**Supplementary materials**

**Appendix A**

**Table 6**

Summary of Empirical Literature Examining Democracy and Climate Change Relations

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Author(s)** | Geographic/  temporal coverage | DV/IV | Controls | Empirical model |
| *Positive Findings between Democracy and Climate Change* | | | | |
| Farzanegan & Markwardt (2018) | 17 MENA countries/ 1980 - 2005 | DV | GDP per capita  Trade Openness  Urbanization  Population density | OLS  Panel data analysis  GMM |
| Sulfur dioxide (SO2) per capita  Carbon dioxide (CO2) per capita |
| IV | *Statistical significance* |
| Polity2  Vanhanen democracy index  Civil liberty score of Freedom House Data | Yes |
| Mayer (2017b) | 55 Countries/1988-2011 | DV | logged population (100,000)  Military Expenditure (% of GDP)  Agricultural Employment (% of total)  Exports (% of GDP)  Natural Resource Rents (% of GDP)  log GNI per capita  log GNI per capita squared  Urban Population (% of total)  Electricity Production (% of total)  Capital formation (% of GDP)  Fossil fuel energy consumption (% of total) | Random intercept and random coefficient generalized linear models (GLM) |
| Total carbon  dioxide emissions in a country (measured in metric tons) |
| IV | *Statistical significance* |
| Levels of democratization (Polity IV) | Mixed with different treatment |
| Obydenkova & Salahodjaev (2017) | 94 countries | DV | GDP per capita at PPP (log)  CO2 emissions per capita  Trade as % of GDP | Cross-sectional OLS with robust & WLS |
| (1) Climate Laws, Institutions and Measures (CLIM) Index  (2) Cognitive skills at a national level |
| IV | *Statistical significance* |
| Democracy Index (Freedom House) | Yes |
| Adams, Adom & Klobodu (2016) | Ghana/1965-2011 | DV | Population as a percent  of total population  Income - GDP per capita (constant 2005 US$)  Trade openness- Ratio of sum of imports and exports to GDP  Urbanization  Regime durability | Cointegration test and the Fully Modified Phillip-Hansen (FMPH)  Technique |
| CO2 emissions (CO2) - CO2 emissions (kilogram per  2005US$ of GDP) |
| IV | *Statistical significance* |
| Regime type  (polity2) | Yes |
| Bernauer and Koubi (2008) | 107 cities of 42 countries/1971-1996 | DV | Income (lagged real GDP per capita)  Degree of trade openness  Topographical and climatic conditions  Topographical conditions  Climate (temperature, precipitation)  Time trend (year) | Fixed and random effects estimations |
| Sulfur dioxide (SO2) |
| IV | *Statistical significance* |
| Level of democracy (Wover’s)  Labor union  Strength Green party shares in national parliaments  Civil liberties  Parl-Pres (Bueno de Mesquita et al) - Presidential vs. Parliamentary | Yes |
| Fredriksson & Wollscheid (2007) | 163 countries/ 1990s | DV | *Treatment Variable*  Democracy  Democratic -Parliamentary  Presidential-Congressional  Majoritarian  Proportional  Investiture | Propensity score matching |
| ESI (Environmental Sustainability Index)  Institutional capacity Environmental governance  Global Stewardship  International Participation Greenhouse Gases |
| IV | *Statistical significance* |
| GDP/capita  Trade Openness  Age  Age 65+  Pop Density  Independence  Muslim  Africa  East Asia  Latin America  UK  Colony  French Colony  Cropland  Forest  Roads paved  Urbanization | Mixed |
| Farzin & Bond (2006) | 45 Countries/  1972-1994 | DV | Population density  (00,000 persons/sq. km)  Urban population  Gini Index, 0 (equal), -100 (unequal)  Youth population (14 yrs or under)  Illiteracy rate  Year | Fixed effect model |
