Phasing Out Fossil Fuels: Determinants of Production Cuts and Implications for an International Agreement

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Abstract

Fossil fuel producers have a major role to play in curbing greenhouse gas emissions through supply-side initiatives. Yet, no study has systematically assessed the determinants of efforts to constrain fossil fuel production for climate purposes. To contribute to climate change mitigation efforts, this article develops a conceptual framework for factors potentially affecting country-level initiatives to keep fossil fuels in the ground. Using data for 124 countries with fossil fuel reserves for 2006–2019 and multivariate Poisson regression analysis, we identify factors influencing the use of such constraints by national governments. Results show that although dependence on fossil fuel rents reduces the likelihood of constraint measures, the size of fossil fuel reserves or production does not impact it. Richer countries are also more likely to use constraints. Organization of Petroleum Exporting Countries membership constitutes a barrier to having moratoria on fossil fuel extraction. These results can help identify potential members for new fossil fuel supply-side initiatives and coalitions.

There is a growing movement to add supply-side approaches to current demand-side efforts to reduce emissions from fossil fuels. This study is the first one to conceptually frame and statistically test for the determinants of supply cuts initiatives taken by countries with fossil fuel reserves since the Kyoto Protocol entered into force in 2005. Identifying these determinants can help us better understand which countries may be more likely to use fossil production constraint measures and join an international agreement to leave fossil fuels in the ground. Building on the Fossil Fuel Cuts Database (FFCD), the first global database of supply-side-focused constraint initiatives (Gaulin and Le Billon 2020; also see fossilfuelcuts.org), our study shows that several factors have a statistically discernible effect on the presence of constraints put in place by national governments.

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Supply-side initiatives targeting fossil fuel production can be defined as measures seeking to "constrain … the production, transportation or transformation of [fossil fuels], either voluntarily or coercively, so that supply is reduced for consumers" (Le Billon and Kristoffersen 2020, 173). Supply-side constraints are increasingly seen as a necessary complement to demand-side measures, notably to reduce investments into fossil fuel production and their market availability (Bauer et al. 2018; Erickson et al. 2018; Lazarus and van Asselt 2018; Sinn 2012). As Collier and Venables (2014) suggest, supply-side approaches have the advantage of focusing on a sector with a relatively limited number of actors (producing countries, especially exporters, and companies) and existing coordination mechanisms (e.g., Organization of Petroleum Exporting Countries [OPEC]) (see also Green and Denniss 2018).

Whereas constraints on production may seem counterproductive for fossil fuel producers, incentives potentially include less volatile revenues, reduced exposure to "resource curse" effects, and lower climate change impacts (Asheim et al. 2019). A "just transition," including producer revenue compensation and redistribution schemes, can also preemptively address some concerns related to potential revenue and employment loss arising from a future "green transition" reducing demand for fossil fuels (Kartha et al. 2018; Le Billon et al. 2021). Supply constraints may also be used in countries in which governments and/or populations may desire and sustain proactive climate change mitigation steps, especially if they are relatively wealthy, but which would face limited costs from forgoing future fossil fuel revenues and which are already pivoting their energy production sector away from fossil fuels.

Growing efforts are now promoting the use of institutional mechanisms to leave fossil fuels underground, or LFFU (Pellegrini et al. 2021; Rempel and Gupta 2022), notably to mobilize fossil fuel producers for climate change mitigation and address concerns over free riders that would benefit from higher prices without reducing their own production (Asheim et al. 2019; Hagem and Storrøsten 2019). Besides fossil divestment initiatives, school strikes, climate marches, and direct action, a call for a Fossil Fuel Non-Proliferation Treaty has been endorsed by a growing number of individuals, organizations, Nobel Prize winners, and subnational governments to put an end to new exploration and production, phase out existing production, and ensure a just transition for fossil fuel–dependent workers, communities, and producing countries (Newell and Simms 2020; van Asselt and Newell 2022).[1]

In the face of the climate emergency, and for the first time in its history, the United Nations Framework Convention on Climate Change (UNFCCC) Conference of Parties (COP) in 2021 officially discussed a phaseout of fossil

1. Fossil Fuel Non-Proliferation Treaty, https://fossilfueltreaty.org/, last accessed September 19, 2022.

fuel production.[2] Launched during the COP26 meeting in Glasgow by Denmark and Costa Rica, the Beyond Oil and Gas Alliance (BOGA) offers governments an institutional process to signal a commitment to phase out fossil fuel production.[3] Conscious of the challenges of taking on such radical decision, BOGA offers three levels of membership, with only "core" members—at this time, Costa Rica, Denmark, France, Greenland, Ireland, Quebec, Sweden, and Wales—committing to a production phaseout with a legislated end date for existing production, while "associate" members—California, New Zealand, and Portugal—and "friends," including Italy, Finland, and Luxembourg, can make looser commitments.

The COP26 also saw a number of governments pledging to end public subsidies for overseas fossil fuel projects. Led by the United Kingdom, the overseas subsidies initiative brings together twenty-seven countries and five development banks committing to "end new direct public support for the international unabated fossil fuel energy sector by the end of 2022" (UKCOP26 2021). The signatories also commit toward persuading other governments and multilateral development banks to do the same, in anticipation of COP27. The climate movement has also become more organized around institutionalized means of stopping fossil fuel production.

So far, studies have documented many supply-side constraint initiatives (Gaulin and Le Billon 2020; Piggot et al. 2020), but no study has yet statistically tested for their determinants. The literature on the resource curse and on supply-side measures to mitigate climate change points to a number of factors that may influence the use of constraints on fossil fuel supply by governments. This study identifies potential determinants of supply-side initiatives through a conceptual discussion of factors likely to influence constraint use by governments and conducts a statistical analysis of actual constraint initiatives to test them using a panel data set (2006–2019) for 124 countries with oil, natural gas, or coal reserves. The results provide some tentative conclusions and suggestions for further research to better understand factors influencing supply-side measure use and bring together a supply-side coalition for a managed decline in fossil fuel production.

Supply-Side Measures: A Conceptual Framework

Measures that constrain fossil fuel supplies can accelerate a transition out of fossil fuel dependence through their direct impacts on production and producers

2. The outcome of these discussions was encouraging, yet underwhelming, as the Glasgow Climate Pact only "calls upon parties to accelerate … efforts towards the phase-down of unabated coal power and inefficient fossil fuel subsidies, recognizing the need for support towards a just transition." For a discussion of environmental regulatory changes, and the ability of governments to sustain environmentally progressive regulations, see Knill et al. (2012).
3. Beyond Oil and Gas Alliance, https://beyondoilandgasalliance.com/, last accessed September 19, 2022.

(Asheim et al. 2019). Compared to market-driven pressure through demand-side initiatives, supply-side measures offer more directed and intentional options to curtail fossil fuel–related emissions and can help producers navigate a transition away from fossil fuel production dependence (Le Billon and Kristoffersen 2020; Piggot et al. 2019). Research on fossil fuel sector constraints as well as literature on the resource curse point to several factors that can potentially influence the government support for supply-side constraints.

