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Energy efficiency and capital-energy substitutability: Evidence from four OPEC countries

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HIGHLIGHTS

- The analysis examines energy efficiency gains in selected OPEC countries during 1972–2010.
- Capital-energy substitutability is also explored to analyze the impact of policy measures to reduce energy use.
- The magnitudes of energy efficiency gains are somewhat small or modest.
- Energy and capital are substitutes in some countries, but complements in others.
- Climate change policies need to internalize the environmental cost of energy consumption in end-use prices.

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ABSTRACT

Rapid economic growth and development in several oil-exporting developing countries have led to increasing energy consumption and the accompanying greenhouse gas (GHG) emissions. Consequently, a good understanding of the nature and structure of energy use in developing economies is required for future energy and climate change policies. To this end, a modified translog cost function is employed in this paper to estimate energy efficiency for selected members of the Organization of the Petroleum Exporting Countries (OPEC) over the period 1972–2010. This also allows for the estimation of energy-capital substitutability, which arguably reflects the likely ease/disruption to long-term growth arising from policy measures aimed at reducing energy consumption and GHG emissions. The estimated results show that energy efficiency gains range from −14% to 13% for sampled countries. Furthermore, factor substitution elasticities suggest that energy and capital are substitutes in Algeria and Saudi Arabia, but are found to be complements in Iran and Venezuela. The insight generated by this study is that, over the last four decades, energy efficiency improvements in selected OPEC countries are modest, possibly reflecting a "subsidy effect" arising from artificially low energy prices. Thus, policy makers should take note that measures aimed at conserving energy need to internalize the environmental cost arising from energy consumption using pricing and fiscal instruments such as carbon taxes.

1. Introduction

OPEC total energy consumption increased by 685% between 1970 and 2010. [1]Similarly, CO_2 emission from the burning of fossil fuels rose by 440% during the same period. Thus, both energy consumption and CO_2 emissions have risen rapidly over time. In particular, total emissions data for all OPEC countries indicate that they accounted for around 7% of global CO_2 emissions in 2010, which is significant in the context of the future energy use and GHG emissions potential of OPEC countries.

Given the foregoing, it is clear that the energy consumption trajectory of OPEC countries has serious implications for global warming which is one of the most critical issues facing mankind today. There is a well-established notion in literature[2] that the main source of global warming is GHG emissions, which in turn is by-product of energy consumption. Therefore, policy makers and governments around the world have focused great attention on devising measures to tackle this problem by stimulating energy efficiency improvements in order to achieve energy conservation and hence reduce energy consumption and the resulting greenhouse emissions. This view about the role of energy efficiency gain in reducing energy use and emissions is highlighted by a report from a United Nations climate report [45] which states inter alia:

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[1] http://stats.ukdataservice.ac.uk/.

[2] See [20,28]. Furthermore, [8] conducted a multi-country study of energy-growth nexus and found evidence of causality from aggregate energy consumption to GDP and vice versa.

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Nomenclature

Y	aggregate output, represented by GDP	a_i	value share of factor i
K	capital stock	τ_i	factor-augmenting technological progress for factor i
L	labor	λ_i	efficiency/technology gains factor i
E	energy	α_i	first-order coefficients/elasticities of translog cost function
M	material		
P_K	price of capital	γ_{ii}	second-order own elasticities of translog cost function
P_L	price of labor	γ_{ij}	second-order cross elasticities of translog cost function
P_E	price of energy	s_i	factor share for factor i
P_M	price of material	σ_{ij}	substitution elasticity between factor i and factor j

"World governments should exploit energy efficiency as their energy resource of first choice because it is the least expensive and most readily scalable option to support sustainable economic growth, enhance national security, and reduce further damage to the climate system".

Fig. 1 shows the rising historical trend in energy related CO_2 emissions attributable to sampled OPEC countries. In particular, given the outlook to the 2020 CO_2 emissions targets, and the ongoing climate change talks, the global climate change agenda requires adequate and reliable information on energy efficiency contributions in developing countries, of which OPEC countries represent a significant bloc. This is underscored by OPEC's submission in its Jan 2013 bulletin [37] on climate change:

"For its part, OPEC is committed to investing in state-of-the-art applications that are helping in the environment presenting solutions for cleaner oil products and groundbreaking processes, such as CCS, which deal with harmful emissions".