| CO2 emissions (Kg per capita)  Nitrogen oxides (NOx) (‘000 metric tons per million persons  Non-methane volatile organic compounds (VOC) (‘000 metric  tons per million persons)  Sulfur dioxide (SO2) (‘000 metric tons per million persons)  GEMSSO2 (Ambient concentration, parts per million |
| IV | *Statistical significance* |
| Polity index (Polity IV) - 0 (autocratic), -20 (democratic) | Yes |
| Winslow (2005) | 107 cities from 46 countries/  1971-1992 | DV | - | Multiple regression |
| Sulfur dioxide (SO2)  Suspended particulate matter (SPM)  Smoke |
| IV | *Statistical significance* |
| Democracy (Freedom House and Polity III) | Yes |
| Neumayer (2002) | Various | DV | lnGDP  lnPOP  POPdens | OLS regression |
| Sum of MEAs  Number of EIOs  % of CITES requirements met  % land area under protection  Number of ESI variables available |
| IV | *Statistical significance* |
| FREE (Freedom House)  POLIT (Polity variable)  GOV (Governance variable)  VAN (Vanhanen variable) | Yes |
| Barrett & Graddy (2000) | Various | DV | Income  Time and physical features of pollution sites  Coast  Desert  Central city  Industrial  Residential  Population density | Generalized least squares with random effect &  Fixed effect |
| Air quality (sulfur dioxide, smoke, heavy particles)  Water quality (dissolved oxygen, Biological oxygen demand, Chemical oxygen demand, nitrates, Fecal coliforms, Total coliforms, lead, Arsenic, cadmium, lead, mercury, nickel |
| IV | *Statistical significance* |
| Civil and political freedoms – Freedom House data | Mixed |
| Congleton (1992) | Various, some samples are drawn from 46 countries and some from 118 countries | DV | GNP per capita  Coal reserve  Oil reserve  Gas reserve  Area  Population | Logit model  OLS  Two-stage least squares |
| CFCs |
| IV | *Statistical significance* |
| Democratic country  Capitalist country | Yes |
| *Negative Findings between Democracy and Climate Change* | | | | |
| Mao (2018) | 1/1999-2010 | DV | Quality of government  Political stability  Log (GDP per capita)  Log (GDP per capita) squared  Industrial structure  Trade openness  Fossil Fuel energy consumption  Energy intensity  Urbanization  Log (total population)  Education | Synthetic control method |
| CO2 emissions per capita (ln) |
| IV | *Statistical significance* |
| Democracy (electoral democracy index) from V-Dem | Yes |
| Mayer (2017a) | 138 Countries/1990-2008 | DV | Military expenditures (% of GDP)  Exports (% of GDP)  Renewable energy consumption  (% Total)  GDP per capita (log)  GDP per capita squared (log)  Urban population (% total)  Life expectancy at birth (in years) | Multilevel generalized linear model (GLM) |
| Ratio of energy use per capita (measured as a kilogram of oil equivalent) |
| IV | *Statistical significance* |
| Elected executive  Elected legislature  Political competition  Full democracy | No |
| Midlarsky (1998) | 108 Countries/  1981-1990 | DV | Agricultural density  Population growth  GDP per capita  Log Age  Deaths per capita  European Location  Precipitation | Multivariate OLS regression |
| Deforestation  Carbon dioxide emissions  Soil erosion by water  Protected land  Freshwater availability  Soil erosion by chemicals | *Statistical significance* |
| Mixed |
| IV |
| Democracy (Polity III) |
| Clulow (2018) | 147/1990-2012 | DV | Per capita GDP  Level of export diversification in the national economy  Percentage of GDP dependent on fossil fuel income  Annual proportion of renewable energy consumption as a percentage of total energy consumption  National population level in a given year  The ratio of change in CO2 emissions to change in GDP | Multivariate OLS  Regression, Random intercept model (RIM), Random coefficient model (RCM) |
