky, 1998; Li and Reuveny, 2006; Chenoweth, 2010; Hendrix and Haggard, 2015). Conversely, citizens do not make substantive contributions to policy development in a less democratic nation, meaning that, by extension, they have little input on environmental issues. Besides, implementing any environmental reform may require radical changes in the mould of authoritarian environmentalism through government mandates, which limit some rights and individual liberties (Beeson, 2010; Mittiga, 2022). This authoritarian dispensation to policy implementation presents autocracies with limited political economy obstacles, potentially placing them in a more favourable 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 Tables 3–4 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 Eq. (2). Specifically, we repeat the regressions used in Tables 3 and 4, augmenting them with a lag of CO_2 emissions, and document the estimated coefficients in Table 5. The results are largely similar to the estimates in Tables 3 and 4. Furthermore, we check whether our estimates are sensitive to additional lags since accumulated CO_2 emissions over time could contribute to more

[18] In Tables A.3–A.6, we confirm that this remains the case by reporting results with current-period international commodity export price index included on the righ-hand side.

Table 4
Commodity windfalls, political regimes, and environmental quality – GMM.

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. Difference							
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
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 B. System							
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
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 method is difference GMM in panel A and system GMM in panel B. All models include year fixed effects. 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-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
ΔCommodity export price index$_{t-1}$	0.033^a	0.026	0.028^a	0.029	0.033^a	0.023	0.035^a	0.027
	(0.002)	(0.244)	(0.008)	(0.185)	(0.005)	(0.247)	(0.009)	(0.155)
CO_2 per capita$_{t-1}$	−0.077^c	0.025	−0.082^b	0.019	−0.090^b	0.043	−0.107^a	0.015
	(0.053)	(0.582)	(0.029)	(0.669)	(0.025)	(0.344)	(0.002)	(0.769)
Country 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	0.169	0.711	0.084	0.597	0.041	0.491	0.363	0.879
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 method is system GMM. All models include year fixed effects. The base sample is a yearly panel of 179 countries, spanning the period 1970–2018. DEM (AUT) is democracy (autocracy) and comprises countries that have a strictly positive (negative) Polity score. SER: Strong Executive Recruitment (WER: Weak Executive Recruitment) comprises countries that have an above (below) mean score of executive recruitment in the sample. SEC: Strong Executive Constraints (WEC: Weak Executive Constraints) comprises countries that have an above (below) mean score of executive constraints in the sample. SPC: Strong Political Competition (WPC: Weak Political Competition) comprises 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.

pollution contemporaneously, a concept known in climate econometrics literature as "harvesting" (Emediegwu et al., 2022). To do this, we include a second lag of CO_2 emissions as part of the right-hand side variables in Eq. (2). The results in Table A.7 validate the stability of our baseline estimates.

The influence of outliers. First, we check if our results are driven by outlier observations/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.[19] The results from the remaining countries, shown in panel A of Table 6, are strongly consistent with the baseline estimates, although with a marginal increase in the size of the estimates. Second, we exclude China and the US, which are the two countries with the highest CO_2 emissions per capita.[20] 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 6, showing estimates similar to our main results, thereby 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 place of CO_2 emissions, we re-analysed our model using NO_2 emissions and got qualitatively analogous estimates, although at the cost of a reduced significance (see panel A of Table 7). 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 in our primary model with an index weighted by a country's GDP. The results, displayed in panel B of Table 7, 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).[21] Using this measure instead of polity2 scores produces similar results, albeit with lower

[19] This is usually defined as $4/N$, where N is the number of observations.
[20] Data from EDGAR indicate that both countries are responsible for more than 40% of global CO_2 emissions annually (Crippa et al., 2021).
[21] Kindly refer to subsection 2.3, where we briefly described this dataset.

Table 6
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$_{t-1}$	0.038[a]	0.014	0.031[a]	0.019	0.042[a]	0.014	0.034[a]	0.014
	(0.000)	(0.533)	(0.002)	(0.403)	(0.001)	(0.494)	(0.003)	(0.470)
Country 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	0.749	0.807	0.849	0.630	0.642	0.496	0.839	0.613
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$_{t-1}$	0.033[a]	0.027	0.028[a]	0.030	0.033[a]	0.024	0.035[a]	0.028
	(0.002)	(0.224)	(0.008)	(0.170)	(0.005)	(0.232)	(0.010)	(0.143)
Country 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	0.162	0.712	0.080	0.598	0.038	0.492	0.352	0.879
Observations	3812	2759	3587	2984	3260	3311	3334	3237
Countries	92	64	86	70	79	77	81	75

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. All models include year fixed effects. 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 7
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 ΔNO_2 emissions p.c.)							
ΔCommodity export price index$_{t-1}$	0.019[b]	0.013	0.019[b]	0.014	0.023[b]	0.013	0.024[a]	0.012
	(0.016)	(0.241)	(0.024)	(0.188)	(0.011)	(0.199)	(0.007)	(0.220)
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AR(1) *p*-value	0.000	0.028	0.000	0.024	0.000	0.021	0.000	0.019
AR(2) *p*-value	0.674	0.244	0.674	0.246	0.707	0.249	0.484	0.228
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$_{t-1}$	0.033[a]	0.026	0.028[a]	0.029	0.033[a]	0.023	0.035[a]	0.027
	(0.002)	(0.244)	(0.008)	(0.185)	(0.005)	(0.247)	(0.009)	(0.155)
Country 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	0.169	0.711	0.084	0.597	0.041	0.491	0.363	0.879
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 NO_2 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. All models include year fixed effects. 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.

magnitudes and significance than the baseline estimates (see Fig. 5). More specifically, we find that international commodity export price index continues to have statistically significant effect in democracies but insignificant effect in autocracies.

Further analyses. In an additional test, we consider a different definition of CO_2 emissions (log-level), where in Tables A.8, A.9, and A.10, we respectively regress log-level of CO_2 emissions per capita on time t, $t-1$, and both t and $t-1$ international commodity export price index, finding largely similar results to the baseline ones. Moreover, we show in Table A.11 that our findings are robust to the use of time-varying polity measures to split our sample countries into democracies and autocracies. The above exercises underscore the importance of our results, which are not driven by spurious variables and are plausibly correctly specified. Therefore, large deviations from the main estimates are unexpected.

Additionally, we employ interaction model specifications in Table A.12, where we model carbon emissions as a function of commodity price shocks, a conceptualisation of democracy from the V-Dem project (deliberative, egalitarian, liberal, participatory, and electoral), and their interaction in columns (1) to (5), respectively. The results largely provide support for our baseline identification strategy of estimating the effect of commodity windfalls on CO_2 emissions for separate samples of democratic and autocratic countries–a positive relation between commodity price shocks and carbon emissions. In terms of the effects of democracy, the findings are similar to those obtained for the African sample in Acheampong et al. (2022)–a positive relation between democracy and carbon emissions, albeit some of the

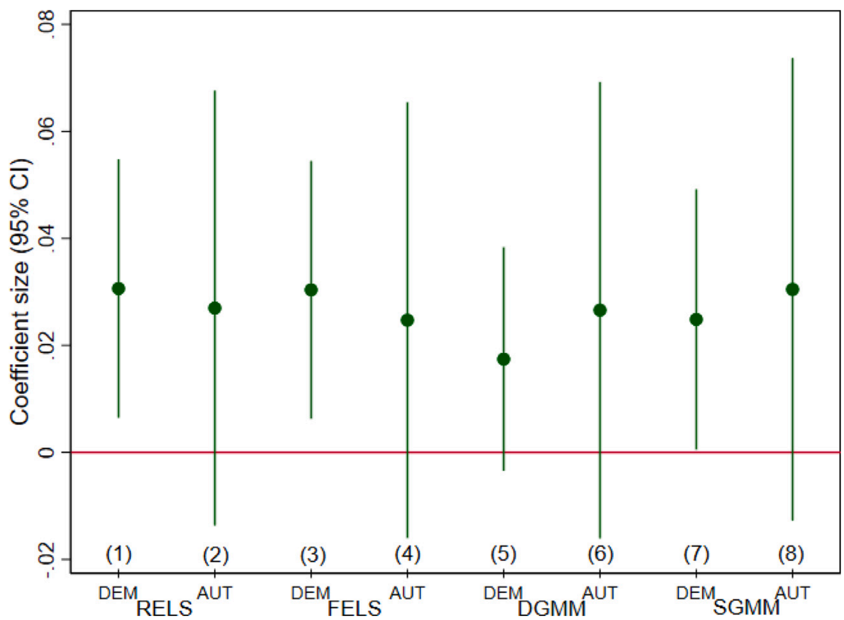

Fig. 5. Robustness check using alternative measure of democracy.
Notes: The figure shows regression estimates from OLS without fixed effects (RELS) in specifications (1)–(2), OLS with fixed effects (FELS) in specifications (3)–(4), difference GMM (DGMM) in specifications (5)–(6), and system GMM (SGMM) in specifications (7)–(8) of the effect of commodity windfalls on the first-differenced log of CO_2 emissions per capita. The base sample is a yearly panel of 179 countries, spanning the period 1970–2018. DEM (AUT) is democracy (autocracy) stratified based on updated Acemoglu et al. (2019) dichotomous measure of democracy. Standard errors are heteroscedasticity-robust and are clustered at the country level.