A core set of factors found in the literature is that democratic countries with high public concern over climate change and low dependence on fossil fuel revenues are those most likely to use supply-side constraints, often as a result of government decisions and/or demands from civil society movements (Dryzek and Niemeyer 2019; Hanusch 2017; Lewis et al. 2019; Peterson 2021). In contrast, countries dependent on revenues from the production of fossil fuels, especially under authoritarian regimes, are not expected to use such supply-side measures, as these would likely translate into financial losses and political turmoil for governments (Bridge and Le Billon 2017; Girod et al. 2018; Smith 2017). Governments may also be likely to use supply-side constraints if their countries are more vulnerable to negative climate change impacts (Demski et al. 2017; Gagliarducci et al. 2019). In this article, we examine specific rationales and associated hypotheses with regard to the characteristics of each country for four main types of factors: fossil fuel (e.g., reserves), economic (e.g., income level), institutional (e.g., regime type), and climate change (e.g., vulnerability to consequences of climate change) (see the summary in Table 1). We also briefly outline within the Discussion section other factors for consideration in further research.

Fossil Fuel Factors

Large fossil fuel reserves and production are often seen as reducing the likelihood of a government using climate-motivated supply-cut measures (Carter and McKenzie 2020; Gaulin and Le Billon 2020). Relatedly, a high level of dependence on fossil fuel revenues from production and/or exports—a situation characterizing "petro-states"—is generally considered a disincentive for production cuts due to concerns over losses in revenue, jobs, and market share as well as broader social and (geo)political effects given the multifaceted domestic and international dimensions of fossil fuel production (e.g., Dietz et al. 2020; Skjærseth and Skodvin 2001).[4] Membership in the Organization of Petroleum Exporting Countries (OPEC) is expected to have a negative effect on the use of constraint initiatives given the organization's pattern of resistance

4. We note in this regard that there can be tensions between subnational and national jurisdictions, such as when some subnational authorities seek to sustain production while national authorities may wish to reduce it for climate purposes.

Table 1

Factors Considered for Their Hypothesized Impact on the Use of Supply-Side Constraint Initiatives by National Governments

Hypothesized Impact	*Fossil Fuel Sector*	*Economic*	*Institutional*	*Climate Change*
Positive (more likely use of constraints)		• Development level • Debt	• Democratic regime and strong civil society	• Vulnerability to climate change impacts
Negative (less likely use of constraints)	• Reserves • Dependency • OPEC membership		• Corruption • Political crisis	

to climate-motivated supply cuts (Muttitt 2020). These provide the basis for the following hypotheses:

H_{1a}. Large fossil fuel per capita reserves reduce the use of constraint initiatives.
H_{1b}. High fossil fuel revenue dependence reduces the use of constraint initiatives.
H_{1c}. Membership in OPEC reduces the use of constraint initiatives.

Economic Factors

People living in countries with higher per capita income levels tend to have greater concerns for climate change while potentially also having a higher capacity to adapt their economy to supply-side constraints (Arikan and Günay 2021; Le Billon and Good 2016; Muttitt and Kartha 2020). External debt offers leverage over domestic governments and may thus increase constraint use if the creditor is itself pushing for supply-side policies, but it is more likely to push both debtors and creditors to maintain fossil fuel production for debt reimbursement purposes (Ghecham 2020). Therefore we make the following hypotheses:

H_{2a}. High income level increases the use of constraint initiatives.
H_{2b}. A high level of debt reduces the use of constraint initiatives.

Institutional Factors

Democratic rule and strong civil society are expected to provide favorable contexts and enable supply-side initiatives (Lewis et al. 2019; Martinez-Alier 2022; Peterson 2021). Both corruption and a (post)-conflict context are expected to reduce the likelihood of supply-cut initiatives, as corrupt financial incentives would negatively influence public decisions over the cancellation or closure of fossil fuel projects (Williams and Le Billon 2017) and the need for postconflict reconstruction would motivate authorities and society to support fossil fuel production to boost public finances and the economy (Le Billon 2014; Lujala and Rustad 2012). Thus we make the following hypotheses:

H_{3a}. Democratic countries are more likely to use constraint initiatives.
H_{3b}. High corruption reduces the use of constraint initiatives.
H_{3c}. Countries in (post)-conflict contexts are less likely to use constraint initiatives.

Climate Change Factors

Countries that are more exposed and/or vulnerable to the negative impacts of climate change should be more willing to constrain fossil fuel production than

those that are less so (Lujala et al. 2015; Virla et al. 2021; Warren et al. 2021). This provides the basis for our final hypothesis:

> H_{4a}. High exposure to climate change impacts increases the use of constraint initiatives.

Data and Methods

The panel data set used in the analysis includes all independent countries with a population of 500,000 or larger in 2018 that, according to the US Energy Information Agency (EIA), had fossil fuel reserves at some point during the study period. The data set includes 124 countries and covers the period 2006–2019, that is, the period after the Kyoto Protocol entered into force in February 2005.[5] In total, we have 1,720 country-year observations. Some of these countries and observations are lost in the analysis due to missing data. For replication data and replication instructions, see Lujala (2022).

Outcome Variable

Our dependent variable is derived from the Fossil Fuel Cuts Database (Gaulin and Le Billon 2020; www.fossilfuelcuts.org). The FFCD includes information on seven different types of supply-side initiatives seeking to reduce, disrupt, or end the supply of fossil fuels through the targeting of their production, transportation, or transformation. To be included in the FFCD, the initiative must actively target upstream fossil fuel processes. The database includes initiatives taken by intergovernmental organizations, national and subnational governments, and civil society. The database has global coverage and covers initiatives taken between 1988 and 2021 and includes in total 1,930 individual cases. The data set does not record the motivations and outcomes of the initiatives. Our analysis focuses on initiatives established by national governments. These fall into four different categories:[6]

1. *Moratoria* are legislated suspensions or total prohibitions on fossil fuel extraction or transportation, with or without compensation for the affected parties. Though moratoria have often been used in jurisdictions with little to no proven reserves, they have proven environmentally and economically

5. For our lagged variables, we use data for 2005–2018. Prior to 2006, only the United States had taken a state-led initiative (a ban in 2002).
6. Other constraint categories include *blockades*, described as physical obstructions or occupations of fossil fuel extraction, transportation, or refining sites to disrupt or prevent further site activity, and *litigation*, which are measures that seek to constrain production through judicial initiatives. Both types of measures are mostly used by civil society organizations, as are divestments. *Emission trading schemes* (ETSs) allocate or sell a limited number of discharge rights to fossil fuel producers or specific production areas. Two state-led ETSs were established during our study period, but they were excluded from the analysis as their identification as a supply-constraint measure is debated (Lazarus and van Asselt 2018).

effective when applied in specific circumstances, such as the closure of Germany's Hambach lignite mine (Rafaty et al. 2020).

2. *Divestments* include withdrawal or exclusion of funds and assets from financial portfolios connected to fossil fuel companies and their extractive activities. Beyond their direct—albeit limited—financial impact, divestments can generate public discourse shifts and temper investor expectations regarding future oil cash flows (Ansar et al. 2013).
3. *Carbon taxes* are environmental taxes imposed on fossil fuel producers in proportion to their emissions. Norway's application of a carbon tax on offshore oil and gas in 1991 effectively encouraged the development of carbon capture projects, in addition to reducing transaction costs (International Energy Agency 2020).
4. *Subsidy phaseouts* are gradual or abrupt cessation of indirect or direct monetary government assistance to fossil fuel companies. With producer subsidies totaling US$ 444 billion in the G20 countries alone, these sums represent a significant opportunity cost, disabling other carbon-neutral investments. It has been estimated that phaseouts could reduce global CO_2 emissions by 37 billion tons by 2050 (Pfefferle 2018).