| Emissions level (Annual CO2 emissions in a given country in MtCO2e) |
| IV | *Statistical significance* |
| Level of democracy  (Freedom House) | Yes |
| Povitkina  (2018) | 144 Countries/1970–2011 | DV | Real GDP per capita in constant 2005 prices  Population density  Urban population  Merchandise exports in PPP  Oil production per capita  Latitude  Kyoto ratification  Island dummy | Time-series cross-sectional |
| CO2 emissions per capita (ln) |
| IV | *Statistical significance* |
| Democracy (electoral democracy index) from V-Dem | Yes |
| Adom, Kwakw, Amankwaa (2018) | Ghana, 1970 - 2014 | DV | Real gross domestic product per capita  Population (total number of population)  Population density  Rate of urbanization (URB) | Stock-Watson dynamic OLS (DOLS)  Covariance (Bartlett Kernel, Newey-West Fixed bandwidth) & Newey-West robust standard errors. Optimal lead and lags selected based on Akaike Information Criterion (AIC) |
| Actual CO2  Potential CO2 |
| IV | *Statistical significance* |
| Price of electricity  Real price of crude oil  Political regime (POLITY2)  Financial development | Mixed |
| Gaarder & Vadlamannati (2017) | 139 Countries/1990-2012 | DV | Per capita GDP (log)  Population (log)  Trade openness  NGOs (log)  Mineral rents/GDP Rents  Rule of law | OLS regression |
| Forest coverage |
| IV | *Statistical significance* |
| Democracy dummy  Autocracy dummy | Yes |
| Lv (2017) | 19 Countries/1997-2010 | DV | Real per capita GDP (ln)  Total population (ln)  Trade openness Industrialization Urbanization | Quantile regression |
| LnCO2 |
| IV | *Statistical significance* |
| Democracy (Freedom House) | Mixed |
| You et al. (2015) | 1985-2005 | DV | GDP - GDP per capita (constant 2005 US$)  POP - Population size  Trade - Ratio of imports plus exports to GDP  Indux - The share of industry in GDP  Kaopen - Financial openness measuring the extent of openness in capital account transactions | Quantile regression methods |
| CO2 - Carbon dioxide emissions (metric tons per capita) |
| IV | *Statistical significance* |
| Polity2 - The difference between the sub-indexes for democracy and autocracy  Freedom - Sum of the Freedom House Political Rights and Civil Liberties Indices | Yes |
| Buitenzorgy and Mol (2011) | 177 Countries/1990-2000 | DV | Education  Rural population  Land area (ln)  Control of corruption  Income (PPP)  Income-sq | OLS regression |
| Rate of deforestation (average annual rate of change in forest cover in the studied period) |
| IV | *Statistical significance* |
| Level of democracy (Polity index)  Democracy-sq | Yes |
| Arvin and Lew (2011) | 141 developing countries/1976-2003 | DV | Per capita GDP (ln)  Per capita GDP-sq  Percentage of Urban population  Growth rate  Population density | Generalized Least  Squares (GLS) with a country and year fixed effect |
| CO2 emissions  Water pollution emissions  Deforestation damage |
| IV | *Statistical significance* |
| Democracy (Freedom House) | Mixed |
| Li and Reuveny (2006) | CO2/  143/1961-1997 | DV | Trade openness  Conflict (dummy)  Real GDP per capita  Real GDP per capita squared  Population density (population divided by land area)  Lagged 1 year | Cross-sectional time Series (pooled) analyses |
| NOx/118/1990 |
| Water pollutants/  112/1980-1998 | Per capita CO2 emissions  logged NOx emissions per capita  Organic water Pollutants Per km3 Annual deforestation rate  Forest area share of land area  Degraded area share of land area |
| Deforestation/ 134/1980s, 1990s | *Statistical significance* |
| Forest areas/134/1980, 1990, and 2000 | IV | Mixed |
| Degradation/  105/1980s | Level of democracy (Polity IV) |

