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Energy Subsidies and the Climate Dilemma in Middle Eastern Petro-States: An Empirical Analysis

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ABSTRACT

This study examines the association between fossil fuel subsidies and greenhouse gas emissions in five major Middle Eastern petro-states: Iran, Iraq, Kuwait, Saudi Arabia, and the UAE, which face a severe dilemma as they weigh the imperative of addressing climate change against their economic reliance on fossil fuels. Covering the period 2010-2023, the analysis estimates the within-country association between per-capita emissions and total and fuel-specific subsidy levels in a two-way fixed effects panel model. The results indicate a consistent and statistically significant positive association between subsidies and emissions, with a 10% lower level of total subsidies associated with a 1.2% lower level of emissions. Among fuel types, gas subsidies show the strongest and most consistent correlation with emissions, while oil and electricity subsidies exhibit weaker or statistically insignificant patterns. The findings highlight the policy relevance of fuel-specific subsidy measures and provide empirical evidence to inform reform strategies that balance fiscal sustainability, resource management, social welfare, and emission-reduction objectives in Middle Eastern petro-states.

Keywords: Energy Subsidies, Fossil Fuel Subsidy Reform, Greenhouse Gas Emissions, Middle Eastern Petro-States, Panel Data Analysis
JEL Classifications: Q48, Q54, H23, Q58

1. INTRODUCTION

Climate change is a global phenomenon, but its impacts are unevenly distributed, with the Middle East and North Africa (MENA) experiencing some of the most severe consequences. The region has been warming at approximately twice the global average, with average temperatures rising by approximately 0.46°C/decade compared to 0.18°C globally (IEA, 2023a; Miller et al., 2022; Zittis et al., 2021). Projections indicate that by 2100, the average temperature in the Persian Gulf could increase by 5-6°C, and the number of days with wet-bulb temperatures above 35°C, a threshold for human survivability, could increase substantially and threaten habitability in parts of the region (Krane, 2020; Lelieveld et al., 2016; 2012; Pal and Eltahir, 2016). Recent analyses show that climate change is altering atmospheric circulation across the MENA region, shifting heat lows, subtropical highs, and jet streams. These changes are projected to intensify under high-emission scenarios, amplifying regional warming and driving more frequent extreme heat and dust events, with serious implications for public health, infrastructure, and productivity (Francis and Fonseca, 2024).

Among the countries in the MENA region, the Middle Eastern petro-states face a severe dilemma, as they weigh the imperative of addressing climate change against their economic reliance on fossil fuels. Unlike northern oil producers, such as Canada and Norway, which may experience temporary benefits from moderate warming due to expanded agricultural land and increased energy demand, Middle Eastern petro-states face significant GDP losses from heightened climate risks, including heat-related labor productivity declines, rising health expenditures, infrastructure stress, and increased disease transmission. According to Acevedo et al. (2020), while northern nations could see GDP gains with moderate warming (e.g., +0.83% in Russia per 1°C increase), the Persian Gulf states rank among the most vulnerable globally, surpassed only by equatorial sub-Saharan and Southeast Asian

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countries. Recent country-level social cost of carbon estimates also indicated that some Middle Eastern petro-states, including Saudi Arabia, incur disproportionately high economic damages per ton of CO_2 emitted (Ricke et al., 2018). Climate change thus represents not only an environmental crisis but a growing fiscal and development liability.

In 2017, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia, and the UAE together produced nearly 6% of global CO_2 emissions, which was more than twice that of Germany and comparable to the combined emissions of Russia and Australia (Krane, 2020). Five of these were among the top ten oil producers based on 2023 global output: Saudi Arabia (11%), Iraq (4%), the UAE (4%), Iran (4%), and Kuwait (3%) (EIA, 2024). As global decarbonization advances, these economies face climate damage, as well as the fiscal risks of stranded assets, declining oil rents, and constrained diversification windows (Peszko et al., 2020; van der Ploeg and Venables, 2008). This dilemma is further complicated by the "Green Paradox," where climate policies that reduce future fossil fuel demand may incentivize resource-rich countries to accelerate extraction in the near term to avoid stranded reserves, a "pump-and-panic" approach that can depress prices, spur short-term consumption, and undermine global decarbonization (Gerlagh, 2011; Jensen et al., 2015; Krane, 2020; Sinn, 2012; van der Ploeg and Withagen, 2012). Ultimately, Middle Eastern petro-states must weigh the escalating costs of climate inaction against the disruptive economic consequences of decarbonization.

Energy subsidies lie at the center of this dilemma and are classified into two categories. Explicit subsidies arise when governments set energy prices below supply costs or provide direct budgetary support, such as rebates or price controls. These subsidies are highly visible in fiscal accounts and often constitute a significant burden on government budgets. Implicit subsidies, by contrast, occur when energy prices fail to incorporate the broader social costs of fossil fuel use, most notably climate damage, local air pollution, and other environmental externalities. While explicit subsidies attract more political and policy attention, implicit subsidies are significantly larger in scale, as they reflect the unpriced damages imposed on societies (Parry et al., 2021).

Globally, explicit fossil fuel subsidies amounted to approximately USD 1.3 trillion in 2022, equivalent to 1.3% of global GDP, with petroleum, natural gas, and electricity representing 26%, 48%, and 25% of the total, respectively. Nearly all were consumer subsidies (97%) that directly lowered end-user prices. The MENA region accounted for 16%, reflecting its deep reliance on subsidized energy (Parry et al., 2021). Between 2010 and 2020, governments in the MENA region allocated USD 2.27 trillion in explicit fossil fuel subsidies, accounting for 50% of the global total of USD 4.57 trillion, with Iran and Saudi Arabia leading this expenditure (Mohseni-Cheraghlou, 2022). Despite successive reform waves, progress has been uneven, and energy prices in many Middle Eastern petro-states continue to fall well below efficient cost levels, reflecting persistent political and fiscal barriers to reform. Major efforts include:

- Iran has undertaken ambitious, multiphase subsidy reforms. The first phase (2007) introduced a fuel card system to curb gasoline consumption. The 2010 reform marked a sweeping overhaul, reducing subsidies across fuels, utilities, and agriculture, while compensating households through universal cash transfers and targeted industry support. Subsequent phases in 2014-2015 further raised energy prices (Kheiravar, 2019; OEF, 2017).
- Saudi Arabia implemented two major reform waves. The first (2016) introduced moderate increases in fuel and electricity prices, while the second (2018) applied steeper adjustments across both sectors (Aldubyan and Gasim, 2021).
- Iraq has pursued gradual and uneven subsidy reforms since the early 2010s, focusing on higher tariffs for large consumers while maintaining low tariffs for residential ones (GlobalPetrolPrices, 2025; IMF, 2023). More recently, the Kurdistan Region has advanced deeper adjustments, diverging from Baghdad's slower national approach (Baban, 2025).
- The UAE became the first Gulf Cooperation Council member state to deregulate retail fuel prices in 2015 by introducing a monthly adjustment mechanism linked to international benchmarks. Electricity and water tariffs were also raised in Abu Dhabi and Dubai, although Emirati nationals remained subsidized (OEF, 2017).
- Kuwait increased gasoline, electricity, and water prices in 2016-2017 for the first time in decades, with higher tariffs applied to expatriates than to nationals (OEF, 2017).