estimates are not statistically significant. On the interaction term, we find a negative effect that is insignificantly different from zero. Extant studies involving democracy have confirmed the possibility of different outcomes between pooled interaction model and split sample analysis (Eberhardt, 2022).[22]

Finally, observing the considerable regional variation in CO_2 emissions, especially between SSA and other regions, we conduct a leave-one-out analysis as an additional robustness check to determine whether any specific region is disproportionately influencing our results. Excluding one region at a time and re-estimating the model, we are able to assess the impact of each region on the overall effect. The findings, presented in Fig. A.2, illustrate that omitting democratic countries in SSA region amplifies the effect on CO_2 emissions, indicating that SSA countries exert the highest leverage due to their lower emissions. Consistent with our baseline results, we observe no significant differences amongst autocratic economies. We also show in Figs. A.3 and A.4, where we sequentially exclude each country before re-running the model, that our results exhibit relative stability. Hence, no individual country, whether democratic or autocratic, appears to be driving the overall findings.

5. Conclusion

This paper investigates whether carbon emissions respond differently to commodity windfalls in democracies and autocracies. Despite substantial global policy attention towards climate change and a significant increase in the adoption of democracies around the world, evidence is inconclusive on how economic incentives from polluting activities shape emissions' outcomes in democracies and autocracies. Our results highlight the significant implication of commodity windfalls for political distortion by allowing self-interested policymakers to trade off the general welfare of voters as commodity windfalls rise.

Overall, the empirical analysis in this paper supports the claim that increasing commodity windfalls leads to higher CO_2 emissions. Importantly, we find that commodity windfalls significantly lead to higher CO_2 emissions under democracies than in autocracies. Although democracies offer civil society a deliberative role in policy formulation, this 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 (Midlarsky, 1998; Li and Reuveny, 2006; Acheampong et al., 2022). Conversely, autocracies legitimise claims to political offices through indoctrination, passivity, and by implementing pseudo-democratic protocols. Besides, autocratic rulers are relatively not term-restricted. Therefore, they may be 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.

Although we believe that democracy is more desirable than autocracy since the former ensures that the fundamental rights of the citizens are protected. Yet, its democratic principles might stand in the way of achieving safety in periods of crisis, whether it is health-related (e.g., COVID-19) or in responding to climate-based crises. Thus, some researchers, such as Mittiga (2022), have argued that, for democratic governments to retain their legitimacy in the urgent quest to cut down greenhouse gases, democracies may recourse to emergency powers, as seen in lockdown restrictions during the COVID-19 pandemic, which are often authoritarian in design and scope.

Nonetheless, the relationship between commodity windfalls and CO_2 emissions is not easily quantifiable; some hidden mechanisms may

[22] Essentially, heterogeneous democracy greatly affects the identification of empirical models incorporating an interaction variable. If the average effect hides substantial differences in the impact of democracy across countries, then an interaction effect that reports an average effect is seriously misleading and difficult to interpret (Eberhardt, 2022; Papaioannou and Siourounis, 2008).

not be fully explored. Consequently, our results do not imply that democracy is unimportant for decarbonisation. Instead, we emphasise that to reach their full potential in influencing reductions in CO_2 emissions, governments under democratic institutions should be guided by the likely implications of higher commodity windfalls and encourage them to invest in more sustainable abatement technologies as revenues generated from non-tax sources increase.

Further, we note that SSA countries are uniquely positioned to leverage their relatively lower carbon emissions for significant gains in international climate negotiations. Despite their rich endowment of natural resources, SSA nations contribute minimally to global greenhouse gas emissions compared to more industrialised regions. For instance, while resource extraction and commodity production are vital economic activities in the region, their carbon footprint remains disproportionately small (Guo et al., 2023). This scenario provides a strategic advantage for negotiations at international climate summits, such as the Conference of the Parties (COP), as SSA countries can advocate for more substantial support in climate finance and technology transfers, arguing that they have historically contributed least to the problem, while facing some of its harshest impacts (Sandow et al., 2022). Policymakers in Sub-Saharan Africa should harness this leverage to push for equity in global climate policies, ensuring that the region receives the necessary resources to transition to sustainable development pathways without compromising economic growth. This approach not only aligns with the principles of climate justice, but also enables SSA nations to develop resilience against climate change impacts, while maintaining low emissions growth trajectories.

Moreover, the relative stability of our results, even when systematically excluding individual countries and rerunning our model, underscores the superiority of region-wide policies over country-specific measures in effectively addressing carbon emissions. Isolated efforts by individual countries are insufficient to achieve significant impact unless accompanied by similar reforms in other economies. Analogous to the global response required to combat COVID-19, the pursuit of zero carbon emissions necessitates a coordinated international effort. Thus, regional cooperation, comprehensive policy frameworks, and international collaboration are imperative for substantial progress in reducing carbon emissions.

CRediT authorship contribution statement

Olayinka Oyekola: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Lotanna E. Emediegwu:** Writing – review & editing, Writing – original draft, Software, Data curation, Formal analysis, Visualization. **Jubril O. Animashaun:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Validation.

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Appendix A

See Figs. A.1–A.4 and Tables A.1–A.12.

Appendix B. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.eneco.2024.107813.

