

Energy Environment and Economic Studies

ISSN: 3149-8477

available at http: www.econjournals.com

Energy Environment and Economic Studies, 2026, 2(4), 1-15.

Spatial Spillovers of Energy Subsidy Reform on Industrial Emissions across Arab Economies

Muddassar Sarfraz*

College of Business Administration, Prince Mohammad Bin Fahd University, Al-Khobar, Saudi Arabia. *Email: msarfraz@pmu.edu.sa

Received: 10 August 2026 **Accepted:** 07 November 2026 **DOI:** https://doi.org/10.32479/eees.25378

ABSTRACT

Reforms in subsidies will lead to changes in industrial costs; however, changes in regional emissions will be dictated by domestic adjustments and cross-border transfers. This literature review analyzed 21 journal articles and a single regional policy report, with an addition of a numerical analysis that can be replicated. Using Saudi data, a demand for industrial natural gas and electricity is predicted to decrease by 10.36% and 2.70%, respectively, for a 20% price hike assuming activities remain constant. Should there be activity growth, the predicted demand for electricity will likely change from a decrease to an increase. A 4-unit spatial model demonstrates that feedback changes in the indirect effects and that marginal coefficients need to be converted to reflect shocks of finite magnitude. The reforming unit in a hypothesized 20% scenario is predicted to decrease emissions by 5.25%, whereas emissions from other units will increase by 15.94%, with the overall emissions from the units decreasing by 1.10%. These values, however, do not reflect estimates for the Arab countries. Equal-log-shock comparisons distinguish treatment scale from nonlinear aggregation. In addition to a taxonomy of efficiency, substitution, contraction and relocation, this review makes a distinction between industrial emissions from source and trade of embodied goods and services from upstream sectors. In addition to clear policies and regulations regarding implementation, compensation mechanisms and effective industrial prices need to be correlated with their impact on industry specific activities.

Keywords: Energy Subsidy Reform, Industrial Emissions, Spatial Spillovers, Arab Economies, Carbon Leakage, Regional Policy
JEL Classifications: Q35, Q43, Q5

1. INTRODUCTION

Efficiency lowers production's footprint while production itself stays unchanged. Reducing production decreases emissions but also lowers output. Moving a facility might reduce the emissions of one country while increasing the emissions of another. The differentiation of these four solutions is essential to assessing if a policy has caused emissions to drop or just moved them from one location to another.

While many reform policies consider affordability and the country's fiscal situation, it's necessary to dig deeper to consider industrial production, particularly when a business relies heavily on an energy source to sustain operations. An increase in the price of electricity affects an electro-intensive manufacturing business, for instance, differently from a fertilizer producer that might be more impacted by a rise in the price of natural gas. A change in the cost of diesel used to transport goods might affect manufacturing via the cost of shipping. These costs, like so many other aspects of a nation's economy, reach across national borders. As intermediate goods, international investment and energy imports, it's important to understand the different impacts a policy change can have across borders, so a regional analysis of policies needs to account for those various connections.

Recent evidence from the Arab world is a useful starting point. Gasim et al. (2023) measure the energy-demand response across sectors and products in Saudi Arabia. Darandary et al. (2024) assess regional fuel consumption and power-sector emissions related to Saudi Arabia's electricity sector reforms. Timilsina and

This Journal is licensed under a Creative Commons Attribution 4.0 International License

Sebsibie (2026) analyze the removal of energy subsidies in Egypt and the introduction of a carbon tax, considering various ways to recycle the revenues. These studies show why the instruments and the economic context matter. They do not, on their own, estimate how the reforms in one Arab country affects industrial emissions in other countries.

The international literature makes the cross-border case economically compelling. Saussay and Sato (2024) analyze where firms located their energy-intensive industries considering differences in relative energy prices, while Misch and Wingender (2024) look at the causes of carbon leakage by considering country- and sector-specific differences in energy prices. Answering the question for the production networks in the Arab region is dependent on factors such as market access, transport costs, the industrial capacity of countries in the region, financing, and the existence of lower emission technologies. Of these, proximity, as in the case of Russia, may be only one of the various possible cases.

The purpose of this review is to assess what recent research has demonstrated about the spatial impacts of energy subsidy reforms on industrial emissions in Arab economies. The review begins by analyzing available evidence based on reform instruments and economic settings at the regional level. It then relates those findings to different transmission mechanisms and accounting boundaries to interpret emissions changes. Furthermore, it develops an empirical framework and policy implications based on research gaps. The article is a comparative review, accompanied with illustrations and examples that are reproducible. It does not provide a new estimate for an Arab spatial panel and/or simulate a regional reform.

Reform is analyzed as a change in effective industrial incentives in an integrated regional economy. A decrease in subsidized spending does not imply an increase in marginal energy price for a factory. Reduction in territorial emissions does not mean a change in production efficiency. A spatial coefficient does not denote a transmission mechanism unless the relationship that links the economies has an economic meaning. Maintaining these distinctions provides a constructive view for energy and industry related policies as well as for the environment.

2. METHODS

2.1. Review Scope and Source Veri ication

The review draws on English language journal articles published between 2023 and 2026, and on a regional assessment of Arab energy subsidy reform published in 2025. A search of publicly available scholarly publications, publisher and institutional records was undertaken on September 25, 2026. Search terms were energy subsidy reform, industrial energy prices, Arab Economies, Egypt, and Saudi Arabia, industrial emissions, carbon leakage, investment and location, spatial spillovers and spatial policy. Reference tracing was used to connect studies of regional reforms to studies on cross border transmission and identification.

The bibliography contains 22 sources, 21 journal articles and one by the International Monetary Fund. Three types of evidence were retained. Regional studies define and provide evidence of the reform in the context of the Arab Region. International and cross border studies provide evidence of international trade, investment and leakage. Methodological studies provide evidence and inform the design and interpretation of spatial policy. Articles were included in the review based on the verification of their publication and relevance. DOI registration was confirmed through the publisher or the author's institution, using the journal issue year where an article had already been assigned to an issue.

The focus is on Arab Economies, rather than on the entire MENA region. Evidence labeled GCC pertains to the Gulf Cooperation Council; evidence regarding MENA may include non-Arab economies and is interpreted accordingly. International and OECD studies are used for methodological insights and not counted as regional observations. The review does not aim for equal treatment for all Arab economies. Saudi and Egyptian studies provide evidence in the selected corpus that is more detailed than several other regional economies.

This is a focused comparative review, rather than a systematic review. It does not provide database-wide retrieval counts, independent duplicate screening or a pooled effect size. Some retrieved records provided complete articles, while others offered abstracts or methodological summaries. The synthesis focuses on verifiable information. Unverifiable information regarding calibration, estimation and robustness are not assessed, and especially compare national models as evidence for regional effects.

2.2. Comparison and Analytical Boundaries

The reform instrument, the affected user, the outcome boundary, and the design used to attribute the effect, were the criteria against which the sources were compared. An increase in industrial gas prices was distinguished from a household fuel reform; national carbon dioxide was distinguished from other emissions; power-sector emissions were treated as an upstream outcome; and investment or trade responses were distinguished from physical emissions. As a result, what seemed to be a large body of evidence was not created by treating economically different outcomes as if they were equivalent.

Numerical results, when reported, are left with their original units and scenarios. No national mitigation estimates are converted to industrial spillover coefficients. No investment elasticity is expressed as an emissions elasticity. Results from computable general equilibrium models are described as scenario-dependent model results, and observed-data associations are left with their design limitations. The comparison identifies what a study contributes to the regional question and what other evidence would be necessary to complete a causal chain.

The synthesis rests on a distinction between own-economy and external responses. An own-economy response occurs following

a country's own reform; external responses happen following reforms in other countries depending on the exposure of the country in question to those economies. Common oil price shocks, co-integrated industrial slowdowns, or shared policy trends can generate joint emissions, and these need not involve any spillovers in either direction. So, the review considers explicit transmission and identification as essential for a spatial claim.

2.3. Reproducible Numerical Extensions

The review is supplemented by two distinct calculations. The first reconstructs conditional demand responses from published Saudi point estimates, rather than re-estimating demand from the original observations. Gasim et al. (2023, Sections 5.1.4-5.1.5) provide the price and activity responses used in Table 1. For an assumed price increase h and change g in the original model's activity indicator, a constant-elasticity reconstruction gives.

$$\Delta Q\ (\%) = 100[(1 + h)^{\varepsilon}\ [(1 + g)\eta - 1] \quad (1)$$

Here ε is the reported price elasticity and η the reported activity elasticity. Calculations use h between 0.10 and 1.00, with g = 0 unless explicitly stated. Original model-specific activity indicators are retained conceptually; the exercise does not treat every indicator as the same physical output measure. The point estimates are treated as fixed inputs, so the resulting values are conditional calculations without newly estimated standard errors. Extending the price grid does not establish that a constant elasticity remains valid outside the original data support.