These examples illustrate the diversity of reform approaches across the region. Beyond their fiscal dimensions, fossil fuel subsidies in these economies function as deeply embedded social and economic institutions that shape household energy behavior, industrial cost structures, and the political bargains between states and citizens. Understanding how variation in these subsidy structures relates to emissions outcomes therefore requires engagement with both the economic and social systems through which energy pricing operates. While numerous modeling and case studies have examined energy subsidy reform in the Middle East, empirical cross-country analyses of its relationship with Greenhouse Gas (GHG) emissions remain limited. Most existing work relies on aggregated data and does not distinguish among fuel types, making it difficult to assess which subsidies are most closely associated with emission patterns. This study focuses on five major Middle Eastern petro-states: Iran, Iraq, Kuwait, Saudi Arabia, and the UAE, which together account for the majority of regional fossil fuel subsidies, recent reform efforts, and greenhouse gas emissions. These countries thus provide a consistent and data-rich context for examining how variation in subsidy structures is associated with differences in GHG-emission trajectories over time.

Fossil fuel subsidies also pose direct challenges for sustainable development: By absorbing fiscal resources, suppressing incentives for efficiency, and weakening the competitiveness of cleaner energy technologies, they can limit progress toward affordable, reliable, and cleaner energy systems. In Middle Eastern petro-states, these tradeoffs are particularly acute because subsidy reform intersects with household welfare, fiscal stability, energy security, and climate vulnerability. This makes fuel-specific subsidy analysis relevant not only for emissions policy but also

for broader sustainable energy reform and long-term development planning.

Using a fixed-effects panel model covering 2010-2023, this analysis examines the statistical association between GHG emissions and energy subsidies, disaggregated by fuel type. In doing so, the paper contributes to the literature by identifying which subsidy types are most closely associated with emissions outcomes in a cross-country setting. The results suggest that gas subsidies exhibit the most consistent association with emissions, while other subsidy types show less stable relationships across specifications, underscoring the importance of distinguishing among subsidy types in the design of reform strategies. By linking disaggregated subsidy structures to emissions outcomes, the paper provides an empirically grounded perspective on fuel-specific subsidy reform in Middle Eastern petro-states. More broadly, the paper speaks to the resource economics literature on how fossil fuel dependence and subsidy structures shape environmental outcomes in resource-rich economies, where fiscal reliance on hydrocarbons complicates the transition away from carbon-intensive energy. The paper proceeds as follows: Section 2 reviews the previous literature; Section 3 describes the data and variables; Section 4 outlines the methodology; Section 5 presents the empirical results; and Section 6 discusses the findings and their policy implications for designing reforms that are both environmentally effective and socially equitable across Middle Eastern petro-states.

2. PREVIOUS LITERATURE

Fossil fuel subsidies are widely recognized as key drivers of excessive energy consumption and GHG emissions. The literature emphasizes that by distorting energy prices, subsidies function as a negative carbon price and disincentivize investment in clean energy and energy efficiency (UNDP, 2021). According to IMF estimates, full reform of fossil fuel subsidies could reduce global carbon dioxide emissions by roughly one-third relative to baseline trajectories, helping align global emissions with the 1.5-2°C thresholds (Parry et al., 2021). Several studies have discussed how energy subsidies impede climate goals, inflate fiscal burdens, and disproportionately benefit wealthier households (GSI, 2019; IISD, 2019; Victor, 2009). Yet empirical assessments remain limited in isolating the impacts of fuel-specific subsidies on emissions, a gap this study aims to address.

Empirical investigations of subsidy-emission relationships have largely relied on simulation or partial-equilibrium models. The Global Subsidies Initiative modeled the removal of fossil fuel consumer subsidies across 26 countries, including Iran, Iraq, Saudi Arabia, and the UAE, and found an average emissions reduction of about 6% by 2025 compared with business-as-usual. Reinvesting fiscal savings in renewables and efficiency could roughly double that impact by 2030 (GSI, 2019). Similarly, an IMF global simulation estimated that pricing fossil fuels at efficient levels, accounting for both supply and environmental costs, could reduce CO_2 emissions by 36% below the baseline by 2025, while raising substantial fiscal revenue and preventing millions of pollution-related deaths (Parry et al., 2021). These findings demonstrate the scale of potential gains from comprehensive reforms paired with green reinvestment.

Several studies have examined individual countries relevant to this analysis. Moshiri (2013) estimated price and income elasticities for electricity, natural gas, and gasoline in Iran, finding that subsidy removal alone produces limited demand reductions without complementary efficiency measures. Aryanpur et al. (2022a) evaluated the long-term effects of electricity-subsidy reform in Iran and found that gradual price adjustments could reduce total electricity demand by about 16% and lower cumulative CO_2 emissions by roughly 31% by 2050. In a related analysis (Aryanpur et al., 2022b), they estimated that full subsidy removal could have reduced electricity use by 22% and avoided nearly 950 million tons of CO_2 between 1984 and 2017. They also showed that each 5-year delay in reform adds approximately 100 million tons of additional CO_2, underscoring the costs of inaction. Zarepour and Wagner (2022) found that Iran's 2010 reform, which coupled price hikes with universal cash transfers, reduced real household consumption 7-9% and modestly improved income distribution. Darandary et al. (2024) analyzed the 2016 and 2018 electricity price reforms in Saudi Arabia and found a "triple dividend": Improved fiscal performance, reduced growth in electricity demand, and lower emissions. They estimated the reforms avoided 8-102 million tons of CO_2 and saved around USD 1.3-1.4 billion in fuel costs, rising to USD 9.8 billion when accounting for international oil prices. Aldubyan and Gasim (2021) modeled the 2018 energy price reforms in Saudi Arabia and found that both gasoline and residential electricity demand were relatively unresponsive to price and income changes, likely due to structural constraints, such as limited transport and cooling alternatives. Zaidan et al. (2025) found that in Qatar, citizens living in subsidized housing consume 50-100% more electricity than non-citizens or citizens paying market-based rates. This study highlights how subsidy policies shape consumption behavior and highlights the need for tailored reforms that combine pricing adjustments with behavioral and regulatory measures. Gelan (2018) analyzed the impacts of a 25% reduction in energy subsidies in Kuwait and found that, without compensation, the reform led to sharp increases in energy prices (e.g., 255% for electricity) and a modest GDP decline of about 0.3%. When paired with direct cash transfers, however, the reform not only offset welfare losses but increased GDP by roughly 1%, underscoring the importance of complementary redistributive policies. These studies provide valuable national insights but underscore the need for comparative, data-driven analysis across Middle Eastern petro-states.