**Appendix Table A.x**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Variable | Observation | Mean | Standard Deviation | Minimum | Maximum |
| Independent variables |  |  |  |  |  |
| V-Dem’s Electoral Democracy | 3,661 | 0.549 | 0.264 | 0.014 | 0.948 |
| Polity2 | 1,482 | 4.424 | 6.444 | -10 | 10 |
| Freedom House’s democracy | 1,676 | 9.791 | 3.843 | 2 | 14 |
| Economist Intelligence Unit (EIU) | 1,457 | 57.134 | 21.900 | 12.6 | 99.3 |
| Bertelsmann’s Transformation Index (BTI) | 1,664 | 5.959 | 2.0224 | 1.65 | 9.95 |

Notes: This table reports unbalanced descriptive statistics for the six democracy indices prior to harmonizing with controls or balancing the panel. Observation counts differ because temporal and country coverage vary across indices (e.g., EIU and BTI begin in 2006; the BTI total of 1,664 reflects ≈128 countries over 13 years). Scales are not comparable in levels: V-Dem ranges 0–1; Polity2 –10–10; Freedom House 2-14; EIU 0-100; BTI 1-10. In the main analyses, each index is estimated on its native scale; comparisons emphasize sign and statistical significance, not coefficient magnitude. Balanced-panel descriptives for the analytic samples appear in Table 3 and in the robustness appendix as referenced in the Methods.

**Appendix B**

*List of Countries/Territories Dropped from the Dataset (38 Countries/Territories)*

Turk Cyprus, Aruba, Andorra, American Samoa, Antigua and Barbuda, Bavaria, Bahamas, Brunei, Cuba, Djibouti, Fiji, Prussia, Grenada, Ivory Coast, Kosovo, Laos, Monaco, Modena, Marshall Islands, Nauru, Orange Free State, Palau, Papal States, Parma, Sardinia, Saxony, Saint Kitts and Nevis, Saint Lucia, San Marino, Somalia, Saint Vincent & Grenadines, Swaziland, Syria, Taiwan, Trinidad and Tobago, Tuscany, Wuerttemburg, Yemen

Note: The geographical coverage of the dataset was kept as wide as possible to reduce the risk of concluding correlations that are caused by country-specific regional attributes rather than the attributes of political institutions. The primary criterion for dropping a country from the data was missing observations for two or more independent variables across the temporal coverage in the study. A total of 38 countries/territories are dropped out of the dataset.