The second calculation examines a hypothetical four-unit spatial system. The units A-D are not named countries, and the assumed links are not observed Arab trade or electricity flows. Each unit begins with an emissions index of 100. The symmetric, row-normalized matrix is

$$W = \begin{bmatrix} 0 & 0.5 & 0 & 0.5 \\ 0.5 & 0 & 0.5 & 0 \\ 0 & 0.5 & 0 & 0.5 \\ 0.5 & 0 & 0.5 & 0 \end{bmatrix} \quad (2)$$

Every diagonal entry is zero and every row sums to one. The benchmark sets $\beta = -0.30$, $\theta = 0.10$, $\rho = 0.20$; sensitivity calculations vary ρ over {0, 0.20, 0.40} and θ over {0, 0.05, 0.10, 0.20}. These are assumed emissions-response parameters, not estimates from the regional studies and not conversions of fuel-demand elasticities into emissions elasticities. The policy component of the spatial model is evaluated as

$$\Delta y = M\, r,\ M = (I - \rho W)^{-1}\ (\beta I + \theta W) \quad (3)$$

The vector r contains log changes in effective industrial energy prices, and Δy contains log changes in emissions. Section 5.3 provides the fuller evaluation specification. For $0 \le \rho < 1$, the chosen matrix has spectral radius one and the inverse exists. Numerical checks verify row normalization, the matrix inverse, the direct-indirect decomposition and finite-shock aggregation. Results distinguish published inputs, reconstructed demand responses and wholly illustrative spatial outputs. They do not create a new Arab-country panel or identify a causal cross-border coefficient.

3. RESULTS

3.1. The Reform Instrument Determines Industrial Exposure

Energy subsidy reform should be seen as a wide range of different treatments. Prices of administered fuels can be increased, preferential electricity tariffs removed, costs of utilities changed and prices of industrial feedstock altered. Reforms may be combined, such as removing a tariff and changing an automatic adjustment rule (AAR). Strand (2024) provides an important example of how various types of fuels and tariffs need to be examined in a differentiated manner, along with various country settings, when analyzing GCC energy pricing. Different reform pathways for energy-intensive activities should be considered.

The measurement of the subsidy also deserves attention. Gasim and Matar (2023) provide an important example of the assumptions made in calculating the cost of energy support in Saudi Arabia, and reopen a previous estimate of subsidies. In determining support for the industrial sector, the concept of cost and the reference price must be defined. A gap, or a price shortfall, relative to export parity may both be economically important, but need not imply a change in a firm's marginal incentive to produce, or lead to the same budgetary transfer.

A measured price gap may decline due to a fall in the price of reference, even if domestic prices are not changed. Rising nominal tariffs may be offset by changing the real value of money, for example, due to inflation. A reform focused on aggregate subsidy expenditure, therefore, muddles price, consumption and policy. The correct industrial approach, however, should be focused on the effective input price and the rules that govern preferential treatment.

Table 1: Published elasticities and calculated conditional demand responses

Series	ε	η	h=10% g=0	h=20% g=0	h=20% g=10%
Industrial natural gas	−0.60	1.03	−5.56	−10.36	−1.12
Industrial diesel	−0.14	0.14	−1.33	−2.52	−1.21
Industrial electricity	−0.15	1.27	−1.42	−2.70	9.82
Total industrial energy	−0.30	0.33	−2.82	−5.32	−2.30
Feedstock methane	−0.05	0.26	−0.48	−0.91	1.58
Feedstock ethane	−0.15	0.20	−1.42	−2.70	−0.83
Feedstock LPG/naphtha	−0.31	0.65	−2.91	−5.50	0.54

Elasticities are published point estimates from Gasim et al. (2023), Sections 5.1.4-5.1.5, p. 15. Last three columns are author calculations in percent. Activity refers to each source specification. Aggregate and product rows overlap and are not additive. No new coefficients or confidence intervals are estimated

Table 2 sets out the instruments most relevant to industrial exposure. The distinction between a fuel used for combustion and a fuel used as feedstock is especially important. A process using gas as a material input cannot necessarily respond through the same technical substitution as a boiler. Electricity tariffs also need to be separated from the emissions intensity of the electricity supplied. These distinctions shape both the domestic adjustment and the type of cross-border relationship that should be examined.

Author classification informed by Gasim and Matar (2023), Gasim et al. (2023), Strand (2024), Hasanov et al. (2025), and Timilsina and Sebsibie (2026). The channels are analytical possibilities rather than estimated spillovers. A consumer-price measure does not necessarily describe the price paid by an industrial user.

3.2. Saudi Evidence Separates Demand and Power-System Responses

Saudi literature offers various insights into how domestic adjustments are unfolding. Gasim et al. (2023) take a close look at energy demand, breaking it down across five end-use sectors and fifteen different energy products. They find significant differences in how prices and income affect energy consumption. Their analysis also suggests that energy price reform cut carbon dioxide emissions by a cumulative 164 million tonnes between 2016 and 2018. That number is a model-based national estimate for those years, not a measured drop in industrial emissions alone, and it doesn't account for emission changes in neighboring economies.

Darandary et al. (2024) link electricity-price reforms to fuel consumption across regions and to emissions from the power sector. For the question here, what they add is a way of placing some of the adjustment inside an electricity system that varies from region to region. When demand for electricity falls, generators shift the fuels they burn. So the plant reacts at the factory, but the emissions change happens back at the power station, a different link in the production chain. A manufacturing plant can cut the electricity it buys while its own inventory of direct emissions barely moves.

The study by Hasanov et al. (2025) estimates industrial natural-gas demand and then builds that estimated relationship into a macroeconometric model of Saudi Arabia. With the model in place, they simulate different gas-price paths and follow what each does to the macroeconomy and to individual sectors. For anyone working on industrial emissions, the useful part is how an input-price response gets tied to the rest of the economy. Energy demand, sectoral output and household income can shift together through linked channels, and a national emissions regression won't pull those apart just because it adds a control for industrial value added.

Matar et al. (2024) look at energy policy pathways across seven sectors in Saudi Arabia, and they treat price reform as one piece of a wider set of energy and climate choices. That framing matters. When emissions shift after a price change, some of the shift can come from technology deployment, from efficiency measures, or from a different energy mix. Put the whole change down to subsidy reform and you've squashed a package of policies into a single instrument. So a regional study ought to record those complementary policies first, and only then read any external response as relocation or diffusion caused by the reform.

The evidence from Saudi Arabia points to the need for assessments that focus on specific sectors and products. It highlights that results can vary significantly within different regions of a single country and also when comparing countries. For instance, regional power dispatch under one national policy can create a framework that's useful for cross-border electricity trade. However, this doesn't mean that the same framework will work with the same effectiveness in different sovereign electricity markets, where factors like interconnection capacity, dispatch rules, and settlement arrangements can vary widely.

3.3. Egyptian Models show why Revenue Recycling belongs in the Treatment

In the Egyptian work, price reform keeps coming back to one question: What happens to the public money it frees up. Eldeep et al. (2025) take this on with a dynamic general equilibrium model, looking at climate-policy instruments alongside gender-related outcomes. Subsidy removal and carbon taxation both cut carbon emissions in their results, and in the comparison they model, the carbon tax does more. Still, that finding comes from one specified national policy setting. It doesn't give a general ranking you could carry over unchanged to Arab industries at large.

Timilsina and Sebsibie (2026) model what happens when petroleum subsidies are removed and a carbon tax is introduced, under several different ways of recycling the revenue. When they combine both policies and set the carbon tax at EGP 600 per tonne of carbon dioxide, national emissions drop by up to 11%. How individual sectors' output responds changes depending on which recycling scheme is used. That 11% shouldn't be credited to subsidy removal by itself, though. It comes out of the two instruments working

Table 2: Industrial exposure to different energy reform instruments

Instrument	Immediate industrial exposure	Adjustment to examine	External relationship
Industrial fuel-price increase	Cost of combustion energy	Efficiency, fuel switching or activity reduction	Inputs and competing producers
Feedstock-price reform	Material input cost in a process	Process choice, product mix or capacity	Product and investment markets
Electricity-tariff reform	Purchased electricity bill	Electricity demand and own generation	Grid exchanges and upstream supply
Generator fuel-price reform	Generation costs and dispatch incentives	Which plants serve marginal demand	Electricity-system connections
Transport-fuel reform	Freight and distribution costs	Routing, suppliers and delivered prices	Trade corridors and input sourcing
Compensation or revenue recycling	Net income, financing or input incentive	Whether assistance preserves the marginal price signal	Demand, investment and trade

together and rests on the model's assumptions, and it says nothing about industrial leakage across borders.

