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Policies for competitive energy markets: When to tax emissions and when to subsidize carbon capture

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Highlights:

- *Carbon capture enables emission reduction while allowing continued operation of fossil-based infrastructure.*
- *Emission taxes and carbon capture subsidies act as strategic substitutes; strengthening one reduces the need for the other.*
- *In high–carbon intensity systems, a carbon tax aligned with marginal environmental damages is typically welfare-maximizing.*
- *In lower-intensity sectors, targeted subsidies or mixed regimes may be more efficient.*

Keywords:

Carbon capture and storage; CCS; emission tax; abatement subsidy; Monte Carlo simulation; game theory; energy competitiveness.

SDGs:
7, 13

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Background

There is a growing global challenge of reducing carbon emissions while sustaining economic growth and industrial competitiveness. This tension is particularly acute in energy-intensive economies where fossil fuels remain central to power generation and industrial production.

Carbon capture technologies are widely recognized as a key decarbonization tool. These technologies capture carbon dioxide (CO_2) at the point of production, such as power plants or industrial facilities, compress and transport the captured CO_2, and either store it underground in geological formations or utilize it for industrial purposes. By preventing CO_2 from entering the atmosphere, carbon capture technologies help reduce net greenhouse gas emissions while allowing continued operation of carbon-intensive facilities.

However, despite technical advances in carbon capture technologies, global adoption rates remain limited. The primary reason is cost and limited opportunities to earn additional revenue streams to recover investment expenses.

Carbon capture, transport, and storage infrastructure require significant capital investment and operational expenditures. This raises important sustainability questions: Can carbon capture technologies help achieve SDG 13 (Climate Action) without compromising energy affordability? Does supporting carbon capture risk delaying transition to renewable energy (SDG 7: Affordable and Clean Energy)?

The answers depend on policy design. Poorly structured incentives may distort markets or impose excessive fiscal burdens. But well-designed policies can align environmental protection with energy affordability and competitive energy markets.

Under SDG Target 13.2, countries are called to "integrate climate measures into national policies". Under SDG 7, countries are encouraged not only to expand renewable energy but also to "advance cleaner fossil-fuel technologies and strengthen energy infrastructure". In regions where renewable deployment faces geographic or technical constraints, carbon capture could serve as a transitional or complementary solution.

In such contexts, the key question is: How should governments design policies that balance environmental protection, firm profitability, and affordable energy prices? Fikru et al. (2025) address this question by developing a two-stage game-theoretic model of government–industry interaction.

In the first stage, the government sets environmental policy instruments—an emission tax and a carbon capture subsidy—aiming to maximize social welfare. In the second stage, firms respond by choosing output levels and the share of emissions they capture. This framework captures real-world strategic behavior where policymakers anticipate how firms react to policy, and firms optimize given regulatory conditions.

To move beyond theoretical results, the study employs Monte Carlo simulations calibrated using U.S. energy-sector parameters. This allows to test how different combinations of market size, carbon intensity, abatement costs, and environmental damages influence optimal policy choices.

The objective is not to advocate one instrument universally, but to determine under what conditions governments should rely on taxes, subsidies, or a combination of both.

Key Results

One of the central findings of Fikru et al. (2025) is that emission taxes and carbon capture subsidies act as strategic substitutes. Increasing the subsidy reduces the need for a tax, and increasing the tax reduces the need for a subsidy.

This finding implies that when carbon pricing is optimally set, generous subsidies may become redundant. Our results show that, in many cases, a well-designed carbon tax aligned with marginal environmental damage may be sufficient.

The second key result concerns carbon intensity. When production is highly carbon-intensive, the optimal policy is often a tax-only regime. Subsidies become less justified because taxing emissions directly internalizes environmental costs. Monte Carlo simulations show that, in carbon-intensive energy systems, the optimal emission tax closely tracks marginal environmental damages, while subsidies are often zero or even negative (effectively reinforcing taxation). This highlights the need to update scientific estimates of marginal damage costs so carbon pricing can accurately be anchored.

On the contrary, in low-emission sectors, carbon capture subsides alone or a mixed tax-subsidy regime are more efficient. This result implies that carbon capture subsidies should be targeted where carbon intensity is moderate and not applied automatically to every sector.

Overall, these results suggest that governments must tailor instruments based on emission intensity and marginal damages.

Lessons for Kuwait

Kuwait's economy is heavily reliant on oil production and fossil-fuel-based electricity—placing the nation in the high carbon-intensity category. For example, in 2021 electricity production from oil, gas, and coal sources accounted for 99.7% of total production. Hence there is room for encouraging the adoption of carbon capture technologies and designing effective policies informed based on environmental damages and carbon intensity.

Kuwait already demonstrates early adoption of carbon capture technologies, particularly in CO_2 utilization. According to the Global Carbon Capture and Storage Institute (2026), there is at least one operational (since 2016) and one early development utilization facility in Kuwait. Both facilities are CO2 recovery plants and involve a collaboration between Gulf Cryo and Equate Petrochemical.

The operational plant captures and recovers CO_2 emissions from the Equate Petrochemical Plant. It was commissioned in 2014 with a budget of $16.5 million (USD), and the facility reduced annual CO_2 emissions by 55,000 tons.

The second facility, in the Shuaiba Industrial Area, captures 600 metric tons per day (Mtpd) in Phase 1, with planned expansion of over 5,000 Mtpd in Phase 2—potentially making it the largest CO_2 recovery and processing facility in the MENA region. The captured CO2 is processed into industrial and food-grade gas.

The results from the Fikru et al. (2025) model suggest that in a high–carbon intensity economy such as Kuwait's, a carbon pricing mechanism carefully aligned with marginal environmental damages is likely to be the welfare-maximizing instrument, while sectors with relatively lower carbon intensity may justify targeted carbon capture subsidies.

Conclusion

Carbon capture technologies offer a pathway to reduce emissions without immediately dismantling carbon-intensive industrial systems. But their success depends on policy architecture. This research shows that the most effective climate strategies are those that carefully calibrate incentives to environmental damage and sectoral carbon intensity.

References

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