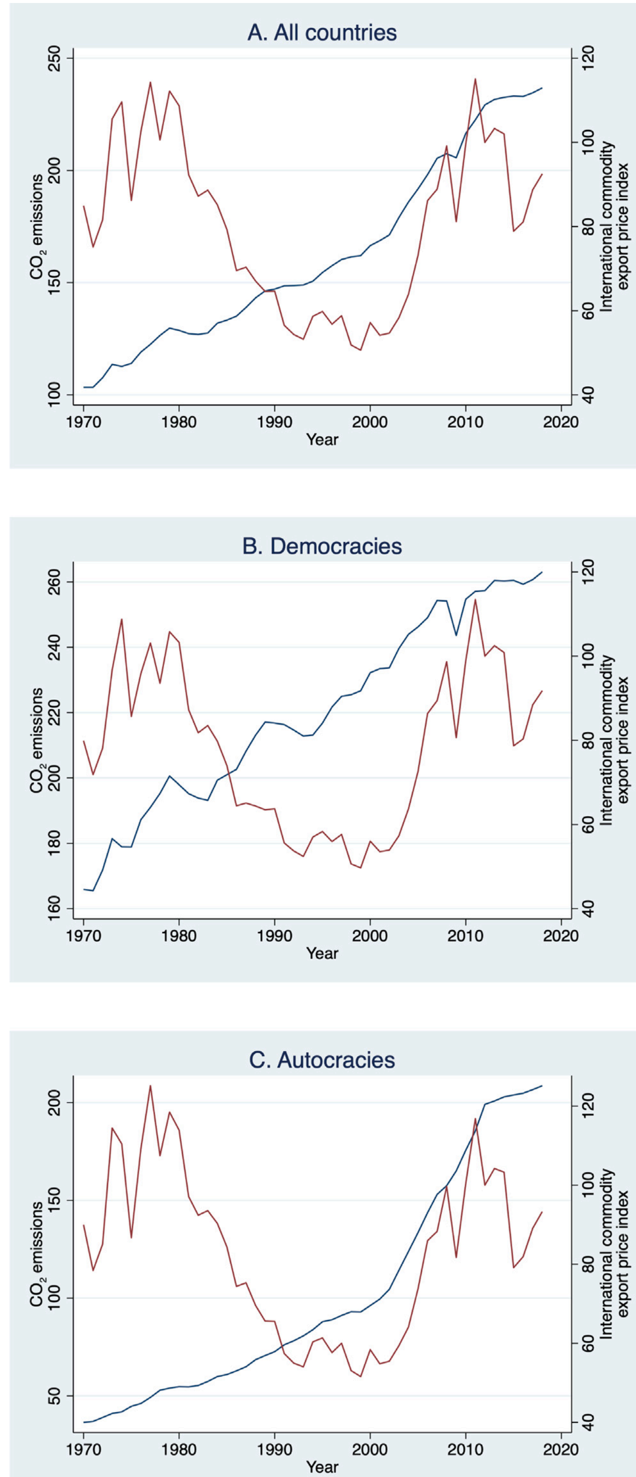

Fig. A.1. International commodity export price and CO_2 emissions.
Notes: This figure shows data for average CO_2 emissions (blue line) and international commodity export price index (red line) plotted over time. Panel A combines all countries in our sample, while panels B and C distinguish between democratic and autocratic countries, respectively.

Table A.1
Summary statistics of main variables by region.

	CO_2 emissions			Commodity windfalls			Democracy		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Full Sample (FS)	174.3	708.7	4.1	79.1	35.9	0.5	1.7	7.3	4.3
East Asia & the Pacific (EAP)	376.1	1,312	3.5	81.6	35.6	0.4	1.9	7.0	3.8
Europe & Central Asia (ECA)	173.5	286.6	1.7	73.5	28.1	0.4	6.3	6.2	0.98
Latin America & the Caribbean (LAC)	62.7	160.0	2.6	78.4	29.4	0.4	4.7	5.8	1.2
Middle East & North Africa (MENA)	71.6	107.9	1.5	62.3	30.4	0.5	−5.6	5.0	−0.9
North America (NA)	3,114	2,579	0.8	68.9	18.4	0.3	9.9	0.5	0.1
South Asia (SA)	324.0	718.3	2.2	87.7	25.9	0.3	1.4	6.7	5.0
Sub-Saharan Africa (SSA)	33.4	83.4	2.5	87.3	40.6	0.5	−1.2	6.1	−5.1

Notes: SD is standard deviation and CV is coefficients of variation (standard deviation-to-mean ratio).

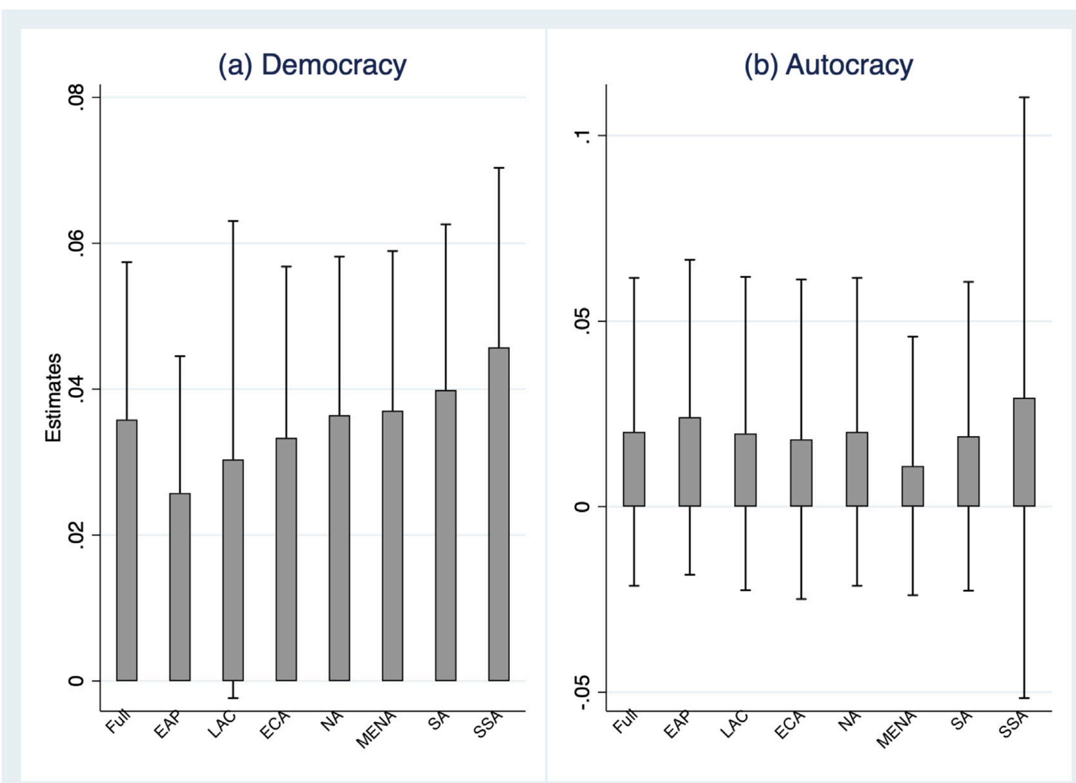

Fig. A.2. Commodity windfalls and environmental quality across political regimes.
Notes: Each bar corresponds to the coefficient of the baseline equation re-estimated without the named region. The spikes are confidence intervals at 95%. The procedure for classifying political regimes is explained in-text. The acronyms for the regions are expanded as follows: EAP - East Asia & the Pacific; EAC - Europe & Central Asia; LAC - Latin America & the Caribbean; MENA - Middle East & North Africa; NA - North America; SA - South Asia; and SSA - Sub-Saharan Africa. 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.

Table A.2
Summary statistics of main variables by country.