The spatial point still carries weight, though. Money handed back to households' works on demand, financing and production costs by one route, and paying down public debt or changing corporate taxes works by others. Picture two countries that put up the industrial fuel price by the same amount but recycle the fiscal gains in different ways. Their industries won't necessarily face the same net incentive. So a treatment variable built across countries ought to record how the revenue gets recycled, instead of reading every tariff increase as the same competitiveness shock.

Compensating households can shift industrial demand too, and it can do so while leaving the marginal incentive to save energy intact. An income transfer props up purchasing power. A rebate tied to how much fuel a firm buys right now is different, because it partly brings back the energy-price subsidy that reform was meant to remove. The two designs may play out differently, both for how credible the reform looks and for how sectors adjust. The review reads this distinction as something that follows analytically from the policy package. It isn't presented as a separately estimated Egyptian spillover.

Looking at the studies from Saudi Arabia is useful because these models tackle different questions. Demand estimates shed light on how products respond, while power-system analysis reveals emissions from upstream sources. Then there are economy-wide simulations that explore how income and sectors interact. It makes sense to weave this evidence together as a series of mechanisms, clearly defining their limits. Just averaging the reported mitigation figures won't yield a unified regional effect or a solid estimate for manufacturing.

3.4. Wider Arab Evidence is Informative but Less Specific about Spillovers

Ibrahiem et al. (2024) look at energy subsidies and carbon dioxide emissions across nine Arab economies from 2010 to 2019, using pooled and panel regressions. They report that subsidies and emissions move together positively, which fits the idea that subsidies push people toward burning more fossil energy. Still, what they find is an aggregate association and nothing finer. It can't pull out the effect of any one industrial tariff reform, and it says nothing about how a reform in one country might shift industrial production and emissions somewhere else.

Lee et al. (2025) survey reform across Arab economies, recording both the progress made and the policy problems that haven't gone away. They put most of their weight on compensation, on how fast reforms get implemented, on institutional improvements and on communication. What matters for this review is how varied the reform packages turn out to be, and the gap Lee et al. draw between what governments announce and what they actually keep implementing. Their assessment gives regional policy context. It does not estimate industrial emissions across borders, and in economies where the journal coverage reviewed here is thin, it shouldn't be read as standing in for sectoral evidence.

Strand's 2024 comparison of the GCC highlights a crucial point about incentives: Even when governments aim for similar reforms, differences between countries and fuels remain. Just because there's a regional group doesn't mean there's a unified approach to industrial energy pricing. Factors like preferential arrangements, price caps, and shifts in how policies are implemented can all impact costs differently. Instead of assuming that being part of a geographical group reflects the real incentives for specific industrial activities, it's better to conduct a spatial analysis that truly measures what those activities face on the ground.

What the selected evidence supports, then, is a limited conclusion. Domestic reform can shift energy use, emissions and outcomes across sectors, though how much depends on the product and on the policy package around it. The Arab sources kept for this review don't give a harmonized estimate of how industrial emissions spill across borders. That gap is why the mechanism analysis and evaluation framework come next. It shouldn't be read as proof that spillovers don't exist, and it doesn't show that every Arab economy is exposed to the same degree.

3.5. International Evidence Identifies Channels without Supplying an Arab Coefficient

Saussay and Sato (2024) use cross-country firm-level data from 41 countries and observe that a 10% change in the differential between bilateral energy prices increases M and As by 3.2%. While relative energy prices affect location decisions, acquisitions do not require relocation of a plant, changing of production, or emission increases.

Misch and Wingender (2024) analyze the determinants of cross-country and cross-sector carbon leakage by using within-country and within-sector energy price changes. They correctly posit that carbon leakage is not only the relocation of production (i.e., territorial emissions), but also includes trade. However, their proposed method for subsidy reform requires both an estimation of policy-specific energy prices and a credible counterfactual, and also does not provide a definitive causal link between a given change in energy price and a policy (i.e., a tax change or commodity market fluctuation).

Kruse-Andersen and Sørensen (2025) split firm relocation from loss of market shares to classify carbon leakage, a useful distinction for manufacturing in the Arab region since demand may be lost to competition without an actual physical relocation. Ambec et al. (2024) study leakage-mitigation policy within a model of trade that incorporates endogenous abatement and confirm that measures meant to provide compensation, like subsidies, are not without an impact on other policy decisions.

The evidence of the spillovers of fiscal policy outside of the region can be useful, especially with a explicit limit of fiscal transfers. Cao et al. (2025) use spatial evaluation to look at the fiscal policy on energy and emission savings that includes industrial links. This provides a methodology that could be used for examining the internal and external reactions to the policy. However, this study uses a different instrument than the fossil fuel subsidy reforms

that occurred in the Arab world, so these policy results cannot be transferred and used for regional fiscal policy.

Table 3 compares selected contributions by the outcome they actually establish. The review finds a coherent set of mechanisms, but uneven evidence along the full chain from industrial energy-price reform to changes in foreign industrial emissions. This distinction between a mechanism supported elsewhere and a causal regional estimate is the main result of the comparison.

Mt denotes million tonnes. Numerical results are reported from the named publications under their original outcome boundaries; they are not recalculated or pooled here. The table selects ten contributions from the review bibliography. It compares relevance, not study quality or the size of a common effect.

3.6. Published Responsiveness Generates different Conditional Demand Changes

Table 1 turns the reviewed demand evidence into explicit calculations. A 20% price increase with activity held fixed implies a 10.36% reduction for industrial natural gas, compared with 2.52% for diesel and 2.70% for electricity. Feedstock methane falls by only 0.91% under the same proportional price assumption. These are calculated responses using different published specifications, not observed outcomes from one common reform. Total industrial energy is an overlapping aggregate and must not be added to the product-specific rows.

The activity column changes the interpretation materially. Combining a 20% price increase with a 10% increase in the corresponding activity indicator gives a 9.82% rise in industrial electricity demand, while the industrial natural-gas response remains slightly negative at −1.12%. Higher prices can therefore reduce demand relative to a counterfactual with unchanged prices even while observed consumption grows. Calling every post-reform increase a failure would ignore the changing activity baseline. Conversely, a decline caused by reduced activity should not automatically be described as improved technical efficiency.

Table 4 and Figure 1 examine the nonlinear price response with activity fixed. For $\varepsilon = -0.60$, a 50% price increase implies a 21.59% reduction, while a doubling implies a 34.02% reduction. The first-order approximation $100\varepsilon h$ would instead give −30% and −60%. Its error grows with the size of the assumed shock because the exact constant-elasticity curve is convex for negative ε.

The approximation error shown in Figure 1b is $100[(1 + h)\varepsilon - 1 - \varepsilon h]$. At h = 0.50 and $\varepsilon = -0.60$ it equals 8.41% points: The linear approximation overstates the magnitude of the demand reduction. These errors are mathematical consequences of the maintained response function, not uncertainty intervals around the source estimates. For small h, the error is approximately $50\varepsilon(\varepsilon - 1)h^2$, which is positive when $\varepsilon < 0$ and explains why linear extrapolation becomes increasingly misleading.

The activity response supplies another policy diagnostic. Offsetting a 10% activity increase in the electricity specification requires $(1 + h)^{-0.15} \times 1.1^{1.27} = 1$. Under the maintained assumptions, the break-even price increase is approximately 124.11%. This value is not a tariff recommendation or a forecast. It demonstrates the sensitivity of an apparently simple price instrument to activity growth and to the particular published specification. Industrial output, fuel substitution, technology and supply constraints still need to be observed before these demand calculations can be translated into emissions.