The political economy of energy pricing is particularly complex in Middle Eastern petro-state economies. These states have historically used fossil fuel subsidies to maintain political legitimacy and social contracts, especially in the absence of broad-based taxation or democratic accountability (Fattouh et al., 2019; Krane, 2020). Reform feasibility and design have become central themes in the subsidy literature, with numerous studies highlighting the political, economic, and institutional challenges of implementing reforms in a socially acceptable manner (Droste et al., 2024; Inchauste and Victor, 2017; Laan and Steenblik, 2023;

Lockwood, 2015; Parry et al., 2021; Rentschler and Bazilian, 2017; UNDP, 2021). The consensus points to gradualism, targeted transfers, and transparent communication as core principles for success (Sterner, 2015; Victor, 2009). This study builds on these insights by translating them into empirically informed recommendations tailored to the Middle Eastern context.

Beyond GHG emissions and fiscal effects, the literature identifies important co-benefits from subsidy reform. Fossil fuel use contributes to severe air and water pollution, congestion, and other urban externalities that cause millions of premature deaths annually (Campbell-Lendrum and Prüss-Ustün, 2019; Jones et al., 2012; Parry et al., 2021; UNDP, 2021; WHO, 2024). Reframing reform around these local health and development benefits can enhance political support, particularly where climate mitigation is not a public priority (UNDP, 2021). Kheiravar (2019) found that Iran's price and consumption-cap reforms significantly improved Tehran's air quality. These findings reinforce the multi-dimensional relevance of subsidy reform for sustainable development.

Overall, the literature shows that subsidy reform is not only an energy-pricing issue but also a sustainable development challenge involving fiscal capacity, household welfare, environmental quality, and long-term transition planning. This study contributes to this discussion by providing comparative evidence on how fuel-specific subsidy structures are associated with emissions outcomes in Middle Eastern petro-states, where fossil fuel dependence, fiscal policy, and climate vulnerability are closely intertwined.

3. DATA

The data on energy subsidies used in this study were obtained from the International Energy Agency for the period 2010-2023 (IEA, 2024). The IEA applies a price-gap approach, defining subsidies as the difference between end-user prices and reference prices that reflect the full cost of energy supply. Reference prices are adjusted for trade position: In exporting economies, subsidies represent the opportunity cost of selling domestically below export parity, whereas in importing economies, they reflect direct budgetary outlays. All prices are quality-adjusted and converted to USD using prevailing exchange rates. For electricity, the IEA estimates subsidy levels based on the annual average cost of generation, transmission, and distribution within each country. This benchmark excludes capacity-expansion costs but adjusts for generation efficiency and fossil fuel input prices to ensure comparability. This consistent framework captures explicit subsidies for both fuels and electricity. These are the subsidies that directly affect fiscal accounts and consumer prices, making the data well suited for analyzing the relationship between government-supported energy pricing and emissions.

Data on GHG emissions were drawn from the Emissions Database for Global Atmospheric Research (EDGAR, 2025), which provides sector-specific and internationally comparable estimates for all countries from 1970 onward. The consistency and coverage of this dataset make it well suited for examining emission trends in relation to energy-subsidy reforms across countries. Economic indicators, GDP and GDP per-capita, were obtained from the World Bank (n.d.). Renewable energy data were sourced from the Sustainable Development Goal 7 (SDG7, n.d.) database, which measures the share of modern renewables in total final energy consumption. Together, these indicators provide consistent controls for economic development and energy-transition trends. Annual global oil prices were incorporated as an additional control variable, using Brent crude oil prices from the World Bank (2026) Commodity Price Data. Table 1 summarizes the key variables used in the analysis.

4. METHODOLOGY

4.1. Conceptual Framework

This section outlines the main channels through which fuel subsidy reforms may be associated with variations in GHG emissions and explains why the overall relationship requires empirical investigation. These relationships are multifaceted and shaped by economic behavior, fuel substitution patterns, and fiscal policy responses that differ across countries and sectors.

A primary mechanism is the price elasticity of demand: Reducing subsidies raises fuel prices, which may lower consumption (Parry et al., 2021; Sterner, 2007). The strength of this effect depends on income levels, energy intensity, and available substitutes. Low-income households may cut consumption more sharply, while industries may respond by improving efficiency or switching fuels (Arze del Granado et al., 2012).

Higher fossil-fuel prices can also strengthen the competitiveness of renewables and energy-efficient technologies. Consumers may adopt cleaner appliances, shift to public transport, or reduce overall demand. On the supply side, utilities may invest in cleaner energy sources (Bridle et al., 2019; IMF, 2013; Merrill et al., 2015). These behavioral and structural adjustments amplify the long-term impact of the reforms.

Fiscal effects represent another important channel. Lower subsidies free public resources that can be redirected toward renewable energy, social protection, or infrastructure investment. The extent of reinvestment determines whether reforms yield sustained developmental and environmental gains (Parry et al., 2021).

Finally, reforms may trigger fuel switching dynamics. Changes in relative prices can shift the consumption among gasoline, diesel, and natural gas, with varying carbon intensities. The net effect on emissions depends on the balance of these substitutions (Kheiravar, 2019).