	CO_2 emissions			Commodity windfalls			Democracy		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Afghanistan	5.812	3.415	0.588	80.206	15.362	0.192	−5.579	2.835	−0.508
Albania	6.541	2.157	0.330	62.115	21.074	0.339	0.674	8.089	12.002
Algeria	86.777	35.608	0.410	50.139	26.122	0.521	−3.766	4.687	−1.245
Angola	32.358	9.227	0.285	48.079	26.176	0.544	−4.500	2.420	−0.538
Antigua and Barbuda	0.478	0.123	0.257	71.328	19.362	0.271			
Argentina	187.253	54.454	0.291	73.910	18.885	0.256	4.894	6.287	1.285
Armenia	4.631	1.131	0.244	68.890	27.996	0.406	4.080	3.174	0.778
Australia	374.479	92.430	0.247	62.220	20.502	0.329	10.000	0.000	0.000
Austria	80.398	12.621	0.157	82.105	14.203	0.173	10.000	0.000	0.000
Azerbaijan	30.212	2.887	0.096	56.619	29.092	0.514	−6.720	0.843	−0.125
Bahamas	2.895	0.509	0.176	97.362	19.929	0.205			
Bahrain	17.390	9.404	0.541	72.145	20.774	0.288	−8.978	1.358	−0.151
Bangladesh	83.698	31.219	0.373	125.069	20.227	0.162	0.311	5.510	17.709
Barbados	1.874	0.176	0.094	69.038	31.235	0.452			
Belarus	67.675	3.878	0.057	58.098	28.569	0.492	−6.120	3.257	−0.532
Belgium	119.407	6.245	0.052	77.408	20.936	0.270	8.667	0.970	0.112
Belize	1.091	0.294	0.269	73.968	16.378	0.221			
Benin	8.081	3.341	0.413	92.496	27.758	0.300	1.196	6.655	5.566
Bhutan	3.383	1.629	0.481	73.309	17.285	0.236	−6.000	6.260	−1.043
Bolivia	19.556	9.763	0.499	68.428	20.359	0.298	5.043	6.093	1.208
Bosnia and Herzegovina	20.415	4.679	0.229	88.260	16.033	0.182			
Botswana	7.623	1.654	0.217	86.932	23.394	0.269	8.000	0.000	0.000
Brazil	744.723	308.773	0.415	63.942	19.313	0.302	4.468	5.729	1.282
Brunei Darussalam	5.494	1.706	0.311	55.068	28.373	0.515			
Bulgaria	69.436	16.618	0.239	62.268	21.279	0.342	2.766	7.527	2.721
Burkina Faso	13.922	5.249	0.377	116.020	38.653	0.333	−2.413	4.064	−1.684
Burundi	7.853	2.617	0.333	111.613	58.619	0.525	−2.359	5.417	−2.296
Cambodia	19.966	11.084	0.555	72.216	19.608	0.272	−0.281	3.503	−12.456
Cameroon	22.794	6.440	0.283	67.525	21.493	0.318	−5.723	1.873	−0.327
Canada	568.913	81.674	0.144	67.300	19.462	0.289	10.000	0.000	0.000
Cape Verde	0.576	0.368	0.638	122.706	35.564	0.290	5.024	6.162	1.227
Central African Republic	3.220	0.404	0.126	88.066	15.796	0.179	−1.977	5.280	−2.671
Chad	7.772	2.895	0.373	81.431	23.356	0.287	−3.351	2.541	−0.758
Chile	65.487	32.302	0.493	64.004	24.373	0.381	3.766	7.417	1.969
China	5388.000	3437.731	0.638	72.914	19.383	0.266	−7.085	0.282	−0.040
Colombia	99.149	22.804	0.230	66.267	22.837	0.345	7.532	0.654	0.087
Comoros	0.358	0.181	0.505	76.251	19.684	0.258	2.171	6.233	2.871
Congo, Dem. Rep. of	53.959	18.782	0.348	55.824	22.328	0.400	−4.152	6.360	−1.532
Congo, Republic of	5.882	2.837	0.482	46.167	25.551	0.553	−4.717	3.810	−0.808
Costa Rica	9.592	3.701	0.386	90.556	22.633	0.250	10.000	0.000	0.000
Cote d'Ivoire	16.610	7.586	0.457	87.155	30.036	0.345	−4.737	5.525	−1.166
Croatia	25.859	2.532	0.098	70.322	23.053	0.328	5.958	5.560	0.933
Cyprus	5.465	2.017	0.369	78.020	18.425	0.236	9.870	0.619	0.063
Czech Republic	133.143	5.826	0.044	76.808	22.022	0.287	9.409	0.503	0.053
Denmark	62.220	6.472	0.104	81.028	19.804	0.244	10.000	0.000	0.000
Djibouti	1.260	0.324	0.257	78.327	17.681	0.226	−2.878	4.880	−1.695
Dominica	0.108	0.052	0.478	78.297	18.944	0.242			
Dominican Republic	23.731	5.740	0.242	77.047	25.489	0.331	5.383	3.517	0.653
Ecuador	31.338	10.658	0.340	63.664	22.106	0.347	5.468	4.745	0.868
Egypt	137.189	76.797	0.560	55.493	23.719	0.427	−5.348	1.320	−0.247
El Salvador	11.939	1.543	0.129	99.241	39.411	0.397	5.190	4.192	0.808
Equatorial Guinea	3.063	2.874	0.938	60.452	21.076	0.349	−6.383	0.610	−0.096
Eritrea	2.689	0.537	0.200	90.471	13.397	0.148	−6.647	0.493	−0.074
Estonia	22.622	2.285	0.101	76.301	21.406	0.281	8.320	1.249	0.150
Eswatini	4.879	0.945	0.194	82.042	19.544	0.238	−8.647	0.786	−0.091
Ethiopia	99.693	45.641	0.458	108.426	47.008	0.434	−3.929	3.598	−0.916
Fiji	4.707	0.861	0.183	103.545	59.275	0.572	3.239	3.831	1.183
Finland	89.668	14.360	0.160	76.093	17.176	0.226	10.000	0.000	0.000
France	461.238	51.745	0.112	68.439	17.746	0.259	9.702	0.462	0.048
Gabon	12.684	5.631	0.444	46.778	25.113	0.537	−4.435	4.549	−1.026
Gambia	0.939	0.439	0.467	108.555	26.699	0.246	1.170	6.384	5.455
Georgia	9.152	2.103	0.230	62.906	26.370	0.419	5.250	1.847	0.352
Germany	996.792	111.487	0.112	67.573	18.907	0.280	10.000	0.000	0.000
Ghana	17.158	4.637	0.270	100.795	36.278	0.360	0.957	6.427	6.712
Greece	79.234	20.719	0.261	67.952	20.458	0.301	8.783	3.508	0.399
Grenada	0.161	0.085	0.528	103.841	32.437	0.312			
Guatemala	35.575	11.635	0.327	85.544	27.400	0.320	3.565	5.269	1.478
Guinea	14.938	4.568	0.306	95.549	19.820	0.207	−3.511	4.544	−1.294
Guinea-Bissau	2.899	0.913	0.315	92.499	20.030	0.217	−0.976	6.187	−6.341
Guyana	4.501	0.570	0.127	96.745	36.448	0.377	1.872	5.621	3.002
Haiti	8.224	1.605	0.195	92.570	31.658	0.342	−2.656	6.528	−2.458
Honduras	15.508	6.570	0.424	94.874	25.145	0.265	5.111	2.940	0.575
Hungary	74.683	12.860	0.172	69.287	17.168	0.248	3.826	8.185	2.139

(*continued on next page*)

Table A.2 (*continued*).

