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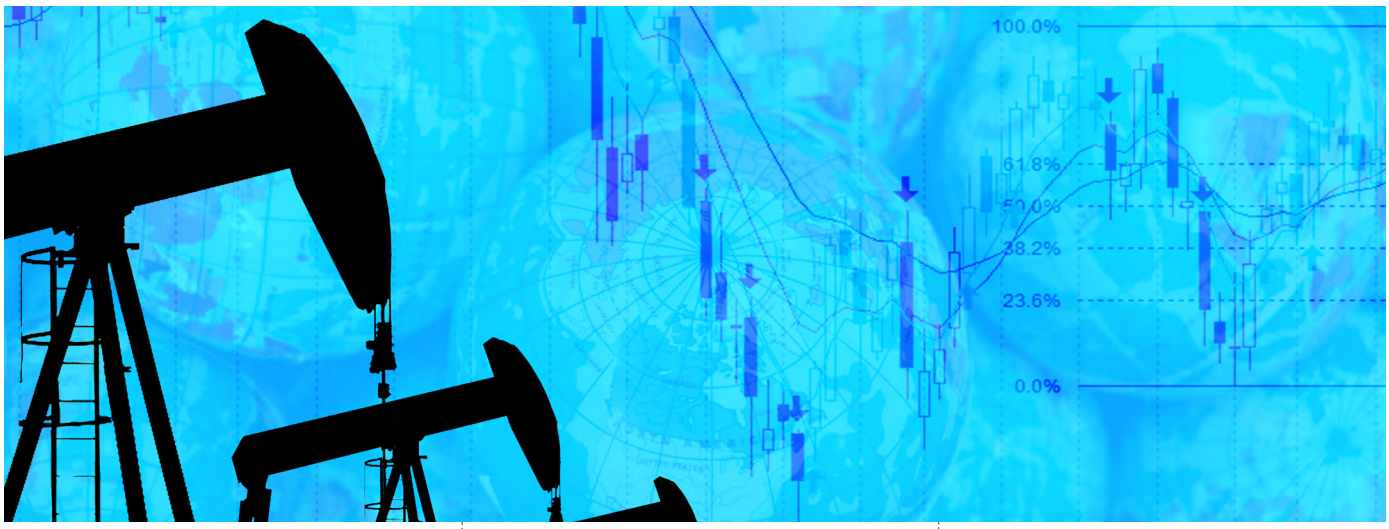
King Abdullah Petroleum Studies and Research Center

KAPSARC Quarterly

Research highlights



The Value of Saving Oil in Saudi Arabia

The instinctive answer to the question "What is the value of a barrel of oil saved in Saudi Arabia and instead exported?" is "The international market price." For oil saved from domestic consumption, this answer is incomplete for the following reasons: The rest-of-the-world demand for Saudi oil is not perfectly elastic, which...

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Measuring the Cost-Effectiveness of Clean Vehicle Subsidies

Many cities, states, and countries subsidize plug-in electric vehicles (PEVs) to help meet environmental goals such as reduced local air pollution and carbon dioxide emissions. Subsidies take various forms, including rebates, sales tax exemptions, and tax credits. Despite the prevalence of of PEV subsidies, research into their...

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The Future of Transportation Energy Demand for Freight in Fast-Growing Economies

India and China are both pursuing strategies to shift modes of freight transportation, to increase the energy efficiency in the movement of goods, relieve traffic congestion and meet emissions reduction objectives. Transport represents the largest oil-consuming...

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OPEC's Impact on Oil Price Volatility: The Role of Spare Capacity

OPEC claims to hold and use spare production capacity to stabilize the crude oil market. We study the impact of that buffer on the volatility of oil prices. After estimating the stochastic process that generates shocks to demand and supply, and assessing OPEC's limited ability to accurately measure and offset those...

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Vehicle Retirement and Replacement Policy: Assessing Impact and Cost-Effectiveness

Vehicle retirement and replacement programs provide incentives for households to replace used, fuel-inefficient vehicles with new, fuel-efficient vehicles. For example, the 2009 United States (U.S.) 'cash for clunkers' program formally known as the Car Allowance...