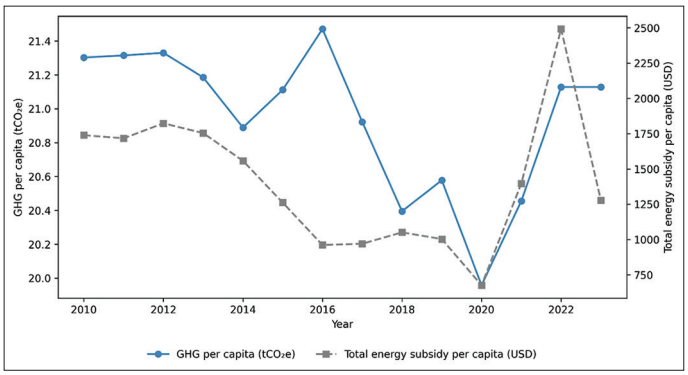
Given the interplay among these factors and the variation in responses across different contexts, the relationship between fuel subsidy reform and GHG emissions is complex. It remains, in part, an empirical question that requires analysis to capture real-world differences in policy implementation and market dynamics. Careful empirical investigation is therefore essential to disentangle these effects and clarify how subsidy reforms are associated with environmental outcomes across economies and energy markets. Figure 1 provides a preliminary illustration of this association, showing that regional averages of GHG emissions and total energy

Table 1: Summary Statistics for key variables (2010-2023, five Middle Eastern petro-states)

Variable	Unit	Obs.	Mean	Median	Standard deviation	Min	Max
GHG emissions	Metric tons (tCO_2e)	70	20.94	22.31	10.86	6.85	42.02
Total subsidy	USD	70	1406	1286	954	160	4388
Oil subsidy	USD	70	500	381	449	17	1864
Gas subsidy	USD	70	439	325	422	3	1954
Electricity subsidy	USD	70	467	353	443	6	2391
GDP	USD	70	23,545	26,385	16,861	2,918	50,924
Renewable energy share	Percentage	60	0.47	0.12	0.49	0	1.67
Brent oil	USD	14	97.85	85.19	35.23	50.66	153.02

(1) All monetary variables are expressed on a per-capita basis and in constant 2023 USD, except Brent crude oil prices, which are expressed in constant 2023 USD per barrel. (2) GHG emissions are expressed on a per-capita basis. (3) Renewable energy share refers to the share of modern renewables in total final energy consumption (SDG7 database). (4) Brent crude oil price varies only by year; observations reflect 2010-2023

Figure 1: Regional trends in Greenhouse Gas emissions and total energy subsidies, 2010-2023



subsidies per capita across the five Middle Eastern petro-states have generally moved in the same direction over time, reinforcing the need for systematic empirical investigation.

4.2. Empirical Method

This study employs a panel data approach to examine the relationship between energy subsidies and GHG emissions in Middle Eastern petro-states during 2010-2023. Equation (1) specifies the baseline regression specification:

$$\text{Ln}\,(\text{GHGpc}_{it}) = \beta_1\,\text{Ln}\,(\text{SUBSIDYpc}_{it}) + \beta_2\,\text{Ln}\,(\text{GDPpc}_{it}) + \beta_3\,\text{REShare}_{it} + \alpha_i + \lambda_t + \epsilon_{it} \quad (1)$$

where *i* indexes country and t year. The dependent variable is GHG emissions per capita (metric tons of CO_2-equivalent). The key independent variable is energy subsidies (USD) per capita, analyzed both in aggregate and disaggregated by fuel type (oil, gas, and electricity). Control variables include GDP per capita and the share of renewable energy in total final energy consumption. Figure 2 provides a visual overview of the relationships between GHG emissions and energy subsidies by fuel type, illustrating the overall variation in the data and the motivation for examining these relationships empirically.

A fixed-effects model was employed in preference to the random effects model. Although the Hausman (1978) test occasionally favors random effects, the core assumption of no correlation between unobserved country characteristics and explanatory variables is implausible in this context. The Fixed-effects model captures within-country variation more credibly over time (Hsiao, 2022; Wooldridge, 2010). Country fixed effects (α_i) account for structural differences that are constant over time, while year fixed effects (λ_t) capture global shocks, such as oil price fluctuations, economic crises, or the COVID-19 pandemic.

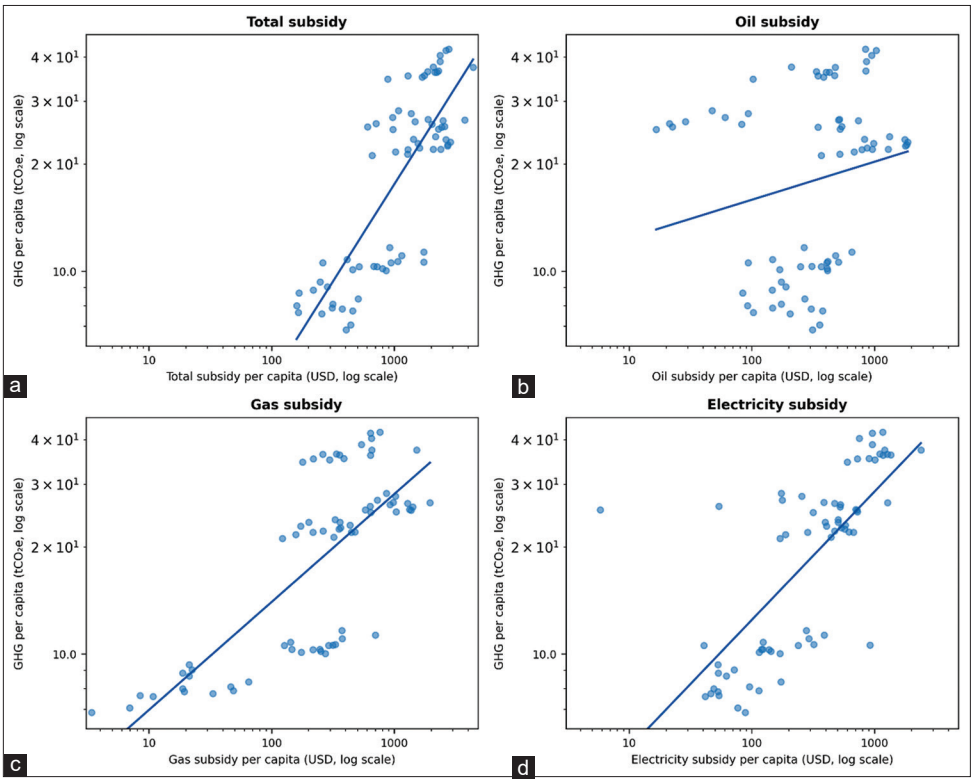
The sample covers 2010-2023 and includes only country-years with complete data on subsidies, emissions, and controls to preserve comparability. The number of observations varies slightly across models due to missing renewable-energy data.

All continuous variables (subsidies, GHG emissions, and GDP) are transformed into natural logarithms to stabilize the variance of the error terms, reduce skewness, and limit the influence of extreme values (Gujarati and Porter, 2009). This specification also allows coefficients to be interpreted as percentage association, improving comparability across scales.