Iceland	2.851	0.607	0.213	148.965	63.453	0.426			
India	1852.170	879.405	0.475	67.320	18.792	0.279	8.362	0.705	0.084
Indonesia	527.798	228.820	0.434	59.443	22.351	0.376	0.681	7.375	10.833
Iran	329.526	191.772	0.582	45.644	25.950	0.569	5.489	3.838	0.699
Iraq	89.854	45.939	0.511	45.206	26.015	0.575	−5.575	5.683	−1.019
Ireland	36.003	8.090	0.225	89.021	19.748	0.222	10.000	0.000	0.000
Israel	46.574	21.563	0.463	81.870	18.052	0.220	6.574	1.193	0.181
Italy	432.242	46.132	0.107	65.075	19.622	0.302	10.000	0.000	0.000
Jamaica	10.763	1.904	0.177	78.969	20.338	0.258	9.447	0.503	0.053
Japan	1182.166	137.499	0.116	63.624	21.271	0.334	10.000	0.000	0.000
Jordan	14.114	7.340	0.520	101.658	17.554	0.173	−5.128	3.449	−0.673
Kazakhstan	211.536	56.652	0.268	59.116	28.572	0.483	−5.880	0.600	−0.102
Kenya	35.011	12.843	0.367	82.959	23.989	0.289	0.021	7.020	329.946
Kiribati	0.039	0.019	0.478	120.440	33.387	0.277			
Korea, Republic of	370.787	204.272	0.551	68.090	21.524	0.316	2.717	6.843	2.518
Kuwait	57.519	24.798	0.431	50.672	25.330	0.500	7.905	1.206	0.153
Kyrgyzstan	7.456	2.154	0.289	72.617	21.514	0.296	1.625	4.670	2.874
Laos	10.756	7.950	0.739	75.042	15.303	0.204	−7.000	0.000	0.000
Latvia	13.585	0.725	0.053	90.959	12.130	0.133	8.000	0.000	0.000
Lebanon	14.094	7.283	0.517	72.936	17.328	0.238	5.471	1.179	0.215
Lesotho	4.041	0.117	0.029	76.245	16.291	0.214	8.000	0.000	0.000
Liberia	6.342	3.335	0.526	46.469	23.456	0.505	0.892	5.656	6.341
Libya	41.577	14.162	0.341	46.077	26.015	0.565	−7.000	0.000	0.000
Lithuania	18.262	1.485	0.081	63.753	26.152	0.410	10.000	0.000	0.000
Luxembourg	10.970	0.913	0.083	90.000	18.317	0.204	10.000	0.000	0.000
Macedonia	10.108	0.766	0.076	73.645	27.153	0.369	8.125	1.393	0.171
Madagascar	15.087	6.784	0.450	109.199	31.047	0.284	1.413	6.224	4.405
Malawi	9.585	2.263	0.236	89.835	32.323	0.360	−1.064	7.420	−6.975
Malaysia	120.827	84.323	0.698	58.782	20.917	0.356	4.149	1.021	0.246
Maldives	0.487	0.559	1.149	175.943	100.957	0.574			
Mali	7.492	3.465	0.462	115.695	37.514	0.324	0.133	6.222	46.662
Malta	1.956	0.708	0.362	81.202	20.952	0.258			
Mauritania	3.297	1.590	0.482	50.917	26.247	0.515	−5.234	2.388	−0.456
Mauritius	6.067	0.530	0.087	101.110	64.024	0.633	9.787	0.414	0.042
Mexico	397.526	121.371	0.305	50.759	24.570	0.484	2.532	5.417	2.139
Moldova, Republic of	10.126	1.877	0.185	71.171	16.391	0.230	8.280	0.891	0.108
Mongolia	12.202	3.903	0.320	63.977	21.097	0.330	3.064	8.173	2.668
Morocco	37.968	18.512	0.488	109.534	25.872	0.236	−6.745	1.594	−0.236
Mozambique	23.529	3.968	0.169	95.500	16.462	0.172	−0.186	6.204	−33.346
Myanmar	66.252	18.872	0.285	74.862	14.159	0.189	−5.522	4.151	−0.752
Namibia	3.739	0.924	0.247	95.858	23.179	0.242	6.000	0.000	0.000
Nepal	36.222	13.420	0.370	90.213	15.924	0.177	0.404	6.107	15.106
Netherlands	171.175	16.262	0.095	59.731	22.136	0.371	10.000	0.000	0.000
New Zealand	31.980	8.852	0.277	104.797	17.545	0.167	10.000	0.000	0.000
Nicaragua	8.637	2.488	0.288	104.090	34.239	0.329	3.021	6.432	2.129
Niger	8.832	3.177	0.360	98.397	19.681	0.200	−0.222	5.819	−26.185
Nigeria	359.070	116.093	0.323	46.065	25.891	0.562	−0.044	5.920	−133.195
Norway	45.887	4.973	0.108	57.635	24.517	0.425	10.000	0.000	0.000
Oman	31.433	23.006	0.732	47.692	25.733	0.540	−9.043	0.884	−0.098
Pakistan	222.602	98.528	0.443	91.229	25.432	0.279	1.717	6.538	3.807
Panama	8.266	2.902	0.351	99.296	20.154	0.203	3.298	7.457	2.261
Papua New Guinea	7.567	2.829	0.374	63.621	21.167	0.333	4.167	0.377	0.091
Paraguay	14.307	4.996	0.349	86.459	25.808	0.298	1.702	7.541	4.430
Peru	46.947	12.548	0.267	64.623	23.429	0.363	4.432	5.963	1.345
Philippines	127.202	34.950	0.275	71.074	19.323	0.272	3.087	7.542	2.443
Poland	385.410	48.046	0.125	68.741	20.540	0.299	3.340	7.902	2.366
Portugal	56.247	19.566	0.348	77.212	17.043	0.221	9.022	3.946	0.437
Qatar	38.559	28.769	0.746	50.140	25.863	0.516	−10.000	0.000	0.000
Romania	149.866	43.238	0.289	58.672	21.149	0.360	2.130	7.719	3.623
Russia	1752.600	65.148	0.037	62.999	27.957	0.444	4.320	1.145	0.265
Rwanda	7.059	1.177	0.167	97.046	43.560	0.449	−5.340	1.760	−0.330
Saint Kitts and Nevis	0.302	0.083	0.275	81.003	16.137	0.199			
Saint Lucia	0.253	0.114	0.450	72.297	20.092	0.278			
Vincent and the Grenadines	0.139	0.066	0.479	75.764	15.332	0.202			
Samoa	0.203	0.073	0.359	125.880	50.871	0.404			
Sao Tome and Principe	0.178	0.074	0.416	120.164	65.871	0.548			
Saudi Arabia	280.490	165.767	0.591	45.619	26.004	0.570	−10.000	0.000	0.000
Senegal	7.012	3.715	0.530	80.197	22.508	0.281	1.638	5.071	3.095
Seychelles	0.619	0.375	0.606	145.700	60.783	0.417			
Sierra Leone	7.513	1.420	0.189	93.221	25.636	0.275	−1.143	6.550	−5.731
Singapore	34.008	16.583	0.488	49.960	24.726	0.495	−3.404	0.925	−0.272
Slovakia	43.622	1.983	0.045	70.002	23.582	0.337	9.292	0.999	0.108
Slovenia	19.057	1.350	0.071	84.898	17.811	0.210	10.000	0.000	0.000
Solomon Islands	0.270	0.063	0.233	90.520	17.532	0.194	7.714	0.458	0.059
South Africa	403.960	84.765	0.210	64.728	20.391	0.315	6.822	2.471	0.362
Spain	273.207	64.849	0.237	75.583	18.589	0.246	8.750	4.319	0.494

(*continued on next page*)

Table A.2 (*continued*).

Sri Lanka	26.669	8.942	0.335	87.058	22.403	0.257	5.447	1.299	0.238
Sudan	34.149	14.076	0.412	78.928	20.342	0.258	−4.596	3.386	−0.737
Suriname	1.797	0.307	0.171	78.055	19.519	0.250	2.905	3.856	1.327
Sweden	103.798	7.215	0.070	70.883	18.192	0.257	10.000	0.000	0.000
Switzerland	48.196	3.078	0.064	80.988	17.405	0.215	10.000	0.000	0.000
Syria	35.479	17.698	0.499	51.839	24.719	0.477	−8.383	1.095	−0.131
Tajikistan	4.027	1.359	0.338	98.380	14.620	0.149	−3.040	1.457	−0.479
Tanzania	46.485	14.598	0.314	103.904	35.429	0.341	−3.043	3.007	−0.988
Thailand	221.336	130.070	0.588	84.395	25.138	0.298	3.511	4.837	1.377
Timor-Leste	1.561	0.501	0.321	80.528	18.762	0.233	7.250	0.775	0.107
Togo	4.164	2.018	0.485	106.041	39.242	0.370	−4.362	2.335	−0.535
Tonga	0.084	0.039	0.460	132.902	40.731	0.306			
Trinidad and Tobago	20.029	11.300	0.564	47.212	25.660	0.544	7.936	2.161	0.272
Tunisia	20.121	9.013	0.448	52.937	24.595	0.465	−4.295	4.623	−1.076
Turkey	240.611	102.445	0.426	76.196	18.610	0.244	5.851	4.438	0.758
Turkmenistan	54.727	16.009	0.293	72.619	25.082	0.345	−8.760	0.436	−0.050
Tuvalu	0.000	0.000	0.531	104.408	18.087	0.173			
Uganda	42.642	15.340	0.360	113.487	54.376	0.479	−3.222	3.268	−1.014
Ukraine	344.902	64.874	0.188	60.617	24.909	0.411	6.000	1.118	0.186
United Arab Emirates	98.146	59.809	0.609	48.362	25.521	0.528	−8.000	0.000	0.000
United Kingdom	567.640	60.833	0.107	53.612	23.704	0.442	9.872	0.494	0.050
United States	5659.170	454.078	0.080	70.628	17.289	0.245	9.787	0.623	0.064
Uruguay	10.792	4.914	0.455	91.730	23.158	0.252	5.370	7.689	1.432
Uzbekistan	114.752	10.878	0.095	82.060	19.883	0.242	−9.000	0.000	0.000
Vanuatu	0.162	0.060	0.371	114.501	25.529	0.223			
Venezuela	129.901	39.671	0.305	46.287	25.763	0.557	6.234	3.935	0.631
Vietnam	180.258	91.702	0.509	77.083	21.088	0.274	−7.000	0.000	0.000
Yemen	18.301	6.585	0.360	56.918	28.835	0.507	−1.524	1.504	−0.987
Zambia	19.010	7.260	0.382	55.943	25.779	0.461	−0.574	7.198	−12.530
Zimbabwe	39.901	5.940	0.149	83.274	21.316	0.256	−1.692	4.034	−2.384

Notes: SD is standard deviation and CV is coefficients of variation (standard deviation-to-mean ratio).

Table A.3
OLS without fixed effects estimates when accounting for contemporaneous commodity windfalls.