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The Costs and Gains of Coordinating Electricity Generation in the Gulf Cooperation Council Utilizing the Interconnector

Countries in the Gulf Cooperation Council (GCC) have installed a network of high-voltage transmission lines, known as the GCC Interconnector, which links the member states of Saudi Arabia, Bahrain, Kuwait, Oman, Qatar and the United Arab...

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An Estimation of the Drivers Behind OPEC's Quota Decisions

The factors OPEC takes into consideration when determining output quotas, according to their press releases, include a broad range of macroeconomic and global oil market indicators. Research suggests that the priority and importance of these indicators tend to shift over time. The heterogeneity of OPEC member countries...

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The Future of Energy Demand for Freight Transportation: The Impact of China and India

The economic growth in China and India during the last two decades has led to a significant increase in their freight transportation energy demand, with major implications for the global fuel markets. Among the fundamental forces driving this change is both countries' entry into...

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Electricity Market Integration in the GCC and MENA: Imperatives and Challenges

A number of power systems around the world have combined to form regionally integrated electricity markets in order to achieve efficiency, reliability and environmental objectives. Beyond the physical interlinking of national grids, to date the concept has gained little traction...

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Economic Cycles and the Responsiveness of Natural Gas Demand in China's Residential Sector

Determining which factors drive the growth in gas demand is difficult because of data limitations and the non-convergence of short-term fluctuations to a long-term equilibrium. As a result, we use an unobserved components model to...

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Policy Lessons From China's CCS Experience

Carbon capture and storage (CCS) is a potential bridge to a zero-carbon future for fossil fuel-dominated economies like China. Scenarios show that China will not achieve long-term carbon dioxide (CO_2) emissions reduction without CCS. For CCS to mature and be deployed at scale requires a series of policy instruments...

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Decarbonizing Oil: The Role of CO_2-Enhanced Oil Recovery (CO_2-EOR)

Under the Paris Agreement's 'well below 2 °C' climate target, countries have committed to work towards development paths that, over time, become carbon neutral. Of the key emitting sectors, carbon dioxide (CO_2) emissions from transportation are the most challenging to...

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The Economic Impact of Price Controls on China's Natural Gas Supply Chain

Reforming the pricing mechanism and ensuring efficient third-party access to infrastructure have been the top priorities of China's policy agenda for the natural gas industry. While prices for unconventional gas supplies and liquefied natural gas (LNG) imports have been...

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Potential Effects of Trade Liberalization on China's Imports of Plastics From the GCC

Bilateral trade between the Gulf Cooperation Council (GCC) countries and China has been expanding rapidly since the turn of the century. In 2016, China accounted for 12 percent of the GCC's imports, making it the largest exporter to the region. The GCC countries also...

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Identifying the Roadblocks for Energy Access: A Case Study for Eastern Africa's Gas

Improving access to reliable, modern energy is among the highest priorities of Eastern African countries' economic growth plans and energy strategies. In particular, developing access to electricity – including in rural areas – is the cornerstone of most strategies. On average, only 35 percent of...

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Fostering Joint Leadership on Energy Productivity Transition In Saudi Arabia and China

China's Belt and Road Initiative (BRI) could foster a stronger collaborative relationship between Saudi Arabia and China, which could be an important catalyst for achieving Saudi Arabia's economic transformation goals.The focus of the Chinese government on green development within the BRI may...

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Understanding the Energy Transition

Barely a few years since the phrase 'energy transition' entered the mainstream lexicon, it is becoming clear that conventional economic models are inadequate for deconstructing the complexity surrounding the future trajectory of global energy, the impacts of decarbonization and the required...

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From the KAPSARC president

It has been four months since I arrived in Saudi Arabia to a center that is increasingly being recognized both locally and globally for its impactful research. We intend to make KAPSARC the go-to institution for energy and economic insights relevant to the Kingdom and the region. My vision for KAPSARC has five pillars that should support our efforts to fulfil the aspirations reflected in the world-class environment that has been presented to us:

- Deepen our involvement in issues that are timely and vital to the Kingdom of Saudi Arabia.
- Maintain and build on our independent, unbiased research and advisory capabilities and our international reputation for excellence.
- Enhance our research partnerships with global experts, Saudi stakeholders, and research centers around the world.
- Heighten our communications activities and outreach, both internally and externally.
- Be a role model for think tank culture in Saudi Arabia and nurture the ecosystem for evidence-based policies.