The most common state-led constraint initiatives in our data set are subsidy phaseouts (24) and moratoria (26), followed by carbon taxes (8). Divestments (1) by a state are rare. By far, most initiatives, once established, were active throughout the study period (i.e., until 2019 or beyond), with six initiatives ending in 2018 or earlier. Appendix A lists the included state-led supply-side constraint measures taken by country, year, and type, including the end year for those that ended in 2018 or earlier.[7]

For each country-year, we calculate the number of each measure type active that year.[8] If a measure ended during the study period, it is included in the count for the year it ended but excluded from the following year's count. We also constructed a combined measure that counts the number of any measure active during the year and a variable that denotes the number of different types of measures. In our data set, we have 77 country-years with moratoria, 35 with carbon taxes, 3 with divestment, and 125 with subsidy phaseouts. In total, we have 195 country-years with at least one active supply-side constraint. At most, two countries have had four moratoria in one year (the United States in 2016–2017 and the United Kingdom in 2019), and on one occasion, a country has had four subsidy phaseouts active in a single year (Canada in 2019). No country has had more than one carbon tax measure at the time. The United Kingdom (2016–2019) and Canada (2019) are the only countries with at least five

7. We note that no country in the Middle East or North Africa had adopted a state-led constraint measure by 2020.
8. The FFCD does not allow us to judge the level of effort involved in each initiative or its success.

measures active in one year and also the only countries that have had three different types of constraint measures active at the same time. In addition to these countries, Mexico (since 2016), Ireland (since 2017), Germany and Denmark (since 2018), China (2016–2017), and Japan and Australia (since 2012) have had two different types of measures active in one year.

Independent Variables

The analysis includes several indicators to test the hypotheses outlined in Table 1. The summary statistics for the variables are provided in Appendix B.

Our data for *fossil fuel reserves* come from the US Energy Information Administration.[9] To make the data across the three included fossil fuels (i.e., coal, oil, and natural gas) comparable, the reserve figures were transformed into million tons of oil equivalent (MTOE) before adding them together.[10] We normalized the figures by population size (MTOE per million inhabitants) and transformed them using natural logarithm, as their value distribution is highly skewed. For a robustness check, we created a measure for *fossil fuel production* using the EIA data and the same construction approach. The two variables are relatively highly correlated (0.72; Appendix C). We use oil, natural gas, and coal rents from the World Development Indicators (WDI) to measure dependency on the fossil fuel sector.[11] The rents data are calculated as the difference between the international market value of the production and production costs and are expressed as a share of gross domestic product (GDP). For the analysis, we added the three shares together to get total *fossil fuel rents*. *OPEC membership* is coded with a dummy variable. The dummy takes the value of 1 for the years a country was a member, excluding the years it was suspended or had temporarily withdrawn from the organization.[12] For a robustness check, we obtained *fossil fuel exports* from WDI. It includes mineral fuels, lubricants, and related materials and is expressed as a percentage of total merchandise exports. The data are missing for almost 300 country-years, and they are highly correlated with *fossil fuel rents* (0.85). Another variable for robustness analysis is a dummy denoting countries with a *national oil company*.[13] This variable is, in practice, time invariant.

9. US Energy Information Administration independent statistics and analysis, available at: https://www.eia.gov/international/data/world, last accessed September 19, 2022.
10. We have annual data for all except coal reserves, for which we have average data for the period 2008–2019.
11. World Bank World Development Indicators, available at: https://databank.worldbank.org/source/world-development-indicators, last accessed September 19, 2022.
12. See OPEC, "Member Countries," https://www.opec.org/opec_web/en/about_us/25.htm, last accessed September 19, 2022.
13. National Oil Company Database, National Resource Governance Institute, https://nationaloilcompanydata.org/, last accessed September 19, 2022.

Our measure for the *income level*, GDP per capita, comes from the WDI database and is based on purchasing power parity using current 2011 international dollars. This indicator was transformed using natural logarithm. Data for *debt* come from the World Economic Outlook Database.[14] The variable measures the central government's gross debt as a percentage of GDP. *FDI* is used in the robustness analysis. It comes from WDI, is measured as net foreign direct investment (FDI) inflows, and is expressed as a share of GDP.

Our indicator for *democracy* is drawn from the Polity5 data set (variable *polity2*; data set version p5v2018d) (Marshall and Gurr 2020). The indicator ranges from −10 (strong autocracy) to 10 (strong democracy). We also constructed regime type dummies to be used in analysis focusing on potential nonlinear impact and interaction effects by assigning the country to be an *autocracy* if the original *polity2* score was smaller than −5 and a *full democracy* if the score was larger than 5. *Anocracy* was coded for all the other *polity2* scores, including those coded as missing in the original *polity2*.

The measure for *corruption* comes from the World Bank's Worldwide Governance Indicators database.[15] This composite measure ranges roughly between −2.5 and 2.5, with higher values indicating higher levels of corruption.[16] We measure political crisis through a measure on *armed conflict*. The measure is coded from the UCDP/PRIO Armed Conflict Dataset (version 20.1) (Pettersson and Öberg 2020).[17] The variable indicates the number of years of the previous five-year period in which there was an internal conflict in the country or the country was involved in an international conflict (using the threshold of 25 annual battle-related deaths for both). The values range from 5 (five conflict years during the previous five years) to 0 (no conflict during the previous five years). For robustness check, we include *civil society freedom*, which measures citizens' freedom to participate in selecting their government, freedom of expression, freedom of association, and freedom of the press and other media.[18] Higher scores on this variable indicate a higher degree of openness and accountability in society. Our other alternative indicator for civil society strength, *civil society constraints*, measures the potential pressure from civil society to use supply-side constraints, drawn from the FFCD. It takes the value of 1 if there had been at least one new civil society supply-side initiative in the previous two years.[19]

To measure a country's vulnerability to climate change impacts, we use data from the Notre Dame Global Adaptation Initiative's ND-GAIN Country Index (Chen et al. 2015). Its *vulnerability* subindex measures a country's

15. Available at: https://info.worldbank.org/governance/wgi/, last accessed September 19, 2022.
16. *Corruption* is the inverse measure of the data set's variable Control for Corruption.
17. Available at: https://www.prio.org/data/4, last accessed September 19, 2022.
18. See https://info.worldbank.org/governance/wgi/, last accessed September 19, 2022.
19. For this variable and *armed conflict*, we use data for years prior to 2005 to make the data as complete as possible.

exposure and sensitivity to the negative effects of climate change through its exposure to climate change from a biophysical perspective, the degree it depends on sectors negatively affected by climate change, the proportion of the population particularly susceptible to climate change, and sector-specific adaptation capacity. This measure is highly correlated with the country's income level (0.86; Appendix C). The values for the index range between 0 and 1, where higher values indicate higher vulnerability to climate impacts. As an alternative measure, we use the *exposure* index, which is time invariant but less correlated with income level.