Therefore, in order to design effective energy and climate policies, a clear and precise understanding of the possible role of energy efficiency in restricting energy consumption in oil-exporting developing countries' is needed. In spite of the rapid rise in energy consumption of OPEC countries, most energy efficiency studies[3] have focused on OECD and other developed economies of the world (Zhou et al. [49], Filippini and Hunt [13,14], Fare et al. [12], Hoang and Alauddin [24]). It is arguably important to also explore the role that energy conservation may play in curtailing energy consumption in developing countries, given their increasing energy use, arising from rapid economic growth and urbanization. In particular, given the dominance of fossil fuels in the macro economy of OPEC countries, [4]increasing energy demand in these countries will result in higher GHGs emissions overtime. For instance, in comparative terms, OECD energy consumption rose by 63% between 1970 and 2010, compared to 685% increase in OPEC energy consumption. Similarly, OECD emissions increased by 25% over the same period, compared with 440% for OPEC. Based on the foregoing, fossil rich developing countries clearly have great ramifications for future energy and climate policies.

Several previous studies have attempted to analyze energy use in OPEC countries, with emphasis on price and income elasticities and the causality between energy use and other macroeconomic aggregates such as GDP (growth), greenhouse emissions, employment and so forth. One of the earliest studies of energy use in OPEC countries is Al-Janabi [1] who conducted a time series analysis and forecast for the demand for hydrocarbons in OPEC countries with a view to evaluating the implications of domestic demand trends for future exports capacities. Sari and Soytas [39] investigated the linkages between CO_2 emissions, economic growth, energy consumption and employment in selected OPEC countries, with emphasis on the relationship between energy consumption and growth. Similarly, other studies such as Al-Iriani [3] and Mehrara [35] have also explored the question of causality between energy consumption and income/economic growth.

Squalli [44] also estimated and found evidence of long-run relationship between electricity demand and economic growth of OPEC countries using bound test and causality approach. In terms

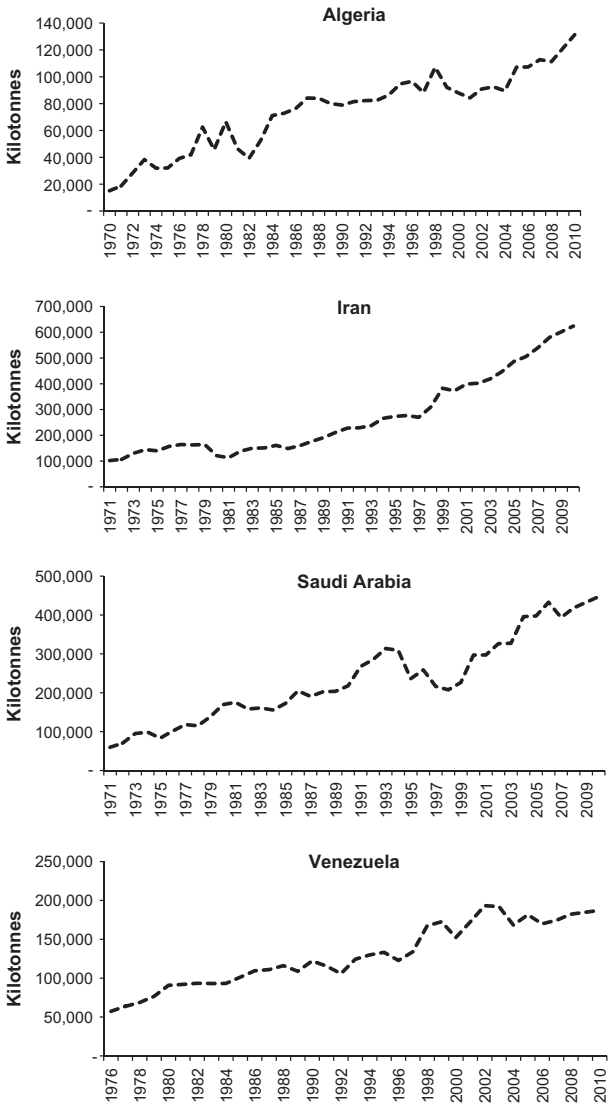

Fig. 1. Historical CO_2 emissions. This contains four panels (one for each sampled country) of CO_2 emissions over the study period.

[3] See [34] for a recent review of literature. Herralaa and Goel [22] evaluated efficiency for several developed countries, but from an environmental/emissions point of view.

[4] The dominance is twofold: export dominance and energy consumption levels.