**Appendix C**

|  |  |  |
| --- | --- | --- |
| *Table I: Definition of Democracy Variables* | | |
| Variable | **Definition** | **Source** |
| Electoral Democracy Index (v2x\_polyarchy) | V-Dem’s electoral democracy index is comprised of a host of attributes that typically embody a regime which can be characterized as democratic. They include the capacity to make rules for citizens achieved through electoral competition with universal suffrage, freedom of political and civil society organizations, free and unbiased elections, freedom of expression and an independent media which can run unbiased and without intervention between the two elections. The index is configured by taking average of, on the one hand, the weighted average of the indices measuring freedom of association, clean elections, freedom of expression, elected officials, and suffrage and, on the other, the five-way multiplicative interaction between those indices. The V-Dem’s codebook further mentions that the aggregation of this electoral democracy is based on the level of Dahl’s subcomponents with the one exception of the non-electoral component. This is an interval level variable ranges from low to high (0-1) (Coppedge, Carl Henrik and Lindberg, & osefine and von Römer, 2019). | Varieties of Democracy (V-Dem) |
| Polity2 Score | The policy2 score is a combined polity score of democracy (democ) and autocracy (autoc) as measured in Polity IV Project by Center for Systemic Peace. The score is computed by subtracting the autoc score from the democ score. This is a revised score of original polity measure where some fixes are introduced in this version of polity2. The polity2 scale ranges from +10 (strongly democratic) to -10 (strongly autocratic).  However, their conceptualization of democracy is based on three elements as mentioned in the codebook; (1) the existence of institutions and procedures by which citizens can express effective preferences about alternative policies and leaders, (2) the presence of established restrictions on the exercise of power by the executive, (3) the guarantee of civil liberties and of political participation to all citizens. The Polity IV project considers that the some other features of plural democracy such as the rule of law, systems of checks and balances, freedom of the press are all inclusive of these three general principles (Marshall, 2019)[[1]](#footnote-1). | The Polity IV Project |
| Democracy as a composite score of civil liberties and political rights | The Freedom House data assigns two ratings to a country or territory – one for political rights and one for civil liberties based on its total scores for the political rights and civil liberties questions. They are measured on a one-to-seven scale, with one representing the highest degree of Freedom and seven the lowest[[2]](#footnote-2).  For the statistical purpose of the research, the present study recoded both of the variables following an inverse direction with one representing the lowest and seven the highest. Both of the recoded civil liberties and political rights variables then summed up and then divided by two to extract a mean composite score for the empirical analysis of the study.  According to Freedom House methodology, an electoral democracy designation requires a score of 7 or better in the electoral process subcategory, an overall political rights score of 20 or better, and also an overall civil liberties score of 30 or better. The methodology further mentions that Freedom House’s designation to an “electoral democracy” should not be equated with “liberal democracy,” a term that implies a more vigorous compliance of democratic ideals and a wider range of civil liberties (Freedom House, 2018). | Freedom House Data (a Stata version of Freedom House Time-Series data, 1973-2018 is taken from Amanda B. Edgell, V-Dem Institute, University of Gothenburg from the website: https://acrowinghen.com/data/) |
| Democracy Index, the Economist Intelligence Unit (EIU) | The Economist Intelligence Unit’s Democracy Index covers 167 countries in the world based on 60 indicators. Their model of democracy is based on five criteria. They are (1) electoral process and pluralism, (2) functioning of government, (3) political participation, (4) democratic political culture, and (5) civil liberties. However, the index is created on a scale of 0 to 10. These scores represent four categories of democracy. They are authoritarian regime (below 4), hybrid regime (4-5.9), flawed democracy (6-7.9), and full democracy (8-10) (Economist Intelligence Unit (EIU), 2018).  Data of Democracy Index is extracted from Gapminder which converted the range of values from 0 to 100 to make it easier to communicate (Economist Intelligence Unit (EIU), 2018). | The Economist Intelligence Unit. Gapminder data is available at (https://docs.google.com/spreadsheets/d/1d0noZrwAWxNBTDSfDgG06\_aLGWUz4R6fgDhRaUZbDzE/edit#gid=501532268) |
| Democracy Status Index, Bertelsmann’s Transformation Index (BTI) | Bertelsmann’s Transformation Index provides a Democracy Status index based on the five following criteria, (1) stateness, (2) political participation, (3) rule of law, (4) stability of democratic institutions, (5) political and social integration. These five criteria are further categorized into several indicators each scaled in a scale of 1 to 10 derived from assessments made in response to 18 questions which in aggregate provide the democracy status scores. Finally, the Democracy Status index ranks the countries according to the state of their democracy (Stiftung, 2018). | Bertelsmann’s Transformation Index (BTI), Available at (https://www.bti-project.org/en/data/) |

**Appendix D**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| *Table II: Robustness check with other controls on CO2 emission per capita for Political Regimes* | | | | |
| Variables | Pooled Cross-sectional OLS  With robust | Random effects,  GLS | Panel-corrected standard errors | Random-effects GLS with Driscoll-Kraay standard errors |
| Democracy | -3.620\*\*\*  (0.368) | 0.332  (0.394) | -0.612\*\*  (0.214) | .332  (0.357) |
| LnGDP per capita | 3.598\*\*\*  (0.088) | 2.010\*\*\*  (0.326) | 2.910\*\*\*  (0.137) | 3.626\*\*\*  (0.077) |
| Trade  (% of GDP) | -0.000  (0.002) | -0.003  (0.003) | 0.001  (0.001) | 0.001  (0.002) |
| Population | - | - | - | - |
| Urbanization (% of total population) | - | - | - | - |
| Renewable energy cons | - | - | - | - |
| Forest (% of land area) | - | - | - | - |
| Annex I | - | - | - | - |
| Island dummy | - | - | - | - |
| Latitude | - | - | - | - |
| Constant | -25.942\*\*\*  (0.583) | -13.466\*\*\*  (2.573) | -20.990\*\*\*  (1.146) | -26.567\*\*\*  (0.462) |
| R2 | 0.607 |  | 0.293 | 0.612 |
| sigma\_u | - | 3.0123 | - | - |
| sigma\_e | - | .91336 | - | - |
| Observations | 3,663 | 3,663 | 3,663 | 3,663 |
| Year FE | No | Yes | Yes | Yes |
| #Country | - | 160 | 160 | 160 |