All estimations include time trend (year dummies) and region effects (dummies for Africa, Asia, and Central and South America; Europe and North America, together with Japan, Australia, and New Zealand, are used as the reference category). We also control for population size (in millions), as larger countries may use more measures because they may have larger capacity and more opportunities to do so or because their absolute levels of greenhouse gas emissions are larger compared to those of less populous countries.

Empirical Strategy

Our analysis tests a set of country-level hypotheses outlined in Table 1 by estimating the following model:

$$\gamma_{mit} = \beta_F F_{it-1} + \beta_E E_{it-1} + \beta_I I_{it-1} + \beta_C C_{it-1} + \delta_X \mathbf{X}_{it-1} + \varepsilon_{it}, \quad (1)$$

where γ_{mit} is our outcome variable (a count variable indicating the number of active state-led measures) for measure m in country i in year t. Our outcomes m include the number of *moratoria* and *subsidy phaseouts*, the total number of *all* measures (i.e., moratoria, phaseouts, divestments, and carbon taxes), and the number of different *types* of measures. Our interest is in all coefficients β that capture the effects of our independent variables measuring fossil fuel F, economic E, institutional I, and climate change C factors. The vector $\mathbf{X}$ includes our controls for population size, time (year dummies), and geographic region, and ε represents our error term. All variables are lagged by one year, except for *civil society constraints* and *armed conflict* (which are lagged by construction).

As our outcomes are count variables, we use Poisson regressions.[20] We use random effects models for two main reasons: first, we want to exploit the full variation in our data set, inclusive of differences between countries, and second,

20. Although means of our outcome measures are smaller than their variations, they are only relatively modestly so (0.063 vs. 0.11 for moratoria, 0.094 vs. 0.15 for subsidy phaseouts, 0.18 vs. 0.39 for the combined measure). When we attempted to run negative binomial regressions, they often failed to converge, except for the models with the combined outcome measure. We provide negative binomial regression results for our main results in Table 2 as an additional robustness check.

Table 2
Supply-Side Constraint Initiatives, 2006–2019

	1	*2*	*3*	*4*	*5*	*6*
	Moratoria	*Phaseouts*	*All*	*All*	*Types*	*Types*
Fossil fuel reserves (log)	0.058	0.072	0.105	0.105	0.107	0.107
	(0.28)	(0.14)	(0.60)	(0.99)	(0.73)	(0.96)
	0.782	0.886	0.550	0.322	0.465	0.339
Fossil fuel rents	−0.565*	−0.103**	−0.133***	−0.133**	−0.145**	−0.145**
	(−1.72)	(−1.96)	(−2.59)	(−2.03)	(−2.21)	(−2.10)
	0.085	0.050	0.010	0.042	0.027	0.036
OPEC member	−18.884***	2.051	0.939	0.939	1.105	1.105
	(−11.28)	(0.62)	(0.49)	(1.04)	(0.55)	(1.20)
	0.000	0.537	0.623	0.297	0.584	0.231
Income level (log)	3.368***	1.133	1.896***	1.896***	1.885***	1.885***
	(4.38)	(1.27)	(3.63)	(3.37)	(3.56)	(3.23)
	0.000	0.203	0.000	0.001	0.000	0.001
Debt	−0.055*	0.007	−0.009	−0.009	−0.011	−0.011*
	(−1.65)	(0.16)	(−1.15)	(−1.62)	(−1.59)	(−1.91)
	0.099	0.877	0.251	0.104	0.113	0.057
Democracy	0.096	0.044	0.087*	0.087	0.112	0.112*
	(0.45)	(0.26)	(1.65)	(1.53)	(1.00)	(1.77)
	0.656	0.796	0.100	0.127	0.319	0.077

Corruption	0.752**	−0.149	0.155	0.155	0.248	0.248
	(1.97)	(−0.18)	(0.41)	(0.53)	(0.71)	(0.80)
	0.049	0.855	0.683	0.597	0.478	0.421
Armed conflict	−0.431***	−0.169	−0.353**	−0.353**	−0.409***	−0.409**
	(−2.79)	(−0.35)	(−2.11)	(−2.15)	(−3.33)	(−2.28)
	0.005	0.725	0.035	0.031	0.001	0.022
Population (log)	1.842**	0.954***	1.079***	1.079***	1.080*	1.080***
	(2.03)	(3.12)	(2.82)	(5.89)	(1.91)	(5.45)
	0.042	0.002	0.005	0.000	0.056	0.000
Observations	1,590	1,590	1,590	1,590	1,590	1,590
No. countries	117	117	117	117	117	117
Regression	Poisson	Poisson	Poisson	Neg. binom.	Poisson	Neg. binom.
Log-likelihood	−151	−219	−356	−356	−335	−335

Table shows coefficients for Poisson and negative binomial regressions, clustered on country. All specifications include year and regional dummies. *Z*-statistics are in parentheses; *p*-values are given below *z*-statistics.
*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

as the fixed effects model excludes all countries with no measures used during the study period (as there is no variation in the outcome variable), use of fixed effects models would substantially reduce our sample, including only the twenty-six countries that have established at least one measure and only fifteen countries in the case of moratoria and subsidy phaseouts. We report robust standard errors clustered on country. Stata 17.0 was used in all analyses.

Results

Table 2 shows the results regarding our main hypotheses using moratoria (model 1), subsidy phaseouts (model 2), combined measures (models 3 and 4; Poisson and binomial regressions, respectively), and different types of measures (models 5 and 6; Poisson and binomial regressions, respectively) as the outcome variables. Table 3 provides results on the climate variables and Table 4 some further results. Results for models 1–3 and 5 (Table 2) are summarized in Figure 1.

One remarkable result is that subsidy phaseouts are difficult to predict. Another is that the same factors seem to be associated with both the total number of active measures and the number of different types of measures. Furthermore, Poisson and negative binomial regression produce comparable standard errors. We therefore only show Poisson regression results in other tables.

Fossil Fuels Sector Factors

Countries with higher dependence on the sector in terms of *fossil fuel rents* (as percentage of GDP) are less likely to have active constraint initiatives. *Fossil fuel reserves* are not associated with active constraints, and neither is *fossil fuel production* when it is used instead of the reserves measure (results not shown).[21] *OPEC* countries are substantially less likely to use moratoria, but we do not find any evidence that this is the case for other types of constraint measures.[22] As a robustness check, we tested whether countries with a *national oil company* or high dependency on fuel *exports* behave differently but found no evidence for this (results not shown).

Economic Factors

Countries with higher *income levels* are more likely to have active constraint measures in general, and moratoria in particular. There is some tentative evidence

21. We looked into potential nonlinearities and differences between oil, gas, and coal production and reserves but did not find any consistent evidence for these (results not shown).
22. This difference may be explained by the direct effects of a moratorium on fossil fuel production and associated revenues, whereas the costs of other measures can be transferred to consumers, some measures may improve the environmental image of a producer and ease access to markets sensitive to the carbon footprint of production, and effective divestments by OPEC members are relatively rare (we thank a reviewer for some of these suggestions).