Heteroskedasticity-robust standard errors (White, 1980) are employed rather than clustered errors. With a relatively small number of clusters (countries), conventional clustering risks downward-biased inference (Cameron and Miller, 2015), whereas the inclusion of both country- and year-fixed effects helps account for time-invariant country characteristics and common time shocks, though residual within-country persistence may remain. This approach avoids efficiency losses while maintaining reliable inferences (Angrist and Pischke, 2009). Inference robustness is further examined using country-clustered wild bootstrap procedures, as reported in Section 5.2.1.

This framework estimates the association between emissions and total and fuel-specific subsidies while controlling for GDP and renewable-energy trends. The model's design allows for testing heterogeneity across fuel types and evaluating robustness through alternative specifications. A key limitation of this design is the potential for reverse causality: Countries with higher emissions may face stronger political incentives to maintain subsidies, which could bias the estimated associations. While reverse causality and omitted variable bias cannot be fully ruled out, robustness checks including 1-year lagged subsidy specifications reported in Appendix Table A-1 provide evidence that the estimated associations are reasonably stable across specifications. Results should accordingly be interpreted as associations rather than causal effects.

Figure 2: Greenhouse gas emissions versus energy subsidies by fuel type: (a) total subsidy, (b) oil subsidy, (c) gas subsidy, (d) electricity subsidy. Per-capita values, log scales.



5. RESULTS

5.1. Regression Results

The regression results in Table 2 show a consistent positive relationship between GHG emissions and energy subsidies. In the fully specified model, which includes GDP, renewable energy share, and country- and year-fixed effects, the estimated coefficient on subsidies is 0.122 and statistically significant at the 1% level. Accordingly, a 10% lower level of total subsidies is associated with approximately a 1.2% lower level of emissions, conditional on the included controls and fixed effects. The relationship remains statistically significant, even in simpler models with fewer controls. In the model that controls GDP but excludes the renewable energy share, the estimated coefficient is 0.110 ($P < 0.01$). In the parsimonious specification that excludes both GDP and renewable energy share, the coefficient falls to 0.044 but remains significant at the 10% level. This progression indicates that, while the magnitude of the association is attenuated when controls are omitted, the positive link between subsidies and emissions is robust across specifications.

When subsidies are disaggregated by fuel type, the results reveal important differences. For oil subsidies, the estimated relationship is positive across all models but small and statistically fragile. In the fully specified model, the estimated coefficient is 0.028, which is not significant at conventional levels ($P > 0.1$). The association becomes somewhat larger and statistically significant in the model that controls for GDP but excludes the renewable energy share (0.035, $P < 0.05$), and remains positive but only marginally significant in the parsimonious model that excludes both controls (0.025, $P < 0.1$). The lack of stability across the models suggests that the relationship between oil subsidies and emissions should be interpreted cautiously.

For electricity subsidies, the results indicate no consistent relationship with emissions. Across all three models, the coefficients remain very small in magnitude, ranging from about 0.002 to 0.014, and are statistically insignificant. This consistent null finding is robust across specifications, indicating that electricity subsidies in this sample do not show a strong or generalizable association with emissions.

In contrast, gas subsidies have the most consistent and sizable association with emissions. In the fully specified model, the estimated coefficient is 0.103 and statistically significant at the 1% level, meaning that a 10% lower level in gas subsidies is associated with about a 1% lower level in emissions. The results are virtually unchanged in the model that controls GDP but excludes the renewable energy share (0.100, $P < 0.01$) and in the parsimonious model that excludes both controls (0.095, $P < 0.01$). The stability of these estimates across specifications indicates a consistent association between gas subsidies and GHG emissions. This pattern is consistent with the central role of natural gas in both direct energy use and electricity generation across the sample countries, which may link gas subsidies to emissions through multiple consumption and power-sector channels.

The estimated magnitudes are modest but economically meaningful and broadly consistent with values reported in the energy literature. Because these estimates reflect aggregate emissions responses rather than sector- or fuel-specific demand elasticities, smaller magnitudes are expected. Overall, the results indicate that changes

Table 2: Regression results: Energy subsidies and GHG emissions in five Middle Eastern petro-states (2010-2023)

	Ln (GHG)											
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Ln (Total subsidy)	0.0435*	0.1095***	0.1216***									
	(0.024)	(0.032)	(0.030)									
Ln (Oil subsidy)				0.0251*	0.0354**	0.0281						
				(0.014)	(0.015)	(0.017)						
Ln (Electricity subsidy)							0.0064	0.0141	0.0017			
							(0.012)	(0.014)	(0.016)			
Ln (Gas subsidy)										0.0954***	0.1002***	0.1026***
										(0.014)	(0.014)	(0.015)
Ln (GDP)		0.2312***	0.3354***		0.1056	0.1571**		0.0747	0.1023		0.0927**	0.1466***
		(0.079)	(0.081)		(0.065)	(0.073)		(0.072)	(0.083)		(0.044)	(0.045)
RE share (%)			−0.1007***			−0.1005**			−0.1269***			−0.0327
			(0.034)			(0.042)			(0.045)			(0.030)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R_2	0.990	0.991	0.993	0.990	0.990	0.991	0.989	0.989	0.990	0.994	0.995	0.996
Observations	70	70	60	70	70	60	70	70	60	70	70	60

(1) All monetary and emission variables are expressed on a per-capita basis. (2) Robust standard errors are in parentheses. (3) *** $P<0.01$, ** $P<0.05$, * $P<0.1$

in subsidy levels are associated with non-negligible differences in per-capita emissions.

Figure 3 summarizes the estimated elasticities from the fully specified model, with 95% confidence intervals shown for total and fuel specific subsidies.