3.7. Spatial Feedback Changes the Sign and Size of External Responses

Table 5 reports twelve deterministic parameter configurations for the declared four-unit network. For an n-unit marginal-effect matrix M, the average direct, total and indirect effects are defined as

Table 3: Selected evidence and its relevance to industrial spillovers

Study	Setting and design	Verified contribution	Boundary for regional inference
Gasim et al. (2023)	Saudi Arabia; sector- and product-level demand estimation	Modelled cumulative avoided national CO_2 of 164 Mt during 2016-2018	Not an industrial-only or foreign-emissions estimate
Darandary et al. (2024)	Saudi regional electricity and power-system analysis	Links electricity-price reform to fuel use and power-sector emissions	Upstream power emissions differ from plant emissions
Hasanov et al. (2025)	Saudi industrial gas demand and macroeconometric simulation	Traces input-price changes through sectoral and macroeconomic outcomes	Scenario results do not identify foreign industrial emissions
Matar et al. (2024)	Saudi energy-policy pathways across seven sectors	Places price reform within a wider energy-policy package	Complementary policies require separate attribution
Eldeep et al. (2025)	Egypt; dynamic general equilibrium model	Compares climate-policy instruments with distributional and gender outcomes	National model comparison is not a regional effect
Timilsina and Sebsibie (2026)	Egypt; general equilibrium and revenue recycling	Combined subsidy removal and EGP 600/tCO_2 tax scenario reduces national emissions by up to 11%	The reduction is neither subsidy-removal-only nor observed leakage
Ibrahiem et al. (2024)	Nine Arab economies; aggregate panel, 2010-2019	Reports a positive subsidy–CO_2 association	Aggregate association does not identify industrial spillovers
Saussay and Sato (2024)	41 countries; firm-level acquisition flows	10% higher energy-price differential corresponds to 3.2% more cross-border acquisitions	Ownership flows are not physical emissions transfers
Misch and Wingender (2024)	Country–sector energy prices and carbon flows	Examines leakage through domestic and traded carbon outcomes	Energy-price variation is broader than subsidy reform
Cao et al. (2025)	Chinese fiscal policy; spatial evaluation and industrial links	Examines local and external carbon responses	Different intervention and institutional setting

$$ADE = \frac{tr(M)}{n}, ATE = \frac{1^T M 1}{n}, AIE = ATE - ADE \quad (4)$$

Here $tr(M)$ denotes the trace and 1 is the n-vector of ones. The direct effect includes feedback returning to the reforming unit. The indirect effect sums responses outside that unit before averaging over reform origins; it is not the mean of the twelve individual off-diagonal entries. This convention is important for reproducing the reported numbers. With the benchmark parameters, the direct effect is −0.29583, the indirect effect is 0.04583 and their sum is −0.25000. The positive external response offsets part of the negative domestic response while leaving the overall log response negative.

Table 4: Exact demand changes over the declared price grid

Price increase (%)	ε=−0.60	ε=−0.30	ε=−0.15	ε=−0.05
10	−5.56	−2.82	−1.42	−0.48
20	−10.36	−5.32	−2.70	−0.91
30	−14.57	−7.57	−3.86	−1.30
50	−21.59	−11.45	−5.90	−2.01
75	−28.52	−15.45	−8.05	−2.76
100	−34.02	−18.77	−9.87	−3.41

Author calculations: $100[(1+h)^{\varepsilon} - 1]$, with activity fixed. Entries are percent changes in demand, not observed reform outcomes or emissions reductions. The grid explores a maintained functional form, including potentially substantial extrapolation

Table 5: Calculated spatial-effect summaries across twelve assumed configurations

ρ	θ	ADE	AIE	ATE	100 AIE/(−ADE)
0.00	0.00	−0.30000	0.00000	−0.30000	0.00
0.00	0.05	−0.30000	0.05000	−0.25000	16.67
0.00	0.10	−0.30000	0.10000	−0.20000	33.33
0.00	0.20	−0.30000	0.20000	−0.10000	66.67
0.20	0.00	−0.30625	−0.06875	−0.37500	−22.45
0.20	0.05	−0.30104	−0.01146	−0.31250	−3.81
0.20	0.10	−0.29583	0.04583	−0.25000	15.49
0.20	0.20	−0.28542	0.16042	−0.12500	56.20
0.40	0.00	−0.32857	−0.17143	−0.50000	−52.17
0.40	0.05	−0.31667	−0.10000	−0.41667	−31.58
0.40	0.10	−0.30476	−0.02857	−0.33333	−9.37
0.40	0.20	−0.28095	0.11429	−0.16667	40.68

Hypothetical four-unit network; β=−0.30 throughout. ADE is the average diagonal, ATE the average row sum, and AIE their difference. Coefficients are log responses to a unit log-price change. The last column is a marginal ratio (%), not the finite-shock leakage rate. Negative values indicate reinforcing external reductions

Figure 2a makes the network interpretation visible. The benchmark diagonal is −0.29583. Adjacent units have response coefficients of 0.02083, while the opposite unit has 0.00417 despite having no direct edge to the reform origin. The latter arises through network feedback. For a 1% price change, these coefficients provide small-shock approximations in percentage terms; finite changes require exponentiation rather than multiplying a large percentage by the coefficient.

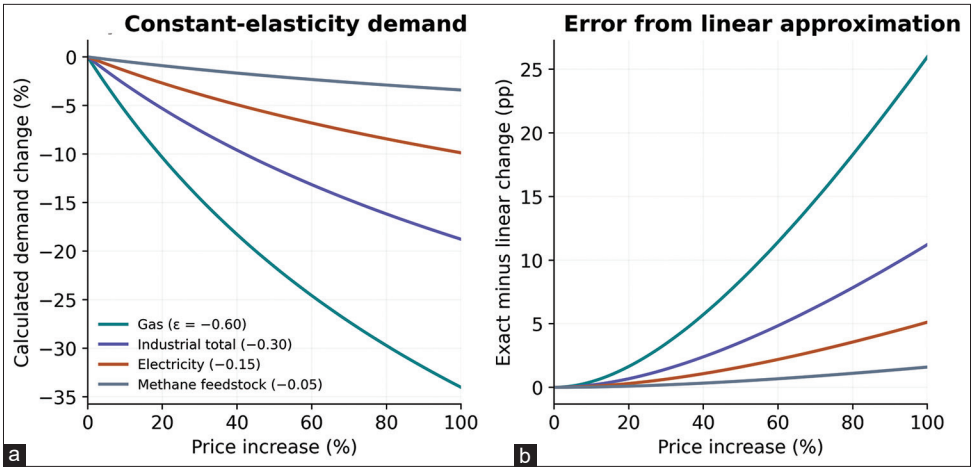
The response matrix can be rearranged to isolate the source of the external sign:

$$M = \beta I + (\theta + \rho\beta)(I - \rho W)^{-1} W \quad (5)$$

For non-negative W and $0 \le \rho < 1$, the inverse expansion has non-negative terms. The sign of nonzero off-diagonal effects is consequently governed by $\theta + \rho\beta$ With $\beta = -0.30$, the sign boundary is $\theta = 0.30\rho$, shown as the dashed line in Figure 2b. At $\rho = 0.20$, raising θ from 0.05 to 0.10 changes the indirect effect from −0.01146 to 0.04583. At $\theta = 0.10$, increasing ρ from 0.20 to 0.40 instead changes it to −0.02857 because the domestic reduction propagates more strongly through outcome feedback.

This result cautions against reading a positive coefficient on externally transmitted reform as a complete leakage estimate. The total response remains $\frac{\beta + \theta}{1 - \rho}$ under the chosen row normalization, while its direct and indirect components depend on the network's feedback paths. Figure 2b is a sensitivity surface, not an estimated relationship for Arab economies. Neither the grid nor its smooth colour field supplies sampling uncertainty, statistical significance or evidence that one transmission mechanism dominates in practice.

Figure 1: Conditional price responses and approximation error. Author calculations from published price elasticities with activity held fixed. Curves show a maintained (a) constant-elasticity response, not observed emissions reductions. Panel (b) subtracts the first-order approximation; pp denotes percentage points



3.8. Finite Shocks Distinguish Leakage from a Coordination Claim

Table 6 compares three explicitly defined policy scenarios at the benchmark parameters. The unilateral scenario raises A's price by 20%. The full-coverage scenario raises every unit's price by 20%, thereby treating 4 times as many units. A third scenario distributes the unilateral total log-price change equally, giving each unit a price increase of approximately 4.66%. The third comparison holds the sum of log shocks fixed; it does not hold fiscal savings, abatement costs or compensation budgets fixed.

To convert the model's log changes into finite emissions changes, the calculation uses

$$E_{i,1} = E_{i,0}\, exp(\Delta y_i),\ \Delta E_i\ (\%) = 100[exp(\Delta y_i) - 1] \quad (6)$$

Under unilateral reform, A's emissions index falls from 100 to 94.749. The directly linked units B and D rise to 100.381, and the opposite unit C rises to 100.076. Regional emissions decline from 400 to 395.586, or 1.10%, rather than by the reforming unit's 5.25%. A finite-shock leakage ratio can be stated for this equal-baseline example as

$$L(\%) = 100\frac{\sum_{i \neq A} E_{i,1} - E_{i,0}}{E_{A,0} - E_{A,1}} \quad (7)$$

The calculated ratio is 15.94%: Increases elsewhere offset approximately that share of A's reduction. The linear marginal-effect ratio is 15.49%, demonstrating that a finite-shock calculation and a marginal calculation need not give identical percentages. The leakage ratio is meaningful here because the domestic denominator is a reduction and all emissions indices use a common scale. It is not an estimate of actual Arab industrial relocation (Figure 3a).

When every unit faces a 20% increase, all four indices decline to 95.544 and the regional total falls by 4.46%. That larger reduction cannot be interpreted as a pure coordination dividend because the total treatment is larger. In the equal-total-log-shock scenario, every index becomes 98.867, giving a regional decline of 1.133%. The unilateral decline is 1.103%, so equal sharing improves the regional percentage change by only about 0.030% points in this benchmark. Figure 3b traces this aggregation gap over the declared price grid.