Table 3
Supply-Side Constraint Initiatives, 2006–2019, Climate Factors

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
	Moratoria	*Phaseouts*	*All*	*Types*	*Moratoria*	*Phaseouts*	*All*	*Types*
Fossil fuel reserves (log)	0.023	−0.058	0.010	−0.003	0.055	0.051	0.106	0.111
	(0.06)	(−0.11)	(0.04)	(−0.02)	(0.25)	(0.07)	(0.62)	(0.78)
	0.948	0.911	0.965	0.987	0.801	0.945	0.538	0.437
Fossil fuel rents	−0.467	−0.066	−0.085	−0.101	−0.604	−0.111*	−0.140***	−0.155***
	(−1.61)	(−1.59)	(−1.58)	(−1.28)	(−1.47)	(−1.80)	(−3.05)	(−2.92)
	0.107	0.111	0.115	0.199	0.141	0.072	0.002	0.004
OPEC member	−18.300***	2.220	0.900	1.103	−18.987***	2.261	0.933	1.077
	(−13.77)	(0.68)	(0.49)	(0.57)	(−9.13)	(0.57)	(0.47)	(0.49)
	0.000	0.496	0.624	0.570	0.000	0.571	0.635	0.622
Income level (log)					3.574***	1.181	1.976***	1.981***
					(4.15)	(1.06)	(3.57)	(3.18)
					0.000	0.288	0.000	0.001
Debt	−0.047	0.002	−0.010	−0.012	−0.058*	0.008	−0.010	−0.011
	(−1.15)	(0.05)	(−1.27)	(−1.06)	(−1.95)	(0.15)	(−0.95)	(−1.54)
	0.251	0.958	0.204	0.289	0.051	0.877	0.342	0.125
Democracy	0.201	0.060	0.136*	0.170	0.078	0.012	0.073	0.094
	(1.13)	(0.27)	(1.67)	(1.14)	(0.33)	(0.05)	(1.19)	(0.66)
	0.258	0.786	0.095	0.253	0.740	0.963	0.234	0.509
Corruption	−0.229	−0.229	−0.257	−0.146	0.895*	0.092	0.263	0.384
	(−0.48)	(−0.37)	(−0.83)	(−0.53)	(1.94)	(0.13)	(0.57)	(0.80)
	0.633	0.714	0.408	0.599	0.053	0.894	0.566	0.425

Table 3
(Continued)

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
	Moratoria	*Phaseouts*	*All*	*Types*	*Moratoria*	*Phaseouts*	*All*	*Types*
Armed conflict	−0.266	−0.195	−0.320***	−0.397***	−0.499***	−0.251	−0.381*	−0.443**
	(−1.08)	(−0.41)	(−3.46)	(−3.31)	(−2.59)	(−0.67)	(−1.67)	(−2.57)
	0.282	0.682	0.001	0.001	0.009	0.502	0.095	0.010
Population (log)	1.784*	0.958***	1.148**	1.200*	1.842**	0.848***	1.019***	0.999
	(1.65)	(3.46)	(2.26)	(1.64)	(2.31)	(4.76)	(2.61)	(1.60)
	0.099	0.001	0.024	0.100	0.021	0.000	0.009	0.110
Vulnerability	−12.336*	−18.702***	−14.163**	−15.079**				
	(−1.68)	(−2.67)	(−2.52)	(−2.33)				
	0.093	0.008	0.012	0.020				
Exposure					5.808	8.345	3.845	4.495
					(0.85)	(0.38)	(0.86)	(0.67)
					0.395	0.706	0.392	0.505
Observations	1,590	1,590	1,590	1,590	1,579	1,579	1,579	1,579
No. countries	117	117	117	117	116	116	116	116
Log-likelihood	−155	−218	−359	−337	−151	−219	−356	−334

Table shows coefficients for Poisson regressions, clustered on country. All specifications include year and regional dummies. *Z*-statistics in parentheses; *p*-values are given below *z*-statistics.
*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table 4
Supply-Side Constraint Initiatives, 2006–2019, Further Analysis

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
	Moratoria	*Phaseouts*	*All*	*Types*	*Moratoria*	*Phaseouts*	*All*	*Types*
Fossil fuel reserves (log)	0.012	0.083	0.098	0.100	0.074	0.071	0.114	0.115
	(0.08)	(0.23)	(0.55)	(0.64)	(0.52)	(0.14)	(0.74)	(0.90)
	0.934	0.819	0.580	0.521	0.604	0.886	0.461	0.369
Fossil fuel rents	−0.391*	−0.090	−0.134***	−0.160**	−0.649***	−0.102**	−0.139**	−0.152**
	(−1.92)	(−1.05)	(−2.75)	(−2.50)	(−3.09)	(−2.02)	(−2.37)	(−2.02)
	0.055	0.296	0.006	0.012	0.002	0.044	0.018	0.043
OPEC member	−19.629***	2.153	1.039	1.215	−21.010***	2.047	0.970	1.152
	(−9.08)	(0.67)	(0.52)	(0.60)	(−15.57)	(0.61)	(0.50)	(0.57)
	0.000	0.506	0.606	0.548	0.000	0.541	0.615	0.569
Income level (log)	3.507***	1.081	1.997***	2.018***	3.332***	1.124	1.933***	1.925***
	(2.64)	(0.89)	(3.46)	(3.61)	(4.17)	(1.33)	(3.64)	(3.62)
	0.008	0.371	0.001	0.000	0.000	0.183	0.000	0.000
Debt	−0.058	0.007	−0.009	−0.011	−0.056*	0.007	−0.008	−0.009
	(−1.53)	(0.18)	(−1.19)	(−1.58)	(−1.84)	(0.15)	(−0.85)	(−1.47)
	0.127	0.861	0.235	0.114	0.066	0.883	0.395	0.141
Democracy					0.058	0.045	0.081*	0.106
					(0.45)	(0.26)	(1.73)	(1.08)
					0.654	0.796	0.083	0.281
Corruption	0.821*	−0.171	0.181	0.241	0.911	−0.162	0.246	0.338
	(1.79)	(−0.25)	(0.51)	(0.74)	(1.59)	(−0.21)	(0.61)	(0.94)
	0.074	0.799	0.612	0.461	0.112	0.831	0.544	0.345

Table 4
(Continued)

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
	Moratoria	*Phaseouts*	*All*	*Types*	*Moratoria*	*Phaseouts*	*All*	*Types*
Armed conflict	−0.247	−0.280	−0.294	−0.346	−0.428***	−0.167	−0.363**	−0.420***
	(−1.27)	(−0.53)	(−0.95)	(−1.34)	(−2.79)	(−0.36)	(−2.17)	(−3.38)
	0.205	0.598	0.342	0.180	0.005	0.722	0.030	0.001
Population (log)	1.804*	1.037*	1.104**	1.074**	1.766**	0.958***	1.043***	1.048**
	(1.72)	(1.80)	(2.44)	(2.03)	(1.98)	(3.39)	(3.01)	(1.99)
	0.086	0.072	0.015	0.042	0.048	0.001	0.003	0.046
Anocracy (dummy)	−20.514***	1.656	0.242	0.365				
	(−5.53)	(1.02)	(0.16)	(0.27)				
	0.000	0.306	0.875	0.786				
Full democracy (dummy)	0.420	1.556	1.262	1.156				
	(0.32)	(0.82)	(1.26)	(1.13)				
	0.747	0.412	0.207	0.257				
Civil society constraints (dummy)					0.694**	−0.031	0.256	0.273
					(2.06)	(−0.12)	(1.34)	(1.35)
					0.040	0.906	0.179	0.177
Observations	1,618	1,618	1,618	1,618	1,590	1,590	1,590	1,590
No. countries	118	118	118	118	117	117	117	117
Log-likelihood	−150	−219	−356	−336	−150	−219	−355	−334