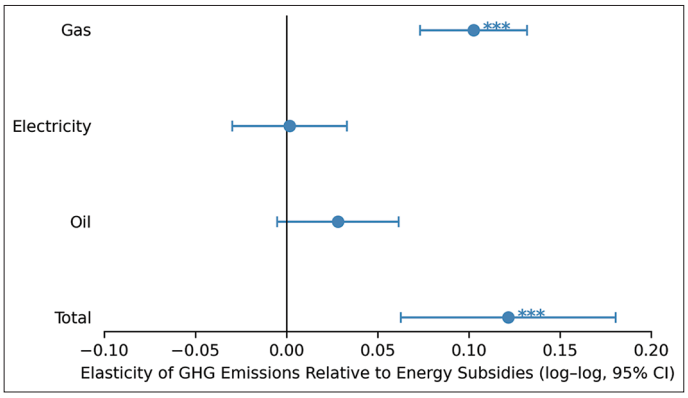
5.2. Robustness and Specification Diagnostics

While the empirical results show statistically significant and theoretically consistent patterns, the fully specified models also display signs of multicollinearity, as reflected in the extremely small eigenvalues of the design matrix (e.g., as low as 5.03e-34). Multicollinearity does not bias coefficient estimates but can inflate the standard errors and reduce precision. To assess the implications of shared variation across fuel types, additional multicollinearity diagnostics were conducted for the disaggregated subsidy measures. Pairwise correlations and variance inflation factors (VIFs) reveal substantial shared variation among oil, gas, and electricity subsidies; despite only moderate pairwise correlations, multicollinearity arises from strong joint linear dependence across subsidy measures, such that their simultaneous inclusion would substantially inflate standard errors and reduce estimation precision (Appendix Table A-2). Accordingly, fuel-type effects are examined in separate specifications rather than jointly, with interpretation focusing on coefficient sign, stability across models, and relative robustness rather than direct cross-fuel coefficient comparison. Despite these specification challenges, the coefficients for total and gas subsidies remain stable and statistically significant across models. The relationship for oil subsidies is small and sensitive to model specification, becoming significant only when the renewable energy share is excluded, suggesting overlap in explanatory power. For electricity subsidies, they remain small and insignificant, a result consistent across diagnostic checks. This warrants cautious interpretation, as it may reflect aggregation at the national level, limited within-country variation, or indirect effects operating through the generation mix rather than the absence of an underlying relationship.

The models also report Durbin-Watson statistics below 1.2, indicating a mildly positive serial correlation in the residuals. In the context of this study, such autocorrelation is expected; the data are structured as annual country-level panel observations, and both subsidy policies and emissions evolve through path-dependent and gradually changing political and economic processes. This persistence is consistent with the nature of both variables, which are typically slow-moving outcomes shaped by long-term institutional and infrastructure dynamics. As a result, some degree of autocorrelation in the residuals is expected in this type of static-panel framework. While fixed effects absorb time-invariant and globally shared shocks, they do not fully capture within-country unobserved factors that persist over time. Although serial correlation may affect conventional standard errors, the stability of the estimated coefficients across specifications and the consistency of results under conservative wild cluster bootstrap inference indicate that the central associations are robust.

Missing data for the renewable energy share reduced the number of observations from 70 to 60 in the fully specified models.

Figure 3: Estimated elasticities of Greenhouse Gas emissions with respect to energy subsidies by fuel type (2010-2023, fully specified model)



While this may limit the statistical power, the consistency of the coefficient estimates, particularly for gas and total subsidies, across specifications suggests that the results are not driven by changes in the sample composition.

The adjusted R-squared values are consistently above 0.98 across all specifications. This high fit reflects the use of fixed effects, which absorb much of the country-level and year-level variation, combined with the strong explanatory power of GDP and renewable energy share. These values are consistent with the structure of the model and should not be interpreted as evidence of overfitting.

5.2.1. Inference robustness in a small-cluster panel

Given the small number of clusters (countries) and the presence of within-country persistence in both subsidy policies and emissions, additional inference checks were conducted using country-clustered wild bootstrap procedures. These methods are specifically designed to improve the reliability of statistical inference in panel settings with few clusters and serially correlated errors (Cameron et al., 2008). Importantly, this procedure affects statistical inference but does not alter coefficient estimates, which remain identical to those reported in the baseline fixed-effects models (Table 2).

Bootstrap-based inference is applied to the fully specified models (3, 6, 9, and 12 in Table 2). The results reinforce the central patterns identified in the baseline analysis. The coefficient on total subsidies remains statistically significant, although the level of significance weakens to the 10% threshold under conservative bootstrap inference, reflecting reduced precision associated with the small number of countries. Among disaggregated fuel types, gas subsidies remain statistically significant at the 5% level, confirming that gas subsidies exhibit the most robust and precisely estimated association with per-capita emissions. Oil and electricity subsidies remain statistically insignificant in the fully specified models, and this result is unchanged under bootstrap-based inference. Overall, these results reinforce the central role of gas subsidies while indicating that aggregate subsidy estimates are more sensitive to conservative inference in small-sample panel settings. Detailed bootstrap results are reported in Appendix Table A-3.

5.2.2. Sensitivity to time-varying factors and dynamic adjustment

To examine the sensitivity of the estimated relationships to additional time-varying influences, robustness checks were conducted for the fully specified models. First, specifications including global oil prices were estimated without year fixed effects to avoid perfect collinearity, as oil prices vary only over time. The inclusion of oil prices does not materially alter the estimated subsidy coefficients. Total and gas subsidies retain positive and statistically significant associations with per-capita emissions, while electricity subsidies remain statistically insignificant. Oil subsidies become marginally significant at the 10% level, indicating a weak and specification-sensitive relationship. The results also show a statistically significant negative contemporaneous association between global oil prices and per-capita emissions during the sample period (Appendix Table A-4). Second, dynamic sensitivity was assessed using 1-year lagged subsidy measures (Wooldridge, 2010). The lagged specifications confirm the baseline findings: Total and gas subsidies continue to exhibit positive and statistically significant associations with emissions, while oil and electricity subsidies remain statistically insignificant (Appendix Table A-1). These two specifications indicate that the estimated associations for both total and gas subsidies are not driven by short-term contemporaneous fluctuations or global price movements.

Taken together, the diagnostic checks indicate that, while there are specification challenges, particularly multicollinearity, mild serial correlation, and limited cluster size, they do not materially alter the central empirical patterns. The strong and consistent association between gas subsidies and GHG emissions remains robust across specifications, while the positive relationship for total subsidies persists but is estimated with reduced precision under conservative inference.

6. CONCLUSION AND POLICY IMPLICATIONS

The empirical results indicate a consistent and statistically significant association between energy subsidies and GHG emissions across Middle Eastern petro-states. In the fully specified model, a 10% lower subsidy level is associated with a 1.2% lower emissions level, suggesting a consistent aggregate, cross-country relationship. When disaggregated by fuel type, gas subsidies show the most consistent and sizable association with emissions, whereas oil subsidies exhibit weaker and specification-sensitive relationships, and electricity subsidies show no statistically meaningful pattern. Taken together, these results point to the prominence of gas subsidies in explaining cross-country variation in emissions and to their relevance as a policy focus for further empirical and reform analysis. A plausible mechanism underlying this pattern relates to the central role of natural gas in electricity generation across the sample countries. In these systems, subsidized gas prices affect both direct consumption and the cost structure of power generation, thereby influencing emissions through multiple channels. In contrast, oil subsidies are more concentrated in transport and industry, while electricity

subsidies operate downstream and may reflect administered pricing structures that partially decouple end-user prices from underlying fuel costs.