The small equal-sharing advantage has an accounting explanation. Symmetry makes column sums equal, so the two equal-total-log-shock scenarios have the same sum of log-emissions responses. Because exp(·) is convex, unequal responses produce a weakly higher sum of level emissions than equal responses with the same log sum. The figure therefore illustrates dispersion and nonlinear aggregation, not the institutional benefits of an Arab reform agreement. Heterogeneous baseline emissions, asymmetric trade links, technology adjustment or fiscal recycling could change the comparison. Those extensions require additional evidence rather than an assumption that regional coordination is automatically superior.

Figure 2: Illustrative spatial response matrix and external-effect sensitivity. All network links and spatial coefficients are assumed. Panel (a): β = −0.30, θ = 0.10, ρ = 0.20. Panel (b) holds β fixed and varies θ and ρ; the circle marks the benchmark and the dashed line the zero-indirect-effect boundary. No sampling uncertainty is represented

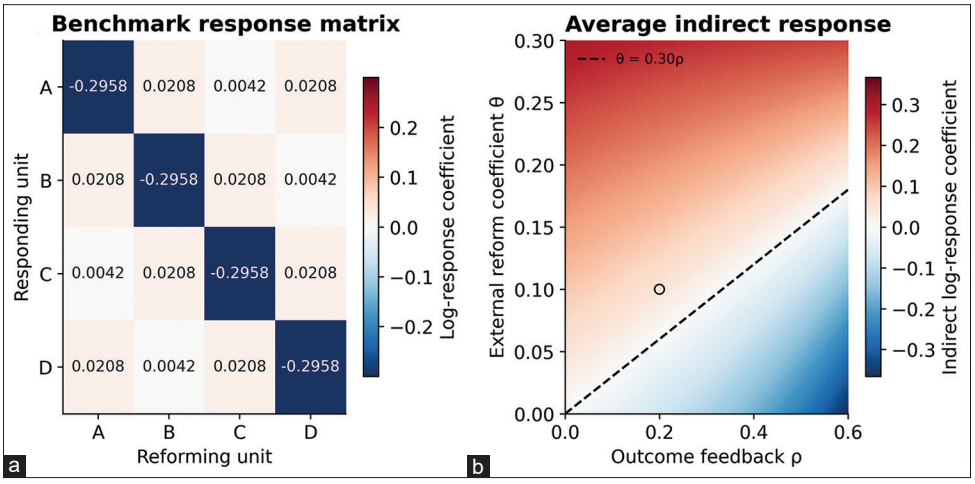
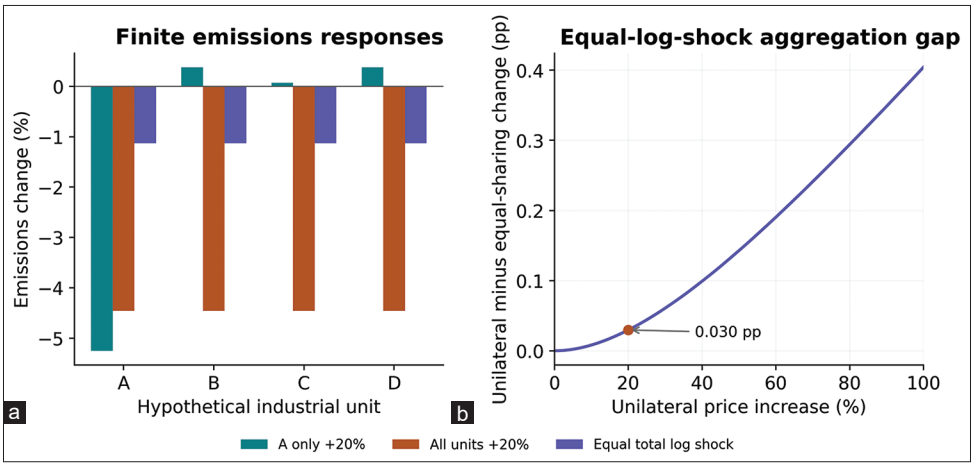


Table 6: Finite emissions indices under unilateral and shared reform scenarios

Unit	E_0	Uni E_1	Uni Δ%	All20 E_1	All20 Δ%	Eq-log E_1	Eq-log Δ%
A	100	94.749	−5.251	95.544	−4.456	98.867	−1.133
B	100	100.381	0.381	95.544	−4.456	98.867	−1.133
C	100	100.076	0.076	95.544	−4.456	98.867	−1.133
D	100	100.381	0.381	95.544	−4.456	98.867	−1.133
Region	400	395.586	−1.103	382.177	−4.456	395.468	−1.133

All entries are calculated from the assumed benchmark, not country observations. Each unit starts at index 100; the regional row sums the four indices. Uni: A price +20%. All20: every price +20%. Eq-log: each price +4.664%, preserving the unilateral sum of log shocks. Percentage changes use the corresponding baseline

Figure 3: Finite-shock responses and equal-log-shock aggregation. Hypothetical equal-baseline units A-D, not Arab-country estimates. Panel (a) compares unilateral +20%, all-unit +20%, and equal-total-log-shock reforms. Panel (b) compares unilateral with equal log-shock sharing; it isolates a model aggregation gap, not an estimated institutional coordination benefit



4. DISCUSSION

4.1. Four Adjustments Can Produce the same National Emissions Decline

Enhancing efficiency is the most straightforward means of reducing emissions without reducing productive industrial output. An increase in effective energy prices can make it more economical to implement waste-heat recovery, equipment upgrades, or better practices. The reaction would depend on availability of financing and the remaining life span of existing capital. If the enterprise cannot afford the upgrade, it will cut back on activity. Thus, an emissions decrease will be more meaningful if reported alongside physical output, fuel consumption, and investment measures.

The shift to another kind of fuel changes the carbon content of energy; the direction of the effect, however, depends on the kind of fuel and the relevant technology. Switching to cleaner electricity can reduce emissions, while switching from a cleaner fuel to a cheaper one with higher carbon content may negate the effect of the increase in prices. Limitations on fuel availability will constrain the substitution options as well. In consequence, it would be wise to observe the fuel mix rather than conclude decarburization from a decrease in expenditure on the refueled product.

Output cuts reduce direct fuel consumption, but disperse sales among other firms. The outcome for regional emissions would depend on whether there was demand reduction, an expansion by competing firms, or import substitution. Contraction can be a costly response despite resulting in improved national emissions. The environmental consequences cannot be assessed regardless of replacement activities and their carbon intensity.

Location shifting is another extensive margin reaction. It involves moving either investments or production to a region with lower net energy cost; yet, many other things matter in the choice of the location besides energy prices. Access to markets, transportation conditions, skills, and energy security could easily outweigh differences in tariffs. Saussay and Sato (2024) have shown that energy prices affect investment decisions, while Kruse-Andersen and Sørensen (2025) have distinguished between relocation and market share changes. Neither study implies that the Arab factory implementing reforms will move to its nearest neighbor.

Figure 4 organizes these four responses by what must be observed to distinguish them. The pathways can operate simultaneously within an industry, and different plants can follow different routes. An average national intensity measure may conceal that heterogeneity. For policy, the aim is to make cleaner production feasible and attractive while recognizing that some reductions may reflect output losses or displacement rather than technical progress.

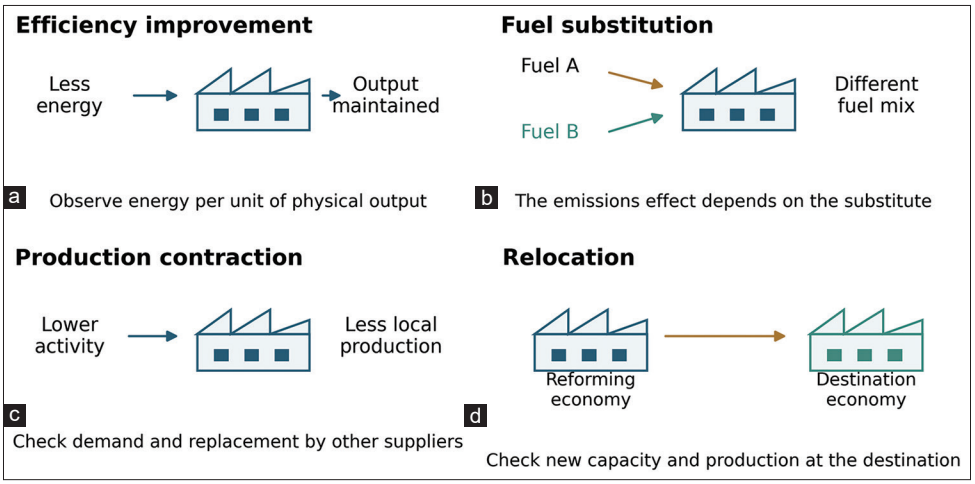
4.2. Industrial Emissions Require a Consistent Production Boundary

Industrial emissions should be defined before an outcome series is selected. Direct combustion at a plant, emissions from industrial processes and emissions from purchased electricity are different components. Power-sector emissions occur upstream of electricity users. They can be allocated to industrial consumers for a footprint calculation, but should not then be added again to a territorial inventory. The Saudi electricity evidence is useful precisely because it identifies an upstream component rather than directly measuring all manufacturing emissions.