Table shows coefficients for Poisson regressions, clustered on country. All specifications include year and regional dummies. *Z*-statistics in parentheses; *p*-values are given below *z*-statistics.
*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

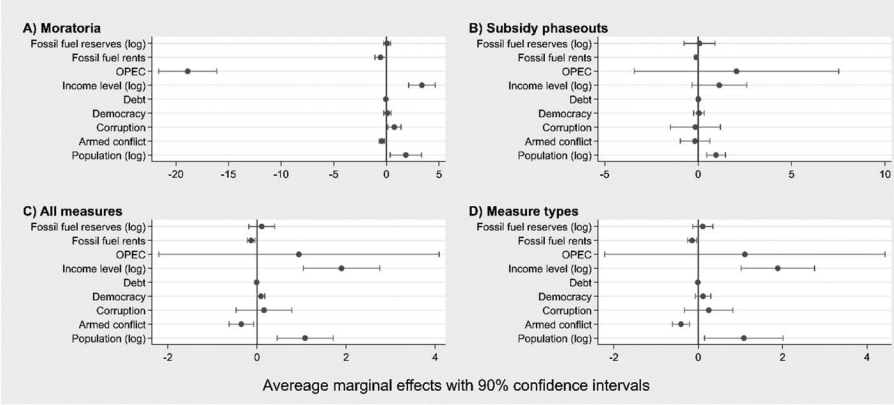

Figure 1
Average Marginal Effects for All Covariates Based on Models 1–3 and 5 in Table 2

that higher *debt* rates can be associated with a decreased likelihood of having active constraint measures. We also tested the impact of *FDI* on constraint measures but did not find any evidence for this (results not shown).

Institutional Factors

The results show some weak evidence that increasing *democracy* levels can have a relation to having a higher number of active constraint measures. We checked for potential nonlinearities by including dummies for democracies and anocracies, the autocratic countries serving as the excluded category. We find strong evidence that anocracies are considerably less likely to have moratoria (Table 4, model 1). We also looked into potential interaction effects between *fossil fuel rents* and *democracy* level and dummies but did not find any evidence for such impacts (results not shown). An alternative measure for democracy—*civil society freedom*—produces positive but nonsignificant coefficients (results not shown). Countries with a civil society that actively promotes supply-side constraints (*civil society constraints*) are more likely to use state-led moratoria measures (Table 4, model 5). Countries in a (post)-conflict context (*armed conflict*) are less likely to use constraint initiatives; however, we do not see this in relation to subsidy phaseouts. *Corruption* produces an unexpected sign in our estimation on moratoria: higher levels of corruption are associated with a higher number of active constraints (Table 2, model 1).

Climate Change Factors

Vulnerability to climate change decreases the likelihood of having ongoing constraint measures (Table 3, models 1–4). The variable highlights countries with

many development challenges and is so highly correlated with GDP per capita that we did not include it simultaneously with income level. The inclusion of *exposure* produces consistently positive coefficients, but these are not significant at conventional significance levels (models 5–8).

Finally, the results show that larger countries in terms of *population* size are more likely to use state-led constraints.

Robustness

Some of our measures are conceptually close to each other or closely related to development level. Appendix C provides a correlation table for the variables included in the analysis. As noted previously, *democracy* and *corruption* are very highly correlated with *civil society freedom* and thus cannot be included in the same estimation. *Income level* is extremely highly correlated with our measure for *vulnerability*. To study multicollinearity's potential impact on our results, we run bivariate analysis of our main covariates (Online Appendix OA1), estimations in which the region dummies have been removed (Online Appendix OA2), and estimations from which each fossil fuel sector covariate has been removed one at a time and an estimation in which only *fossil fuel rents* was included (Online Appendix OA3). These analyses show that our results are remarkably stable, with only modest changes in coefficients and significance levels. When the region dummies are removed, the results for *democracy* are stronger, but they are weaker for *debt* and *armed conflict*. We note that the surprising result for *corruption* with relation to *moratoria* is not supported by bivariate evidence, nor does it survive when the region dummies are removed. The removal of *fossil fuel reserves* weakens the impact of *fossil fuel rents*.

Discussion

Drawing on the literature about fossil fuel supply-side constraints and the resource curse, we developed an analytical framework to examine factors that could impact a national government's likelihood to use fossil fuel production constraints. Using panel data for 124 countries with fossil fuel reserves and a global data set on fossil fuel constraint initiatives, we tested how some factors related to countries' fossil fuel sector, economy, and institutional context, as well as their vulnerability to climate change impacts, affect the likelihood of using such measures. Taken together, the study provides evidence that factors related to the fossil fuel sector, economy, and institutions can be important. These results can be considered when forming coalitions of fossil fuel–producing countries pushing for a managed decline in fossil fuel supply.

Our results confirm that countries dependent on fossil fuel revenues are less likely to use constraint measures. Yet we note that fossil fuel reserves and production do not seem to affect the likelihood of constraint measures, which opens up the possibility of recruiting oil-rich yet not oil-dependent countries

into a supply-side coalition. We also confirm that OPEC membership impedes the use of moratoria, but we do not find such an effect for other constraint measures. Overall, these results suggest that while fossil fuel–rich countries are not less likely than others to join a coalition, it may be more difficult to recruit OPEC members if the main tool proposed by the coalition consists of moratoria rather than other types of instruments. One possible option for this issue is to have different coalitions that share the purpose of constraining supply but use measures that are more likely to be used according to the characteristics of individual countries.

Our results suggest that economic factors can be a determinant of supply-constraint use. First, richer countries are more likely to see national authorities take supply-side measures than poorer ones and would thus be more likely to join a supply-constraint coalition. We note that, to some extent, this seems to be the case within BOGA, though there is no major fossil fuel production within BOGA's current core members, with the exception of Denmark.[23] Having already pivoted from natural gas to offshore wind power (Abraham-Dukuma 2021), Denmark is in a better position to commit to ending its oil and gas production by 2050. Fellow Scandinavian countries Finland and Sweden (with marginal fossil fuel reserves) also joined BOGA, but Norway, a wealthy major oil and gas producer (and potential prime mover, given its massive sovereign fund), did not.[24] Second, to the degree government debt is negatively associated with government constraints, it can be beneficial to tie debt relief to participation in a supply-constraint coalition. FDI, as measured in our analysis, is not related to constraint initiatives, but further research would be needed on the impacts of FDI on fossil fuel projects versus "green transition" ones to determine potential coalition-building implications.