These aggregate patterns are consistent with differences in sectoral energy use and responsiveness to price changes. It is important to note that these estimates are derived from national-level data and therefore reflect economy-wide average emissions responses rather than sector-specific demand elasticities. Sectoral responses to price reform vary. Household energy demand is generally more price-responsive than industrial demand (Arze del Granado et al., 2012; IMF, 2013). In Middle Eastern petro-states, natural gas plays a central role in residential use and power generation, while energy-intensive industries such as petrochemicals, aluminum, and steel tend to be less responsive in the short run due to capital intensity and limited substitutes (Fattouh and El-Katiri, 2013; IEA, 2023b; Krane, 2019). Commercial and transport energy demand generally show moderate responsiveness to price changes, falling between the relatively elastic household sector and the less flexible industrial sector (Arze del Granado et al., 2012; Burke and Nishitateno, 2013; IMF, 2013; Sterner, 2007; UNDP, 2021). These sectoral nuances underscore the need for reform strategies adapted to usage patterns and available alternatives. Broad, uniform subsidy removal may miss these distinctions, whereas targeted approaches can maximize both environmental and social outcomes.

6.1. Why Reform is Politically and Socially Difficult

Despite the compelling environmental rationale and quantifiable benefits, subsidy reform remains politically and socially complex in Middle Eastern petro-states. Subsidies are not merely economic instruments; they are deeply entrenched political tools used to secure public support, stabilize social contracts, and mask structural economic challenges (Inchauste and Victor, 2017; Victor, 2009). Reforms are often resisted by political elites and interest groups that capture the gains from subsidized energy, particularly energy-intensive industries and wealthier consumers (Olson, 1971; Peltzman et al., 1989; Stigler, 1971).

The social and political acceptability of reforms is a decisive factor in their success or failure. Energy subsidies are widely perceived as essential to household welfare, especially among lower-income populations, for whom energy constitutes a larger share of expenditures. Removing subsidies without adequate compensation has frequently been associated with inflationary pressures and episodes of social unrest. Recent cases in Iran, Lebanon, Chile, France, and Bolivia illustrate how fuel price increases, even if economically justified, can ignite widespread protests when perceived as unfair or poorly communicated (Parry et al., 2021; UNDP, 2021).

Institutional and administrative capacity also constrain feasibility. Many governments lack accurate registries, digital infrastructure, or coordination among agencies needed to deliver targeted support, while rural and low-income households often have few affordable alternatives. Abrupt reforms can therefore deepen inequities and erode credibility. Successful reforms depend on gradual implementation, transparency, and visible compensatory measures that build public trust.

6.2. Beyond Climate: Health and Social Co-Benefits of Reform

While climate mitigation remains a central objective, subsidy reform can yield substantial local benefits that strengthen its social and political appeal. Fossil fuel combustion contributes to air and water pollution, congestion, and other urban externalities that impose significant health and economic costs (Campbell-Lendrum and Prüss-Ustün, 2019; UNDP, 2021; WHO, 2024). Framing reforms in terms of these immediate, tangible benefits can enhance support, particularly in societies where long-term climate concerns are less salient (UNDP, 2021).

Empirical evidence reinforces these points. In Iran, reforms combining higher fuel prices with consumption caps improved Tehran's air quality, reducing pollutants such as O_3, PM_{10}, CO, and NO_2 (Kheiravar, 2019). Similar results are plausible in other gas-dependent countries where power generation and transport dominate emissions. By emphasizing both global and local benefits, policymakers can strengthen the narrative for reform and link it to broader sustainable-development objectives.

6.3. A Roadmap for Effective and Just Reform in the Region

Designing and implementing effective fossil fuel subsidy reforms in Middle Eastern petro-states requires a deliberate, phased, and politically grounded approach. Building on the empirical finding that gas subsidies exhibit the most consistent association with emissions, and drawing on the broader literature and practical considerations, this section outlines key design considerations and implementation pathways for reform.

- Conducting pre-reform diagnostics: Policymakers should begin with a robust assessment of the scale, incidence, and distributional effects of subsidies to identify which groups benefit most and which are most vulnerable. Evidence from Ghana shows that petroleum subsidies were disproportionately captured by higher-income households, helping build support for reform and redirect savings toward pro-poor spending (Bacon and Kojima, 2006). Similar exercises in Middle Eastern petro-states would strengthen the legitimacy and effectiveness of reforms. Studies in countries such as Iran and Saudi Arabia have examined the incidence, distributional impacts, and fiscal dimensions of subsidies, highlighting the importance of rigorous diagnostics before implementing reforms (Fattouh and El-Katiri, 2013; Krane, 2019; Moshiri, 2013). Embedding rigorous incidence and distributional diagnostics at the outset of reform would not only strengthen credibility but also provide a solid empirical foundation for designing compensation measures tailored to regional political economies.
- Tailoring reforms based on fuel types and sectoral contexts: The results of this study underscore the importance of evaluating subsidies by fuel type rather than treating them as a single aggregate category. Gas subsidies show a stronger and more consistent association with emissions, oil subsidies

appear more modest and sensitive to renewable penetration, and electricity subsidies display no generalizable association. These differences highlight the value of disaggregated analysis in identifying where subsidies are most closely linked to emissions and where sectoral conditions, such as demand elasticities, technology options, and the composition of the energy mix, may moderate outcomes. This is especially relevant where natural gas is central to power generation and industry, oil remains dominant in transport, and electricity mixes are gradually shifting with renewable investments. Understanding how subsidies interact with these distinct fuel-use patterns enables policymakers to design reforms that are environmentally effective, economically feasible, and aligned with the characteristics of the national energy system.