Industry itself also needs a consistent boundary. Manufacturing, mining, refining and electricity generation may appear together in broad economic indicators while having different technologies and policy exposure. An aggregate industrial value-added series cannot, by itself, establish that the selected emissions series corresponds to the same activities. Sector classifications and fuel allocations must be reconciled before comparing countries or interpreting changes as industrial decarbonization.

A country can reduce territorial emissions while maintaining a consumption footprint through imports. Equation (8) expresses the accounting distinction for an economy-wide, consistently defined carbon balance. It is an identity used to organize interpretation, not an estimate of leakage or an industrial inventory constructed in this review.

Figure 4: Alternative industrial adjustments following energy price reform. Conceptual four-panel comparison. Panels (a-d) distinguish efficiency, substitution, contraction and relocation. A lower national emissions total cannot, by itself, identify which pathway occurred. The pathways may coexist, and no icon or arrow represents an estimated magnitude



Source: Author synthesis of the mechanisms discussed in Section 4

$$C_{i,t} = P_{i,t} - O_{i,t} + F_{\mathrm{i,t}} \quad (8)$$

Here C is emissions attributed to domestic final demand, P is territorial production emissions, O is domestic production emissions serving foreign final demand, and F is foreign production emissions serving domestic final demand. All quantities must use the same emissions coverage, accounting system and period. Restricting the identity to an industry requires compatible allocation of intermediate inputs and final demand. Direct plant emissions alone cannot supply all four terms.

The distinction is especially important where reform changes the purchase of imported energy-intensive intermediates. A manufacturer may retain final assembly while sourcing more processed material abroad. Domestic output can remain relatively stable even as the emissions-intensive production stage changes location. Observing import values is insufficient because commodity prices and product quality can change. Quantities, product composition and embodied emissions are needed to distinguish a supply-chain response from a valuation effect.

The accounting framework also prevents a broader conceptual error. Spatial spillovers of industrial emissions describe economic transmission that changes where emissions are produced. They do not refer here to atmospheric transport of local pollutants. Carbon dioxide contributes to a global climate problem, while local air-quality consequences follow other physical processes and may require separate exposure measures. Combining these outcomes under one spatial coefficient would obscure the policy question.

4.3. Trade and Electricity Relationships Can Matter more than Shared Borders

The reform has the possibility of raising the price of an intermediate input sold into another country's economy. The consumer could bear the cost, reduce production, or seek out alternative suppliers. The resulting emissions response would follow a directed, chain-of-supply relationship. The exporting and importing economies need not have borders in common, and the relevant linkages might differ according to industry such as steel, chemicals, cement, or food processing. The trade policy based on total goods flows might weaken the industrial relationship that we seek to identify.

Competition generates yet another directed relationship. Two economies might compete in serving a third country market but have little bilateral trade between them. In case the reform raises the cost of production for one of the exporters, another economy may gain a market share. Bilateral trade alone might not reveal this exposure. A sector-specific measure of overlap in export markets could be more revealing, as long as it was defined before the reform and not the result of the reform.

Electricity flows through the electricity grid rather than follow the generalized distance relationship. A change in industrial demand could affect electricity generation and, depending on infrastructure, electricity trade. Depending on the marginal generating sources and the nature of response, the emissions effect may occur domestically or internationally. The installed interconnection capacity is not the same as the realized electricity trade and an average emission factor of electricity generation is not the marginal emission factor. The right network will depend on the mechanism and the data available.

The fuel-market channel might extend even further. Lowered domestic use of a fuel-exporting economy will affect its exports and the availability of the fuel in other countries. The relevance of this effect will depend on the size of the reform relative to the relevant market. It should not be inferred simply from the exporter status of the country. Conversely, small reforms could mostly affect product-specific and partner-specific trade with little impact on the international price of the fuel.

Taken together, these effects give rise to several economically relevant notions of proximity. Geographic adjacency may refer to border-based trade or access; input dependence refers to production relationships; electricity relationships are possible

energy transfers; and market overlap refers to competition. Figure 5 shows how these relationships need not link the same units. It is schematic and does not claim to show any existing trade and electricity flows between Arab.

4.4. Reform Durability Changes the Incentives to Invest and Relocate

A short-term price increase and a credible permanent reform imply quite different reactions in industry. Investment postponement in anticipation of subsidy reinstatement and irreversibility avoidance due to uncertainty of future relative prices are possible examples. The growing problem of fragility of fossil fuel subsidy reform has been described by Mahdavi et al. (2025) on an international level. In their findings, the time span and decline of reform have been proved to be important aspects of the treatment to consider in addition to implementation date.

Lessons regarding preparation, timing, communication, gradual approach, and compensation have been drawn by Gasim et al. (2026) based on 417 examples of consumer-energy reforms in 46 countries. Their research is concerned about consumer-regulated energy prices, and no emissions estimation and producer-subsidy reform is included. It concerns implementation and sustainability, however, not the response. The same set of data can hardly be used to argue an industrial reaction in the absence of additional information.

Subsidy reforms in OECD countries and the relations between institutions, renewable energy competition, and policy persistence have been studied by Droste et al. (2024). Although the focus is not Arab, it still confirms the need for institutional characteristics to explain implementation. Even identical formally tariff changes could imply different long-term incentives due to adjustment rules, availability of alternative, and support structure credibility.

Evaluation of spillovers to industry requires the consideration of durability in terms of price trend, eligibility conditions, and compensatory policies. One indicator after implementation can lead to misunderstanding continuation of treatment as its reversal. Comparison of regions will also require taking into account anticipation effect: Investment can react to credible announcement of reform before price change, while consumption can respond to a new bill. Timing depends on the outcome in question.

5. AN EVALUATION FRAMEWORK FOR FUTURE EMPIRICAL RESEARCH

5.1. Construct Exposure from the Industrial Price Actually Faced

The first step in carrying out a plausible study is to draw up a chronological reform timetable by country, fuel type, and industrial consumers. Each timetable entry must include the date of announcement and implementation of the reform, the actual tariff, eligibility for the preferred rate, and any later adjustments. The discussion of each reform must carefully delineate between an actual price reform and a change in the price benchmark used to set the subsidy rate. In the case of reforms involving only certain industrial consumers, the principle of national treatment should not be attributed to all industrial plants.

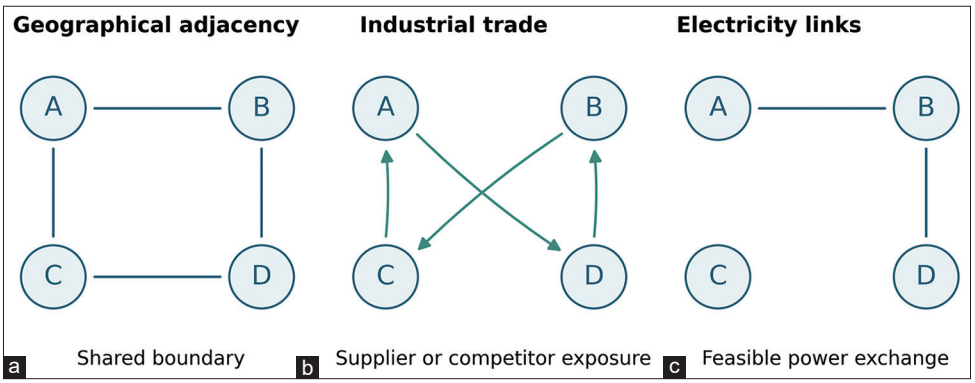
An industry's exposure could be based on its pre-reform shares of energy inputs and the changes in the corresponding effective prices. Keeping the energy-input shares fixed before implementation helps avoid the mistaken belief that an adjustment made by a firm in switching away from a particular fuel constitutes inadequate national treatment. Such a methodology also presupposes that the energy-input shares used are consistent with the chosen production boundary and separate energy inputs from feedstocks. Changes in electricity prices can also account for network costs.