Dependent variable:	ΔCO_2 emissions per capita							
	(1) DEM	(2) AUT	(3) SER	(4) WER	(5) SEC	(6) WEC	(7) SPC	(8) WPC
ΔCommodity export price index$_t$	0.005	−0.015	0.009	−0.019	0.003	−0.011	0.013	−0.018
	(0.689)	(0.350)	(0.447)	(0.236)	(0.813)	(0.464)	(0.401)	(0.191)
ΔCommodity export price index$_{t-1}$	0.036[a]	0.023	0.031[a]	0.027	0.041[a]	0.020	0.041[a]	0.024
	(0.001)	(0.275)	(0.006)	(0.209)	(0.001)	(0.292)	(0.003)	(0.194)
Country fixed effects	No	No	No	No	No	No	No	No
R-squared	0.0424	0.0249	0.0475	0.0221	0.054	0.021	0.045	0.023
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 method is OLS without fixed effects. All models include year fixed effects. 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 A.4
OLS with fixed effects estimates when accounting for contemporaneous commodity windfalls.

Dependent variable:	ΔCO_2 emissions per capita							
	(1) DEM	(2) AUT	(3) SER	(4) WER	(5) SEC	(6) WEC	(7) SPC	(8) WPC
ΔCommodity export price index$_t$	0.004	−0.017	0.009	−0.021	0.003	−0.012	0.013	−0.021
	(0.718)	(0.263)	(0.469)	(0.168)	(0.849)	(0.375)	(0.416)	(0.128)
ΔCommodity export price index$_{t-1}$	0.036[a]	0.021	0.031[a]	0.024	0.041[a]	0.018	0.041[a]	0.022
	(0.001)	(0.328)	(0.007)	(0.255)	(0.002)	(0.340)	(0.004)	(0.236)
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.042	0.025	0.047	0.022	0.054	0.021	0.045	0.023
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 method is OLS with fixed effects. All models include year fixed effects. 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 A.5
Difference GMM estimates when accounting for contemporaneous commodity windfalls.

Dependent variable:	ΔCO_2 emissions per capita							
	(1) DEM	(2) AUT	(3) SER	(4) WER	(5) SEC	(6) WEC	(7) SPC	(8) WPC
ΔCommodity export price index$_t$	−0.006	−0.013	0.000	−0.019	−0.009	−0.010	0.002	−0.019
	(0.666)	(0.403)	(0.985)	(0.237)	(0.548)	(0.500)	(0.899)	(0.189)
ΔCommodity export price index$_{t-1}$	0.024[b]	0.021	0.021[b]	0.023	0.026[b]	0.019	0.027[b]	0.022
	(0.019)	(0.322)	(0.046)	(0.290)	(0.026)	(0.332)	(0.038)	(0.255)
Country 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	0.175	0.701	0.089	0.585	0.045	0.475	0.361	0.880
Hansen J p-value	0.137	1.000	0.347	0.962	0.721	0.974	0.961	0.862
Observations	3766	2740	3547	2959	3227	3279	3299	3207
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 difference GMM. All models include year fixed effects. 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 A.6
System GMM estimates when accounting for contemporaneous commodity windfalls.

Dependent variable:	ΔCO_2 emissions per capita							
	(1) DEM	(2) AUT	(3) SER	(4) WER	(5) SEC	(6) WEC	(7) SPC	(8) WPC
ΔCommodity export price index$_t$	0.003	−0.011	0.008	−0.016	−0.001	−0.007	0.011	−0.015
	(0.797)	(0.459)	(0.521)	(0.304)	(0.974)	(0.636)	(0.498)	(0.273)
ΔCommodity export price index$_{t-1}$	0.036[a]	0.026	0.031[a]	0.029	0.039[a]	0.024	0.040[a]	0.028
	(0.001)	(0.228)	(0.005)	(0.178)	(0.002)	(0.219)	(0.004)	(0.145)
Country 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	0.177	0.702	0.090	0.586	0.046	0.476	0.368	0.883
Hansen J p-value	0.966	1.000	0.999	1.000	1.000	0.998	1.000	0.996
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 method is system GMM. All models include year fixed effects. 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 A.7
Commodity windfalls, political regimes, and environmental quality-accounting for higher 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
ΔCommodity export price index$_{t-1}$	0.033[a]	0.024	0.029[a]	0.028	0.035[a]	0.022	0.035[a]	0.026
	(0.001)	(0.272)	(0.006)	(0.195)	(0.003)	(0.247)	(0.006)	(0.160)
CO_2 per capita$_{t-1}$	−0.023	0.028	−0.031	0.022	−0.037	0.032	−0.032	0.017
	(0.540)	(0.368)	(0.390)	(0.498)	(0.335)	(0.290)	(0.197)	(0.638)
CO_2 per capita$_{t-2}$	−0.054	−0.095[a]	−0.022	−0.114[a]	−0.033	−0.103[a]	−0.057	−0.096[a]
	(0.201)	(0.009)	(0.609)	(0.002)	(0.427)	(0.003)	(0.177)	(0.009)
Country 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	0.020	0.384	0.029	0.307	0.008	0.500	0.068	0.210
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. All models include year fixed effects. The base sample is a yearly panel of 179 countries, spanning the period 1970–2018. DEM (AUT) is democracy (autocracy) and comprises countries that have a strictly positive (negative) Polity score. SER: Strong Executive Recruitment (WER: Weak Executive Recruitment) comprises countries that have an above (below) mean score of executive recruitment in the sample. SEC: Strong Executive Constraints (WEC: Weak Executive Constraints) comprises countries that have an above (below) mean score of executive constraints in the sample. SPC: Strong Political Competition (WPC: Weak Political Competition) comprises 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 A.8
Alternative model specification I.

Dependent variable:	CO_2 emissions per capita							
	(1) DEM	(2) AUT	(3) SER	(4) WER	(5) SEC	(6) WEC	(7) SPC	(8) WPC
ΔCommodity export price index$_t$	−0.001	−0.011	0.004	−0.014	−0.008	−0.007	0.004	−0.012
	(0.942)	(0.494)	(0.731)	(0.370)	(0.577)	(0.650)	(0.798)	(0.364)
Country 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	0.222	0.698	0.096	0.550	0.056	0.480	0.407	0.825
Hansen J p-value	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Observations	3945	2864	3715	3094	3381	3428	3458	3351
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 log of CO_2 emissions per capita. The estimation method is system GMM. All models include year fixed effects. 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 countries that have an above (below) mean score of executive constraints in the sample. SPC: Strong Political Competition (WPC: Weak Political Competition) comprises 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 A.9
Alternative model specification II.

Dependent variable:	CO_2 emissions per capita							
	(1) DEM	(2) AUT	(3) SER	(4) WER	(5) SEC	(6) WEC	(7) SPC	(8) WPC
ΔCommodity export price index$_{t-1}$	0.033[a]	0.026	0.028[a]	0.029	0.033[a]	0.023	0.035[a]	0.027
	(0.002)	(0.244)	(0.008)	(0.185)	(0.005)	(0.247)	(0.009)	(0.155)
Country 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	0.169	0.711	0.084	0.597	0.041	0.491	0.363	0.879
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 log of CO_2 emissions per capita. All models include year fixed effects. The estimation method is system GMM. 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 countries that have an above (below) mean score of executive constraints in the sample. SPC: Strong Political Competition (WPC: Weak Political Competition) comprises 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 A.10
Alternative model specification III.

Dependent variable:	CO_2 emissions per capita							
	(1) DEM	(2) AUT	(3) SER	(4) WER	(5) SEC	(6) WEC	(7) SPC	(8) WPC
ΔCommodity export price index$_t$	0.000	−0.012	0.005	−0.015	−0.006	−0.008	0.005	−0.014
	(0.973)	(0.456)	(0.687)	(0.333)	(0.671)	(0.596)	(0.725)	(0.292)
ΔCommodity export price index$_{t-1}$	0.034[a]	0.026	0.029[a]	0.030	0.034[a]	0.023	0.036[a]	0.028
	(0.002)	(0.236)	(0.008)	(0.171)	(0.004)	(0.240)	(0.008)	(0.139)
Country 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	0.169	0.706	0.085	0.591	0.039	0.486	0.366	0.884
Hansen J p-value	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
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 log of CO_2 emissions per capita. All models include year fixed effects. The estimation method is system GMM. 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 countries that have an above (below) mean score of executive constraints in the sample. SPC: Strong Political Competition (WPC: Weak Political Competition) comprises 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 A.11
Sample split by time-varying Polity scores.