We note that, so far, no countries in the Middle East and North Africa have seen their government initiate state-driven constraints, yet some take economically motivated restrictions on production that can contribute to an overall reduction of supply. One implication is that, for example, OPEC producers could consider a combination of lower production volumes and higher prices as long as competing producers, in particular, the United States, do not instrumentalize these higher prices to increase their own production and market shares. For this, the wealthiest non-OPEC producers could be part of a climate-focused coalition restricting production. The two types of coalitions, one driven by economic objectives, the other by climate concerns, could prove complementary. We note, however, that lack of quota compliance has been a recurrent issue within OPEC (Colgan 2014; Van de Graaf 2020), which could also be the case among members of a climate-driven coalition.

23. Beyond Oil and Gas Alliance, https://beyondoilandgasalliance.com/, last accessed September 19, 2022.
24. Neither did the other major Western producers (Australia, the United Kingdom, the United States, or Canada), nor did the other top producers (China, Russia, Saudi Arabia).

Our results for institutional factors are mostly in line with our hypotheses, but not as strongly as expected. There is some weak evidence that democratic countries are more likely to use state-led constraint measures in general and strong evidence that anocracies do not use moratoria. Instead, moratoria are used in countries with a civil society that promotes supply-side constraints. Countries with a recent past of armed conflict are unlikely to use constraint initiatives. We unexpectedly found support for corruption increasing the likelihood of moratoria; possible explanations include moratoria being used by corrupt regimes to exert pressure on oil companies for private gains or—in the case of low-level (or "petty") rather than high-level (or "grand") corruption—moratoria being considered by the government as simpler to administer and less prone to graft than other measures. In the latter case, this could mean that governments characterized by high-level integrity could be joining a coalition, even if affected by low-level corruption. This result, however, may be spurious and merits further investigation.

Finally, we found that climate vulnerability reduces the likelihood of constraint use, which may be explained by low development level, biased risk perceptions, and short-term policies (Stewart 2020; Virla et al. 2021), or the need for fossil fuel revenues to finance adaptation or recovery from climate-related disasters (Lyster 2015). Though ethically problematic, conditioning disaster-related assistance to joining a supply-constraint coalition could change the incentives of climate-vulnerable fossil fuel producers.

As mentioned in the Conceptual Framework section, a number of other factors should be considered for further research. For example, high levels of FDI into non–fossil fuel sectors should support supply-cut initiatives, while on the contrary, FDI into fossil fuel sectors should dampen this support. The provenance of FDI may also have some influence, with some investors having fewer climate concerns than others (Sanna Randaccio 2012). A government may also be more likely to use supply-constraint measures if the country has had a poor record of fossil fuel–based development (Hilmi et al. 2020) or if it has a high potential for renewable energy production to replace fossil fuel exports or satisfy national energy needs (but see Temper et al. 2020). There is a vast literature on policy diffusion pointing at more indirect "network" factors that could potentially influence decisions to use supply-constraint measures, including aid dependence, cultural similarities, historical ties, economic interdependence, and geographical proximity or "neighborhood" effects (Baldwin et al. 2019; Gilardi and Wasserfallen 2019).

Conclusions

This article, to our knowledge, is the first to examine statistically the use of supply-side fossil fuel production constraints by national governments. It was motivated by the lack of systematic research on what kinds of countries are most likely to use such constraints. Understanding what factors impact a state's use of

constraint initiatives is crucial in designing international policies that seek to complement demand-side measures through a supply-side climate treaty (Newell and Simms 2020). We note in this regard the experience of the Extractive Industries Transparency Initiative, which still awaits the participation of major fossil fuel–rich countries but nonetheless has fostered greater extractive revenue transparency even beyond its own participating members (Rustad et al. 2017).

This study is not without limitations and stakes out several avenues for further research. First, we lack data on some key factors that could predict the use of supply-side measures, such as FDI going into fossil fuel sectors, level of climate concern among populations, or potential for renewable and nuclear energy sources. Second, we did not analyze, also due to lack of relevant data, potential factors related to the sense of responsibility associated with environmental justice and ecological debt, the local environmental impacts of the fossil fuel industry, or the influence of memberships other than OPEC. Further analysis is also needed to study the diverse array of factors identified in the policy diffusion literature, such as neighborhood effects or geopolitical relations—the latter being particularly acute in the context of Russia's invasion of Ukraine in 2022 and resulting sanctions. Third, a more in-depth and finer-grained analysis could also better capture the impact of the different types of fossil fuel reserves (i.e., coal, natural gas, and oil) and how present production and dependency on fossil fuel sector and future production potential relate to the use of constraint initiatives. There is also a need to better understand which factors are related to the use of subsidy phaseouts.

Finally, although the constraint initiatives were coded from the FFCD, it does not allow for examining the costs and effectiveness of these initiatives. Further research should attempt to measure and identify the factors influencing the effectiveness of these constraint measures in reducing fossil fuel production, as well as processes that may entice countries to join a supply-side coalition. This could build on a metareview study by Rempel and Gupta (2022), which identified twenty-eight LFFU approaches, including twelve environmentally effective ones.

Several policy suggestions result from our findings. The first is that policy communication should continue to raise awareness about the rationales for supply-side measures and a just transition away from fossil fuel revenue dependence. Second, there should be greater support for civil society initiatives to curtail fossil fuel supply, noting that a detailed analysis could help understand better when such initiatives may have positive or counterproductive effects on constraint use by national governments. The third is that discussions over supply-side measures should include a broader range of countries than usually considered (e.g., "first movers"; see Carter and McKenzie 2020). Such discussions, and supply-side institutionalization processes, should be further promoted within intergovernmental forums, including through the UNFCCC COP, OPEC, G20, the World Trade Organization, and the United Nations General Assembly (see Blondeel et al. 2021; Rayner 2021). To help these

discussions, the climate change policy community should invest more effort into the elaboration and implementation design of supply-side measures, including the recently created BOGA and an international agreement for a managed decline in fossil fuel production.

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Appendix A

National Government–Led Supply-Side Constraints, 2006–2019

Country	*Start Year*	*End Year*[a]	*Carbon Tax*	*Subsidy Phaseout*	*Moratorium*	*Divestment*
Argentina	2018		1	0	0	0
Australia	2012	2014 (c. tax)	1	1	0	0
Australia	2016		1	0	0	0
Bulgaria	2012		0	0	1	0
Canada	2007		0	1	0	0
Canada	2010		0	1	0	0
Canada	2011		0	1	0	0
Canada	2016		0	0	1	0
Canada	2019		1	1	0	0
China	2010		0	1	0	0
China	2016	2017	0	0	1	0
Czech Republic	2012		0	0	1	0
Denmark	2014		0	1	0	0
Denmark	2018		0	0	1	0
France	2011		0	0	1	0
France	2017		0	0	1	0
Germany	2016		0	0	1	0
Germany	2018		0	1	0	0
Indonesia	2017		0	1	0	0
Ireland	2017		0	0	1	1
Italy	2019		0	0	1	0
Japan	2011		0	1	0	0
Japan	2012		1	0	0	0
Mexico	2014		1	0	0	0
Mexico	2016		0	0	1	0
Netherlands	2015		0	0	1	0
Netherlands	2018		0	0	1	0
New Zealand	2009		0	1	0	0
New Zealand	2018		0	0	1	0

(Continued)

Country	*Start Year*	*End Year*[a]	*Carbon Tax*	*Subsidy Phaseout*	*Moratorium*	*Divestment*
New Zealand	2019		0	1	0	0
Norway	2016		1	0	0	0
Poland	2006		0	1	0	0
Portugal	2011		0	1	0	0
Russia	2014		0	1	0	0
Russia	2019		0	1	0	0
Slovakia	2010		0	1	0	0
South Africa	2011	2012	0	0	1	0
South Africa	2018		0	0	1	0
South Korea	2010		0	1	0	0
Spain	2011		0	1	0	0
Spain	2015		0	1	0	0
Spain	2018		0	1	0	0
UK	2011	2012	0	0	1	0
UK	2013		1	0	0	0
UK	2015		0	1	2	0
UK	2016		0	2	0	0
UK	2017		0	0	1	0
UK	2019		0	0	1	0
United States	2006		0	0	1	0
United States	2010	2010 & 2017	0	0	2	0
United States	2016		0	0	2	0

[a]If 2018 or earlier.