The same principle applies to exposure from reforms elsewhere. Equation (9) defines a sector-specific external exposure index using relationships measured before reform. The definition makes the direction of influence explicit.

$$S_{i,s,t} = \sum_{j \neq i} w^{0}_{i,j,s} R_{j,s,t} \quad (9)$$

The index S for country i and sector s at time t is the weighted sum of reform intensities R in other countries j. The weights w^0 are fixed in a pre-reform period, have zero own-country entries and represent a specified mechanism. Trade-input dependence,

Figure 5: Different relationships imply different external exposure. Illustrative networks for the same hypothetical units A-D. Panel (a) connects adjacent units; Panel (b) shows directed industrial exposure; Panel (c) connects units with feasible electricity links. Edges are assumed solely to illustrate alternative exposure definitions. They are not measured trade, border or electricity relationships among actual Arab economies



Source: Author construction

competing export exposure and electricity links would generally require different weights. Normalization and the treatment of economies with no observed links should be reported. These indices are proposed measurements rather than quantities calculated for an Arab panel in this review.

Using predetermined links reduces one source of endogeneity but does not make reform assignment exogenous. Governments may reform when fiscal pressure rises, energy prices change or industrial conditions deteriorate. Firms may also anticipate a reform before the selected baseline. The evaluation needs evidence about those circumstances and about the stability of the pre-reform relationship. A convenient matrix should not be chosen after comparing which specification produces the largest external effect.

5.2. Separate a Spatial Response from a Common Regional Shock

The same goes for country- and time-specific effects, which could account for persistent heterogeneous shocks and common shocks, but do not imply isolation of the reform effect. Changes in oil prices could affect exporter countries and importer countries in different ways. Movements in exchange rates change the price of the foreign currency cost of imports. Industrial cycles and supply chains could transmit emissions between countries that share industrial relations. Interactions and controls must be built upon a justified causal story, especially since it is crucial not to hide away the effect that constitutes the part of the reform itself.

Debarsy and Le Gallo (2025) argue that identification of spillovers cannot only rely on estimation of a spatially dependent model. The argument is particularly important for a small regional country panel: The model could fit well the dependent variables, but not identify the cause of their dependence. Sun and Delgado (2024) also explain the importance of spatial response interaction and correlated treatment in a difference-in-difference design. The contributions give strong motivation to choose exposure and counterfactuals prior to interpreting the spatial parameter.

Information at subnational or plant level could help when treatment and industrial exposure are different inside the country. Butts (2023) studies the difference-in-differences with geocoded data, showing how to use the distance based definition of treatment in spatial evaluation. This methodology does not answer the Arab cross-country question, because in that case the relation between the countries is trade and not distance. The lesson is to motivate the choice of units, boundaries, and comparison groups.

A policy evaluation framework in counterfactual neighborhood intervention is proposed by Lee et al. (2026). This framework defines the research question where the outcome of an economy depends not only on its own policy but also on policies that take place in other connected economies. Untreated countries that are subject to reforms of their economic neighbors may be impacted by the intervention and thus cannot be considered control cases a priori. The target effect needs to define the treatment states of the own-country and the neighboring treatment states to compare. Therefore, different research questions may require different designs. National event studies are suitable for examining the short-run effects on the use of fuels in industry. Matched sector design is useful if there is already some existing variation in energy intensity. Network design is used to examine the impact of exposure to the intervention. The structural model can predict the effects of packages of policies, although the conclusions depend on behavior and markets assumptions. Combining several designs is informative if they capture different aspects of the mechanism.

5.3. Interpret Spatial Model Coefficients through their Implied Effects

A spatial model can describe interaction among industrial outcomes and neighbouring reform incentives. Equation (10) gives a static spatial Durbin representation for one consistently defined sector. It is included to explain interpretation; it is not fitted to data in this article.

$$y_t = \rho W y_t + \beta r_t + \theta W r_t + X_t \gamma + W X_t \delta + \mu + \tau_t 1 + \varepsilon_t \quad (10)$$

Here y_t is a vector of emissions outcomes across economies, r_t is reform intensity, W is a specified spatial or economic relationship matrix, and X_t contains covariates. Their coefficients are γ and δ for own-economy and spatially lagged covariates, respectively. Country effects μ and common time effects τ_t are included, and ε_t is an error vector. The vector 1 contains ones, so τ_t represents a common time effect. The parameters ρ, β and θ govern the outcome and reform interactions. A spatial lag of the dependent variable introduces simultaneous feedback and requires estimation assumptions beyond an ordinary regression.

The marginal-effect matrix for reform in this specification, holding covariates fixed, is given by Equation (11), assuming the inverse exists. The identity matrix is denoted by I. The expression clarifies why the coefficient on a neighbouring reform term is not, by itself, the complete external effect.

$$M = (I - \rho W)^{-1}) (\beta I + \theta W) \quad (11)$$

Diagonal elements of M trace own-economy effects including feedback, while off-diagonal elements trace effects across economies within the specified model. Average direct and indirect summaries require a stated aggregation convention. Their scale depends on whether y is a level, a logarithm or an emissions-intensity measure and on the unit used for r. The same coefficient cannot be interpreted as both a percentage change in total emissions and a change in emissions per unit of industrial output.

Such a presentation is a modelling decision and not necessarily a requirement for every analysis. It imposes a certain type of feedback through matrix W and makes an assumption about the appropriateness of the chosen network. Debarsy and Le Gallo (2025) caution against allowing economically determined spatial specification to take the place of a theory about spillover effects. A study that focuses on units affected by some shock but not receiving treatment may help answer a different research question with less reliance on structural assumptions.

The robustness analysis must account for economically meaningful relations, timing of treatment, definition of outcomes, and influential economies. In a small-country panel, estimates can depend significantly on the presence of a single country which is a large exporter or features intensive industrial development. Rather than providing various similar specifications, it is better to explain what happens if observations that cause problems are left out. The uncertainty needs to reflect the nature of dependence and scarcity of policy changes, not simply the number of annual observations.

5.4. Distinguish Lower Emissions from Successful Industrial Adjustment

An analysis of emissions should be coupled with measures of physical output and energy use. Where emissions decrease, but output declines by an equivalent amount, it is indicative of contraction, not any improvement in emissions intensity. In the case where intensity does improve, consideration must also be given to possible changes in product mix and outsourcing. Direct emissions and electricity purchased should be distinguished before computing a total footprint. These results answer different questions about productivity and competitiveness as well as climate performance.

Information on investment and trade can help test the external impact. Evidence of changes in capacity, facility activity, and production at the destination supports the relocation claim. An acquisition provides data on ownership and investment behavior, but not the transfer of emissions. Similarly, any leakages also require a sensible counterfactual scenario, as the industry at the destination could have expanded anyway in the absence of the policy. This flows immediately from the limitations of international evidence discussed above.

In addition, simulations of policy impacts can be used to analyze the alternative uses of revenues, possibilities for fuel switching, and coordinated reforms. The case of the models of Egypt shows how important it is to make such assumptions. Any gains simulated in a region depend on its trade pattern, technology choice, and fiscal treatment, and should not be treated as predictions from the model in isolation. Simulation results can be compared with the estimated effects without being aggregated together.

6. POLICY IMPLICATIONS

6.1. Preserve the Marginal Incentive While Supporting Adjustment

Results from energy subsidy reform are more likely to include cleaner industrial output when firms can respond to price signals. Inventory of efficient equipment and access to lower-emission electricity influences the type of response (i.e., whether firm responds by changing their process or by shrinking their activity). Therefore, the type of support needs to be assessed based on the type of investment barrier. Reversing reforming the subsidy by partially offsetting the price increase for fossil fuels would, to some extent, counteract the created negative incentive.

Temporary support can be targeted to cover verifiable costs associated with the adjustment and not guarantee a low fuel price. The appropriate design varies based on public finance considerations and the industry. A plant using gas as its feedstock faces a different adjustment problem compared to a plant using diesel for onsite generation. A uniform compensation rate would likely protect the least efficient activity, and not provide support for a durable response.

Investigations of leakage should occur prior to establishing permanent exemptions. Ambec et al. (2024) illustrate that leakage-mitigation instruments can interact with abatement incentives and trade. Kruse-Andersen and Sørensen (2025) break down the pathways through which emissions can shift abroad. For Arab policy-makers, these papers suggest identifying the exposure and evaluating possible alternatives. These papers do not show that every energy-intensive exporter needs the same kind of protection.

The aim is more far-reaching than preserving existing production at any emissions intensity. Reform may improve the allocation of energy while creating adjustment costs for certain firms and workers. Policy assessment should make these costs clear and consider them in comparison with the savings from reduced fuel waste, as well as the benefits of improved environmental and public health co-benefits from production. It should also analyze whether support is directed at viable adjustment rather than preserving a price advantage at energy prices without a credible pathway to a zero-carbon economy.