Dependent variable:	ΔCO_2 emissions per capita							
	(1) DEM	(2) AUT	(3) SER	(4) WER	(5) SEC	(6) WEC	(7) SPC	(8) WPC
ΔCommodity export price index$_{t-1}$	0.037[a]	0.026	0.032[b]	0.028	0.033[b]	0.031	0.038[a]	0.021
	(0.009)	(0.222)	(0.017)	(0.189)	(0.022)	(0.139)	(0.003)	(0.335)
Country 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	0.732	0.875	0.691	0.793	0.642	0.906	0.475	0.778
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 the first-differenced log of CO_2 emissions per capita. The estimation method is system GMM. All models include year fixed effects. 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 countries that have an above (below) mean score of executive constraints in the sample. SPC: Strong Political Competition (WPC: Weak Political Competition) comprises 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.

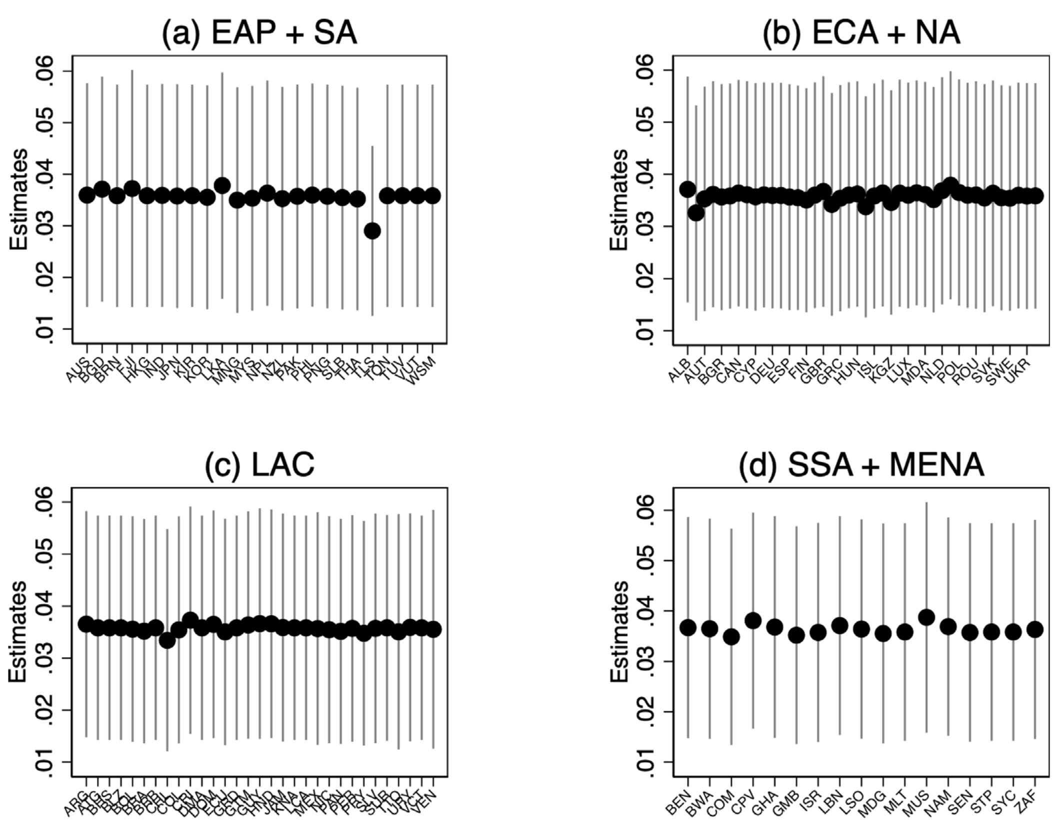

Fig. A.3. Commodity windfalls and environmental quality in democracies.
Notes: Each line corresponds to the coefficient of the baseline equation re-estimated without the named country. The spikes are confidence intervals at 95%. The procedure for classifying political regimes is explained in-text. The acronyms for the regions are expanded as follows: EAP - East Asia & the Pacific; EAC - Europe & Central Asia; LAC - Latin America & the Caribbean; MENA - Middle East & North Africa; NA - North America; SA - South Asia; and SSA - Sub-Saharan Africa. 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. The country names of the respective ISO 3166 country codes can be found at https://www.iso.org/standard/72482.html.

Table A.12
Interaction model.

Dependent variable:	ΔCO_2 emissions per capita				
	(1)	(2)	(3)	(4)	(5)
	Panel A. OLS without fixed effects				
ΔCommodity export price index$_{t-1}$	0.0418[b]	0.0415[b]	0.0421[b]	0.0391[b]	0.0371[c]
	(0.0175)	(0.0187)	(0.0128)	(0.0222)	(0.0679)
Deliberative Democracy$_t$	0.0098[b]				
	(0.0279)				
ΔCommodity export price index$_{t-1}$ ×Deliberative Democracy$_t$	−0.0440				
	(0.1142)				
Egalitarian Democracy$_t$		0.0133[a]			
		(0.0073)			
ΔCommodity export price index$_{t-1}$ ×Egalitarian Democracy$_t$		−0.0410			
		(0.1425)			
Liberal Democracy$_t$			0.0107[b]		
			(0.0150)		
ΔCommodity export price index$_{t-1}$ ×Liberal Democracy$_t$			−0.0410		
			(0.1051)		
Participatory Democracy$_t$				0.0104[c]	
				(0.0737)	
ΔCommodity export price index$_{t-1}$ ×Participatory Democracy$_t$				−0.0441	
				(0.2010)	
Electoral Democracy$_t$					0.0078[c]
					(0.0776)
ΔCommodity export price index$_{t-1}$ ×Electoral Democracy$_t$					−0.0198
					(0.5138)
CO_2 per capita$_{t-1}$	−0.0066[a]	−0.0071[a]	−0.0069[a]	−0.0064[a]	−0.0063[a]
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Country fixed effects	Yes	Yes	Yes	Yes	Yes
R-squared	0.0255	0.0257	0.0262	0.0251	0.0250
Observations	6978	6978	6949	6978	6978
Countries	166	166	166	166	166
	Panel B. OLS with fixed effects				
ΔCommodity export price index$_{t-1}$	0.0395[b]	0.0388[b]	0.0397[b]	0.0370[b]	0.0356[c]
	(0.0230)	(0.0257)	(0.0177)	(0.0286)	(0.0764)
Deliberative Democracy$_t$	0.0031				
	(0.7998)				
ΔCommodity export price index$_{t-1}$ ×Deliberative Democracy$_t$	−0.0441				
	(0.1087)				
Egalitarian Democracy$_t$		0.0072			
		(0.6821)			
ΔCommodity export price index$_{t-1}$ ×Egalitarian Democracy$_t$		−0.0401			
		(0.1422)			
Liberal Democracy$_t$			0.0012		
			(0.9257)		
ΔCommodity export price index$_{t-1}$ ×Liberal Democracy$_t$			−0.0413[c]		
			(0.0970)		
Participatory Democracy$_t$				0.0039	
				(0.8212)	
ΔCommodity export price index$_{t-1}$ ×Participatory Democracy$_t$				−0.0445	
				(0.1877)	
Electoral Democracy$_t$					0.0016
					(0.8830)
ΔCommodity export price index$_{t-1}$ ×Electoral Democracy$_t$					−0.0216
					(0.4661)
CO_2 per capita$_{t-1}$	−0.0645[a]	−0.0646[a]	−0.0643[a]	−0.0645[a]	−0.0645[a]
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Country fixed effects	Yes	Yes	Yes	Yes	Yes
R-squared	0.0075	0.0076	0.0079	0.0075	0.0074
Observations	6978	6978	6949	6978	6978
Countries	166	166	166	166	166
	Panel C. Difference GMM				
ΔCommodity export price index$_{t-1}$	0.0388[b]	0.0388[b]	0.0388[b]	0.0353[b]	0.0370[c]
	(0.0228)	(0.0223)	(0.0188)	(0.0348)	(0.0624)
Deliberative Democracy$_t$	0.0713				
	(0.1581)				
ΔCommodity export price index$_{t-1}$ ×Deliberative Democracy$_t$	−0.0524[c]				
	(0.0532)				
Egalitarian Democracy$_t$		0.1573[c]			
		(0.0773)			
ΔCommodity export price index$_{t-1}$ ×Egalitarian Democracy$_t$		−0.0508[c]			
		(0.0523)			
Liberal Democracy$_t$			0.0813		
			(0.1401)		

(*continued on next page*)

Table A.12 (*continued*).