- Sequencing and timing reforms carefully: Gradual reforms give households and firms time to adapt, build predictability, and reduce the risk of social unrest. Governments should also seize favorable political or market windows, such as post-election periods or oil price downturns, when more ambitious measures may be feasible. Evidence from Iran and Indonesia shows that abrupt, unplanned price shocks often trigger backlash, whereas phased approaches strengthen acceptance (UNDP, 2021). In Middle Eastern petro-states, where subsidies are closely tied to social contracts, aligning reform timing with favorable conditions is particularly critical.
- Reallocating fiscal savings visibly and progressively: Savings from subsidy removal should be channeled into strengthening social protection systems and visible public investments, such as direct cash transfers, energy efficiency programs, and improvements in health, education, and transport. Evidence shows that energy-decoupled transfers effectively protect vulnerable households while preserving incentives to conserve energy (IMF, 2023, 2013; UNDP, 2021). In Middle Eastern petro-states, where subsidies often represent a large share of spending, making reallocation transparent and progressive is essential for trust and reform durability. Iran's 2010 reform illustrates both potential and limitations where near-universal cash transfers initially improved equity and acceptance, but inflation and administrative challenges eroded effectiveness over time (UNDP, 2021). This highlights the need for well-targeted and durable mechanisms to ensure that fiscal savings translate into lasting welfare and environmental gains.
- Prioritizing communication and trust building: Governments must clearly explain the rationale for reform, expected benefits, and safeguards. Communication is most effective when tailored to local concerns, such as air quality or congestion, rather than framed solely in abstract climate terms (UNDP, 2021). In many Middle Eastern countries, low institutional trust raises the stakes for credibility and transparency (KAS, 2021). Ensuring consistent messaging, participatory outreach, and visible delivery of compensation is especially critical in these contexts.
- Strengthening institutional coordination and long-term planning: Fossil fuel subsidy reform spans fiscal, energy, and social policy, requiring strong inter-ministerial coordination and dedicated task forces for sequencing and implementation. Fragmented governance and overlapping mandates often complicate coherent energy policies (Fattouh and El-Katiri, 2013; Krane, 2019). Embedding reforms within broader national strategies can improve durability and coherence. For example, Saudi Vision 2030 (n.d.) and UAE Energy Strategy 2050 (n.d.) link subsidy rationalization with diversification and clean-energy goals, framing reform as part of long-term economic transformation. More generally, aligning subsidy reform with future carbon pricing or broader climate targets ensures that short-term changes are consistent with longer-term development pathways (UNDP, 2021).

From a policy design standpoint, effective fossil fuel subsidy reform in Middle Eastern petro-states requires a phased and empirically grounded strategy built on rigorous diagnostics, differentiated pricing across fuels and sectors, and transparent reinvestment of fiscal savings into social protection, energy efficiency, and clean-energy deployment. When coupled with clear communication, institutional coherence, and alignment with broader diversification and energy-transition goals, such an approach can transform subsidy reform from a politically sensitive adjustment into a durable foundation for fiscal sustainability, social equity, and low-carbon growth in the region.

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APPENDIX

Table A-1: Sensitivity to lagged subsidy measures: Energy subsidies and GHG emissions in five middle eastern petro-states (2010-2023)

	Ln (GHG)			
	(1)	(2)	(3)	(4)
Ln (Total subsidy$_{t-1}$)	0.0658** (0.031)			
Ln (Oil subsidy$_{t-1}$)		0.0105 (0.018)		
Ln (Electricity subsidy$_{t-1}$)			−0.0016 (0.018)	
Ln (Gas subsidy$_{t-1}$)				0.0801*** (0.016)
Ln (GDP)	0.1827** (0.082)	0.0866 (0.071)	0.0666 (0.083)	0.0907* (0.052)
RE share (%)	−0.0866* (0.043)	−0.0971* (0.051)	−0.1163** (0.057)	−0.0466 (0.036)
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Adj. R^2	0.992	0.991	0.991	0.995
Observations	55	55	55	55

(1) All monetary and emission variables are expressed on a per-capita basis. (2) Subsidy variables enter the specification with a one-year lag to assess sensitivity to dynamic adjustment and mitigate contemporaneous correlation. (3) Robust Standard errors are in parentheses. (4) ***P<0.01, **P<0.05, *P<0.1

Table A-2: Multicollinearity diagnostics for fuel-specific subsidy measures

Panel A: Pairwise correlations (log, per-capita)			
	Ln (Oil subsidy)	Ln (Gas subsidy)	Ln (Electricity subsidy)
Ln (Oil subsidy)	1.000	0.151	0.544
Ln (Gas subsidy)	0.151	1.000	0.654
Ln (Electricity subsidy)	0.544	0.654	1.000
Panel B: Variance inflation factors (VIFs)			
Variable	**VIF**		
Ln (Oil subsidy)	60.44		
Ln (Gas subsidy)	59.77		
Ln (Electricity subsidy)	137.06		

(1) All monetary variables are expressed on a per-capita basis. (2) VIFs are computed using the log per-capita fuel subsidy variables only, without fixed effects. (3) Total subsidies are excluded from the correlation and VIF diagnostics because they are mechanically constructed from the sum of oil, gas, and electricity subsidies.

Table A-3: Wild cluster bootstrap inference for fully specified models

	Ln (GHG)	
	Heteroskedasticity-robust SEs (White)	Wild cluster bootstrap SEs (Country-clustered)
Ln (Total subsidy)	0.1216***	0.1216*
Ln (Oil subsidy)	0.0281	0.0281
Ln (Electricity subsidy)	0.0017	0.0017
Ln (Gas subsidy)	0.1026***	0.1026**

(1) All monetary and emission variables are expressed on a per-capita basis. (2) Results correspond to the fully specified models reported in Table 2. (3) Wild cluster bootstrap P-values are computed using country-level clustering following Cameron et al. (2008). (4) Coefficient estimates are identical across columns; only statistical inference differs. (5) ***P<0.01, **P<0.05, *P<0.1

Table A-4: Sensitivity to global oil prices: Energy subsidies and GHG emissions in five middle eastern petro-states (2010-2023)

	Ln (GHG)			
	(1)	(2)	(3)	(4)
Ln (Total subsidy)	0.1033*** (0.025)			
Ln (Oil subsidy)		0.0283* (0.015)		
Ln (Electricity subsidy)			0.0062 (0.013)	
Ln (Gas subsidy)				0.0704*** (0.013)
Ln (GDP)	0.299*** (0.067)	0.1675** (0.062)	0.1272* (0.069)	0.1371*** (0.045)
RE share (%)	−0.1048*** (0.029)	−0.0968*** (0.035)	−0.1147*** (0.036)	−0.0836*** (0.027)
Ln (Oil price)	−0.2085*** (0.044)	−0.122*** (0.044)	−0.068* (0.037)	−0.0946*** (0.024)
Country FE	Yes	Yes	Yes	Yes
Year FE	No	No	No	No
Adj.R^2	0.994	0.992	0.992	0.995
Observations	60	60	60	60

(1) All monetary and emission variables are expressed on a per-capita basis. (2) Year fixed effects are excluded because global oil prices vary only over time and would be perfectly collinear with year fixed effects. (3) Robust Standard errors are in parentheses. (4) ***P<0.01, **P<0.05, *P<0.1