Appendix B

Summary Statistics

Variable	*Obs.*	*M*	*SD*	*Min.*	*Max.*
Dependent variables					
Moratoria	1,720	0.06	0.33	0	4
Carbon taxes	1,720	0.02	0.14	0	1
Divestments	1,720	0.002	0.04	0	1
Phaseouts	1,720	0.09	0.38	0	4
All	1,720	0.18	0.63	0	8
Types	1,720	0.14	0.42	0	3
Fossil fuel sector					
Fossil fuel reserves (MTOE per million inhabitants)	1,703	374	1,490	0.00	27,633
Coal reserves (MTOE per million inhabitants), time invariant	1,703	113	377	0	3,978
Gas reserves (MTOE per million inhabitants)	1,703	146	1,223	0	25,236
Oil reserves (MTOE per million inhabitants)	1,703	116	492	0	6,098
Fossil fuel production (MTOE per million inhabitants)	1,679	4.32	12.28	0	120
Coal production (MTOE per million inhabitants)	1,692	0.37	1.22	0	12
Gas production (MTOE per million inhabitants)	1,692	1.63	6.38	0	71
Oil production (MTOE per million inhabitants)	1,679	2.32	7.15	0	71
Fossil fuel rents (% of GDP)	1,659	7.09	12.80	0	68
Fossil fuel exports (% of merchandise exports)	1,437	22.8	29.8	0	100
National oil company (dummy), time invariant	1,720	0.45	0.50	0	1
OPEC member (dummy)	1,717	0.10	0.30	0	1

(Continued)

Variable	*Obs.*	*M*	*SD*	*Min.*	*Max.*
Economic					
Income level (GDP per capita, international $)	1,635	18,493	19,251	519	141,635
Debt (% of GDP)	1,652	45.13	32.30	0.488	234
FDI (% of GDP)	1,650	4.13	6.74	−40	87
Institutional					
Democracy	1,688	3.31	6.66	−10	10
Full democracy (polity2 > 5)	1,717	0.54	0.50	0	1
Autocracy (polity2 < −5)	1,717	0.17	0.38	0	1
Anocracy (−6 < polity2 < 6)	1,717	0.29	0.45	0	1
Civil society freedom (index)	1,703	−0.26	1.03	−2.31	1.74
Civil society constraints (dummy, past two years)	1,720	0.20	0.40	0	1
Corruption (index)	1,703	0.18	0.99	−2.47	1.87
Armed conflict (past 5 years)	1,720	1.01	1.81	0	5
Climate change					
Vulnerability (index)	1,692	0.43	0.10	0.24	0.69
Exposure, time invariant (index)	1,692	0.43	0.07	0.27	0.63
Controls					
Population ('000)	1,703	55.27	169	0.50	1,393

Summary statistics for variables in italics are calculated for the period 2006–2019. For other variables, the data are shown for the period 2005–2018.

Appendix C

Correlation Table

	Reserves	*Production*	*Rents*	*OPEC*	*National*	*Income*	*Debt*	*FDI*	*Dem.*
Reserves (log)	1								
Production (log)	0.7217	1							
Fossil fuel rents	0.4278	0.4775	1						
OPEC	0.3238	0.3063	0.5574	1					
National oil company	0.3198	0.4531	0.515	0.3505	1				
Income level (log)	0.4892	0.5134	0.1689	0.1899	−0.0109	1			
Debt	−0.1296	−0.0844	−0.3046	−0.2097	−0.2336	0.1801	1		
FDI	0.0451	0.0097	−0.0029	−0.122	−0.0834	−0.0082	0.0147	1	
Democracy	−0.1299	−0.1262	−0.5172	−0.3044	−0.3528	0.1986	0.3157	0.0362	1
Autocracy	0.3089	0.3178	0.4768	0.2854	0.2568	0.1935	−0.276	−0.0118	−0.7558
Anocracy	−0.1493	−0.1792	0.0976	0.0983	0.1974	−0.5051	−0.0807	−0.0258	−0.3213
Full democracy	−0.0909	−0.0701	−0.4404	−0.3001	−0.3697	0.3196	0.277	0.0323	0.8504
Corruption	−0.1077	−0.065	0.2586	0.0925	0.3253	−0.681	−0.2549	−0.0623	−0.4659
Civil society freedom	−0.037	−0.0336	−0.4525	−0.2569	−0.3724	0.4846	0.3351	0.0523	0.8613
Civil society constraints	0.0721	0.1058	−0.0965	0.0323	0.0387	0.1565	0.0671	−0.0635	0.2693
Armed conflict	−0.0701	−0.0655	0.0442	0.0905	0.1742	−0.2663	−0.0226	−0.1127	−0.088
Vulnerability	−0.4084	−0.3854	0.0328	−0.0218	0.1753	−0.855	−0.2127	−0.0342	−0.3371
Exposure	−0.318	−0.2147	−0.0737	−0.04	0.2199	−0.4638	0.0376	−0.1351	0.0247
Population (log)	−0.1191	−0.0082	−0.1584	0.0299	0.1912	−0.159	0.2035	−0.1548	0.0706

(Continued)

	Autocracy	*Anocracy*	*Full Dem.*	*Corruption*	*Freedom*	*Constraints*	*Conflict*	*Vulnerab.*	*Exposure*
Autocracy	1								
Anocracy	−0.2814	1							
Full democracy	−0.4788	−0.7077	1						
Corruption	0.1526	0.4505	−0.5245	1					
Civil society freedom	−0.5437	−0.4383	0.8013	−0.7773	1				
Civil society constraints	−0.1841	−0.0917	0.2194	−0.2255	0.2891	1			
Armed conflict	−0.1287	0.2718	−0.1539	0.2741	−0.2586	0.1123	1		
Vulnerability	−0.0344	0.4552	−0.3912	0.6592	−0.5568	−0.1674	0.2935	1	
Exposure	−0.2138	0.2355	−0.0581	0.2487	−0.12	0.1187	0.3043	0.6438	1
Population (log)	−0.1168	0.0551	0.0356	0.0854	−0.0203	0.3074	0.4364	0.1044	0.3938

N = 1,457. Table does not include fossil fuel exports as these data are missing for more than 300 country-years.