Dependent variable:	ΔCO_2 emissions per capita				
ΔCommodity export price index$_{t-1}$ ×Liberal Democracy$_t$			−0.0497^{b}		
			(0.0427)		
Participatory Democracy$_t$				0.1569^{c}	
				(0.0600)	
ΔCommodity export price index$_{t-1}$ ×Participatory Democracy$_t$				−0.0536	
				(0.1075)	
Electoral Democracy$_t$					0.0670
					(0.1236)
ΔCommodity export price index$_{t-1}$ ×Electoral Democracy$_t$					−0.0325
					(0.2644)
CO_2 per capita$_{t-1}$	−0.1251^{a}	−0.1291^{a}	−0.1148^{a}	−0.1237^{a}	−0.1347^{a}
	(0.0006)	(0.0003)	(0.0013)	(0.0011)	(0.0003)
Country fixed effects	Yes	Yes	Yes	Yes	Yes
AR(1) p-value	0.0000	0.0000	0.0000	0.0000	0.0000
AR(2) p-value	0.5051	0.5072	0.5087	0.4982	0.5099
Observations	6811	6811	6782	6811	6811
Countries	166	166	166	166	166
	Panel D. System GMM				
ΔCommodity export price index$_{t-1}$	0.0443^{b}	0.0439^{b}	0.0441^{a}	0.0410^{b}	0.0410^{b}
	(0.0116)	(0.0122)	(0.0096)	(0.0167)	(0.0433)
Deliberative Democracy$_t$	0.0022				
	(0.9205)				
ΔCommodity export price index$_{t-1}$ ×Deliberative Democracy$_t$	−0.0513^{c}				
	(0.0645)				
Egalitarian Democracy$_t$		0.0269			
		(0.4597)			
ΔCommodity export price index$_{t-1}$ ×Egalitarian Democracy$_t$		−0.0492^{c}			
		(0.0709)			
Liberal Democracy$_t$			0.0067		
			(0.7696)		
ΔCommodity export price index$_{t-1}$ ×Liberal Democracy$_t$			−0.0481^{c}		
			(0.0577)		
Participatory Democracy$_t$				0.0169	
				(0.6006)	
ΔCommodity export price index$_{t-1}$ ×Participatory Democracy$_t$				−0.0516	
				(0.1340)	
Electoral Democracy$_t$					0.0083
					(0.6865)
ΔCommodity export price index$_{t-1}$ ×Electoral Democracy$_t$					−0.0297
					(0.3237)
CO_2 per capita$_{t-1}$	−0.0620^{c}	−0.0632^{c}	−0.0491	−0.0550^{c}	−0.0801^{b}
	(0.0503)	(0.0540)	(0.1172)	(0.0872)	(0.0178)
Country fixed effects	Yes	Yes	Yes	Yes	Yes
AR(1) p-value	0.0000	0.0000	0.0000	0.0000	0.0000
AR(2) p-value	0.5171	0.5202	0.5166	0.5178	0.5204
Observations	6978	6978	6949	6978	6978
Countries	166	166	166	166	166

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 OLS without fixed effects in panel A, OLS with fixed effects in panel B, difference GMM in panel C, and system GMM in panel D. All models include year fixed effects. The base sample is a yearly panel of 179 countries, spanning the period 1970-2018. The five conceptions of democracy are from the Varieties of Democracy (V-Dem) database (Coppedge et al., 2011) and are defined as follows: (1) Deliberative democracy focuses on the process by which decisions are reached in a polity. A deliberative process is one in which public reasoning focused on the common good motivates political decisions–as contrasted with emotional appeals, solidary attachments, parochial interests, or coercion. (2) Egalitarian democracy addresses the goal of political equality. An egalitarian polity is one that achieves equal participation, equal representation, equal protection, equal resources, and in which citizens enjoy equal access to political power. (3) Liberal democracy stresses the intrinsic importance of transparency, civil liberty, rule of law, horizontal accountability (effective checks on rulers), and minority rights against the tyranny of the state and/or the majority. (4) Participatory democracy underscores the relevance of active participation of by citizens in all political processes, electoral and non-electoral. (5) Electoral democracy is the idea that democracy is achieved through competition among leadership groups, which vie for the electorates approval during periodic elections before a broad electorate. Parties and elections are the crucial instruments in this largely procedural account of the democratic process. Standard errors are heteroscedasticity-robust and are clustered at the country level. Values in parentheses are *p*-values.

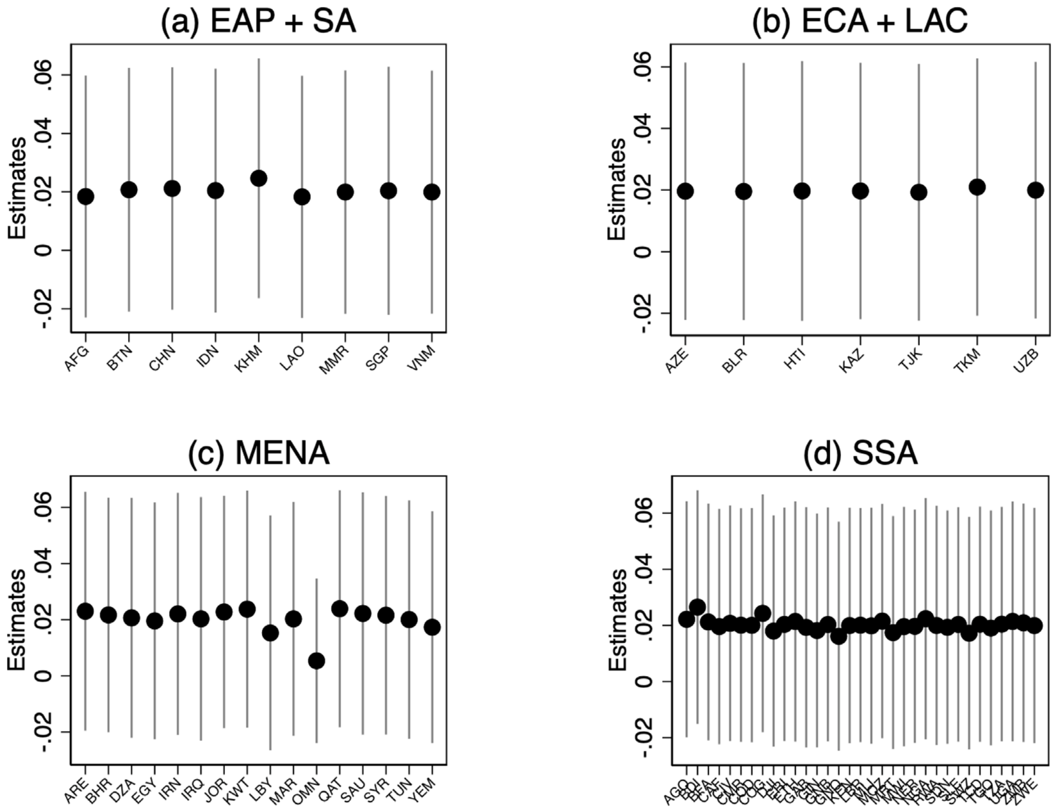

Fig. A.4. Commodity windfalls and environmental quality in autocracies.
Notes: Each line corresponds to the coefficient of the baseline equation re-estimated without the named country. The spikes are confidence intervals at 95%. The procedure for classifying political regimes is explained in-text. The acronyms for the regions are expanded as follows: EAP - East Asia & the Pacific; EAC - Europe & Central Asia; LAC - Latin America & the Caribbean; MENA - Middle East & North Africa; NA - North America; SA - South Asia; and SSA - Sub-Saharan Africa. 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. The country names of the respective ISO 3166 country codes can be found at https://www.iso.org/standard/72482.html.

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