Note: ^Significant at 10% (p<0.1) \*Significant at 5% (p < 0.05). \*\*Significant at 1% (p < 0.01). \*\*\* Significant at 0.01% (p < 0.001). Robust standard errors in parentheses.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| *Table III: Random Effect Within-Between Estimation for the Relationship between CO2 per capita and Political Regimes (other controls included)* | | | | | | | |
|  | Null | | FE | | RE | | REWB |
| Within-part | | | | | | | |
| Constant | 4.313\*\*\*  0.409 | | - | | 4.941\*\*\*  0.952 | | 1.561  1.742 |
| Democracy | - | | 0.257  0.252 | | 0.337  0.251 | | 0.367^  0.201 |
| LnGDP per capita | - | | 1.517\*\*\*  -0.124 | | 1.680\*\*\*  -0.119 | | 1.680\*\*\*  -0.1 |
| Trade  (% of GDP) | - | | -0.002^  -0.001 | | -0.002  -0.001 | | -0.004\*\*\*  -0.001 |
| Population | - | | - | | - | | - |
| Urbanization  (% of total population) | - | | - | | - | | - |
| Renewable energy cons | - | | - | | - | | - |
| Forest (% of land area) | - | | - | | - | | - |
| Annex I | - | | - | | - | | - |
| Island dummy | - | - | | - | | - | |
| Latitude | - | - | | - | | - | |
| Between-part | | | | | | | |
| Democracy | - | - | | - | | -2.389  1.562 | |
| LnGDP per capita | - | - | | - | | 3.506\*\*\*  -0.251 | |
| Trade  (% of GDP) | - | - | | - | | 0.005  -0.007 | |
| Population | - | - | | - | | - | |
| Urbanization  (% of total population) | - | - | | - | | - | |
| Renewable energy cons | - | - | | - | | - | |
| Forest (% of land area) | - | - | | - | | - | |
| Annex I | - | - | | - | | - | |
| Island dummy | - | - | | - | | - | |
| Latitude | - | - | | - | | - | |
| Level 2: Country |  | | | | | | |
| sigma\_u | - | 22142.61 | | - | | - | |
| Level 1: Year |  | | | | | | |
| sigma\_e | - | - | | - | | - | |
| Observations | 3,663 | 1,540 | | 1,540 | | 3,663 | |
| R2 | - | 0.164 | | - | | - | |
| #countries | 160 | 67 | | 67 | | 160 | |
| Year FE | No | Yes | | Yes | | Yes | |

Note: ^Significant at 10% (p<0.1) \*Significant at 5% (p < 0.05). \*\*Significant at 1% (p < 0.01). \*\*\* Significant at 0.01% (p < 0.001). Robust standard errors in parentheses.

**Appendix E**

*Regression results (including Qatar) with and without ‘robust’*

1. For details of coding, refer to Polity IV Project: Dataset Users’ Manual v2018, pp.14-15. [↑](#footnote-ref-1)
2. For a detail explanation of the ratings and status characteristics of ‘civil liberties’ and ‘political rights’ variables, please refer to the website: https://freedomhouse.org/report/methodology-freedom-world-2019 [↑](#footnote-ref-2)