6.2. Coordinate Information before Attempting Uniform Regional Prices

Regional coordination doesn't have to kick off with the same energy tariffs. Each country has its own supply conditions, fiscal resources, industrial setups, and social policies. Instead, starting with a shared reporting framework could lay a more solid groundwork. By focusing on comparable industrial tariffs, eligibility criteria, reform timelines, fuel-input shares, and emissions limits, we can get a clearer picture. This kind of information would help separate real cross-border cost differences from measurement inconsistencies and enhance how we evaluate both national and regional results.

Industrial trade and electricity authorities each play distinct roles in this framework. Trade data reveals how much industries rely on intermediate inputs and highlights competing export markets. On the other hand, information from electricity systems helps pinpoint possible exchanges and shifts in generation. Environmental inventories show where emissions take place. By linking these records, we get a clearer picture of spillovers instead of just assuming that being close together means everything is connected.

Coordination can also alleviate abrupt uncertainty about relative policy paths. Reforms in Arab states have progressed when the adjustment rule has been communicated, and/or reversals and compensation levels have been observed. Lee et al. (2025) provide evidence of this in the Arab context. Mahdavi et al. (2025) provide evidence of this internationally. Consequently, rather than view a formal commitment as the completion of an

industrial transition, it may be warranted to appraise continuity of effective incentives.

A coordinated assessment should sustain economically significant differences. For instance, after structural reform in one member state, a more efficient producer may enter and displace a high emitting producer. An assessment in other member states would need to be done to evaluate this outcome. Harmonizing policies in the absence of information on what determines the supply response may remove necessary production competition or keep mal-coordinated production structures.

6.3. Evaluate Regional Benefits without Weakening National Accountability

Production networks now cross borders all the time, and national emissions reporting still matters anyway. A territorial inventory tells you where the emissions physically happen, which is what gives a government something it can actually be held responsible for at home. Measures built on consumption and trade add a different kind of information, about the chains of demand and supply that connect back to those emissions. Neither view should push the other out. If someone puts forward a reform and wants it taken seriously, the assessment has to show how the reported measures fit together, and it has to say plainly which outcome the policy is meant to improve.

The review sets out an order for evaluating things that could be a real help when making policy decisions. First, work out how industrial energy prices have shifted and what that tells you. Then see what that does to fuel use, output, and emissions here at home. Finally, check if related foreign industries shifted in a way that's justifiable compared to a reasonable counterfactual. This approach ensures that regional claims are linked to actual mechanisms and stops us from assuming that a drop in national emissions automatically means regional efforts are working.

There are limits to what this evidence can carry. I picked recent research that could be verified, which is not the same as a full census of the region, and some Arab economies and some industrial activities get only thin coverage as a result. Nor do the accessible records let anyone independently replicate every model. The equations and exposure measures proposed here are meant to make future evaluation possible. When the numerical extensions report results, those are conditional demand calculations and responses under an assumed network; I don't estimate any new country-level spillover coefficients. So the main policy contribution is a framework, one that lets you ask sharper questions and see what evidence it would take to answer them.

7. CONCLUSION

Reforming energy subsidies helps to cut industrial consumption of fossil fuels, but it's impossible to forecast how regional emissions change as a result of shifting trade, production, and technology. Domestic research on Arab energy consumption and mitigation trends does little to illuminate the international impact of subsidies. Researchers haven't nailed down the numbers and aren't in agreement. Existing international research points in the right direction but leaves too many questions regarding Arab energy policies and economies.

First, you must understand the new industrial incentive that results from reform. New industrial incentives can range from lower fuel and feedstock costs to electricity tariffs, compensation, and how quickly the new reforms will actually take hold. Responses can either be in the form of efficiency gains, substitution, contraction or relocation. Emissions must be accounted for by the country in which the industrial activity occurs until the accounting systems of individual nations and global entities align.

In empirical research, the focus should be on connecting specific reforms related to products and sectors with established economic relationships and solid counterfactuals. Geographic proximity alone isn't enough to explain how trade, electricity, or competitive pressures get transmitted. On the policy side, providing targeted support for adjustments and improving regional information can help maintain the motivation to reduce fossil energy use while also making the costs of displacement and distribution clear. This method assesses reform based on outcomes tied to cleaner production and regional emissions instead of just looking at national totals or subsidy spending.

The numerical extensions push on these same boundaries. Take the published price responses: They produce conditional demand changes that differ sharply from one industrial fuel or feedstock to the next, and activity growth can cancel out the price effect. The assumed spatial benchmark shows direct reductions sitting alongside positive external responses. It also shows that leakage under a finite shock is a different thing from a ratio of marginal effects. Comparing shocks of equal log size pulls the scale of a reform apart from nonlinear aggregation. With these calculations the framework becomes testable, and none of it requires treating assumed network parameters as evidence about how actual Arab economies behave.

REFERENCES

Ambec, S., Esposito, F., Pacelli, A. (2024), The economics of carbon leakage mitigation policies. Journal of Environmental Economics and Management, 125, 102973.

Butts, K. (2023), JUE insight: Difference-in-differences with geocoded microdata. Journal of Urban Economics, 133, 103493.

Cao, Y., Zhang, H., Shi, Q., Cao, Z., Zhao, Y., Zhang, Z. (2025), Spatial carbon emission and fiscal incentive: Considering spatial spillover boundaries and industrial linkages. Sustainable Futures, 9, 100738.

Darandary, A., Mikayilov, J.I., Soummane, S. (2024), Impacts of electricity price reform on Saudi regional fuel consumption and CO2 emissions. Energy Economics, 131, 107400.

Debarsy, N., Le Gallo, J. (2025), Identification of spatial spillovers: Do's and don'ts. Journal of Economic Surveys, 39(5), 2152-2173.

Droste, N., Chatterton, B., Skovgaard, J. (2024), A political economy theory of fossil fuel subsidy reforms in OECD countries. Nature Communications, 15, 5452.

Eldeep, C., Elshenawy, A., Zaki, C. (2025), Gender and climate policies: A general equilibrium analysis for Egypt. Journal of Economic Policy Reform, 28(3), 237-262.

Gasim, A.A., Agnolucci, P., Ekins, P. (2026), Lessons from an international review of successful and unsuccessful consumer energy subsidy reforms. The Energy Journal, 47(2), 1-30.

Gasim, A.A., Agnolucci, P., Ekins, P., De Lipsis, V. (2023), Modeling final energy demand and the impacts of energy price reform in Saudi Arabia. Energy Economics, 120, 106589.

Gasim, A.A., Matar, W. (2023), Revisiting energy subsidy calculations: A focus on Saudi Arabia. The Energy Journal, 44(1), 245-276.

Hasanov, F.J., Javid, M., Mikayilov, J.I., Shabaneh, R., Darandary, A., Alyamani, R. (2025), Macroeconomic and sectoral effects of natural gas price: Policy insights from a macroeconometric model. Energy Economics, 143, 108233.

Ibrahiem, D.M., Hanafy, S.A., Esily, R.R. (2024), Appraising the role of energy subsidy on the environmental sustainability in Arab nations-is it compatible or confronting? International Journal of Global Warming, 32(1), 65-80.

Kruse-Andersen, P.K., Sørensen, P.B. (2025), Optimal unilateral climate policy with carbon leakage at the extensive and the intensive margins. The Scandinavian Journal of Economics, 127(2), 427-459.

Lee, J.D., Nashin, J.T., Tabti, B., Troug, H. (2025), Reforming energy subsidies in the Arab region. International Monetary Fund, 2025, 21.

Lee, Y., Hettinger, G., Mitra, N. (2026), Policy effect evaluation under counterfactual neighborhood interventions in the presence of spillover. Journal of the Royal Statistical Society Series A: Statistics in Society, 189(1), 392-411.

Mahdavi, P., Ross, M.L., Simoni, E. (2025), Fossil fuel subsidy reforms have become more fragile. Nature Climate Change, 15(5), 569-574.

Matar, W., Mansouri, N.Y., Umeozor, E. (2024), Energy policy pathways to inform climate policy in Saudi Arabia. Journal of Cleaner Production, 445, 141190.

Misch, F., Wingender, P. (2024), Revisiting carbon leakage. Energy Economics, 140, 107786.

Saussay, A., Sato, M. (2024), The impact of energy prices on industrial investment location: Evidence from global firm level data. Journal of Environmental Economics and Management, 127, 102992.

Strand, J. (2024), Fuel and electricity pricing and subsidies in the GCC states: Recent developments. Middle East Development Journal, 16(2), 164-195.

Sun, S., Delgado, M.S. (2024), Local spatial difference-in-differences models: Treatment correlations, response interactions, and expanded local models. Empirical Economics, 67(5), 2077-2107.

Timilsina, G.R., Sebsibie, S. (2026), Energy subsidy removal and carbon taxation in Egypt: Economic and distributional impacts. Energy Economics, 160, 109470.