I'm delighted to have the opportunity and honor to lead KAPSARC, building on the achievements of my predecessors, and I look forward to working with you, our stakeholders, on the journey towards our mutual goals.

Adam Sieminski

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The past 12 months have seen 'peak oil' back on the agenda. Unlike the last time the term was in vogue, talk is of peak oil demand (a world, according to its proponents, of lower oil prices) rather than peak oil supply (anticipated to deliver uncomfortably high prices). Invariably, both narratives represent extreme views of the future which fail to recognize the power of markets to balance supply and demand. Indeed, the antidote to the peak supply story was the prospect of high oil prices that precipitated innovations which created a boom in light tight oil development in North America.

The peak demand narrative is built on the foundation of global policy support for low emissions energy supplies and demand reduction measures. It foresees a world in which coal, oil and gas all face diminished markets. This transition is initially driven by policies designed to encourage the adoption of low-carbon energy, including carbon markets – examples include the European Union's (and shortly China's) emissions trading schemes – and technology mandates. In the power sector, these mandates include renewable obligations and, in the mobility sector, zero emissions vehicle mandates and low carbon fuel standards. Many governments have committed themselves to the electrification of transport over varying time frames, although the small print qualifies the phase-out of internal combustion engines in many cases by accepting hybrid power trains — stopping short of pure electrification. Proponents believe that these policy supports will not be required in the next phase, with technologies maturing to a point where they are organically adopted on cost grounds alone.

This research update builds on the arc of research first shared in the last Quarterly – particularly a series of papers on the effectiveness and costs of policies that seek to encourage the adoption of electric vehicles. However, we begin this quarterly review with a set of papers that focus on oil markets.

Focus on oil markets

A key question for global oil markets is the future trajectory of Saudi domestic oil consumption. This question is especially important when considering that OPEC production targets are not 'export' quotas. As such, OPEC member exports are the net result of total production less their domestic demand.

The future trajectory of domestic demand is guided by answering the question: What is the value of saving a barrel of oil that would otherwise have been consumed domestically? ***The Value of Saving Oil in Saudi Arabia*** provides one perspective, taking a long-run general equilibrium approach. In the case of Saudi Arabia, the difference between the domestic price of oil and the international price represents an opportunity to improve economic efficiency across different activities and sectors. This drives changes in the Kingdom's fuel and technology mix and will influence domestic oil demand. The report finds that policies designed to curb oil consumption have positive impacts on the Saudi economy and carbon emissions, although the costs of policies and their impact on economic productivity are critical to their success.

Beyond Saudi domestic consumption, the role of OPEC in stabilizing oil markets is a topical issue. This includes the decisions its members will make to ensure the sufficient availability of oil in the coming months and years.

The Energy Journal recently published a paper by Axel Pierru, Program Director for Energy and Macroeconomics, James Smith, KAPSARC Visiting Fellow and Professor at Southern Methodist University,

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and former KAPSARC researcher Tamim Zamrik on the implications for the world economy of OPEC member states holding spare capacity to reduce price volatility. ***OPEC's Impact on Oil Price Volatility: The Role of Spare Capacity*** provides a basis for analyzing what would have happened if there had been no spare capacity and estimates the extent to which the resulting volatility would have damaged global gross domestic product (GDP) growth. A summary of the framework used to estimate the annual global GDP benefit of $170-200 billion from OPEC's spare capacity can be found on page 29 in the Viewpoint section of this update.

As oil markets try to assess the short- and medium-term oil supply/demand balance, a key question will be whether the unprecedented levels of compliance with production commitments under the 2017 'OPEC+' deal will continue. ***An Estimation of the Drivers Behind OPEC's Quota Decisions*** provides econometric estimations of the key determinants that appear to shape OPEC's quota strategy and implementation, based on historical data. It examines the factors that seem to most influence members' adherence to their production commitments in the short-term. It will be possible to assess likely compliance under the new paradigm of OPEC+ when there is sufficient data to analyze the period from early 2017.

Focus on transport and mobility

Mobility is one of the main pillars of global oil demand, and the prospects for new paradigms in both personal mobility and freight transportation are critical to any long-term view of oil demand. One of the challenges of understanding the outlook for personal mobility is determining the affordability of alternative fuel vehicles. Recent analyses of policies to encourage sales of plug-in electric vehicles (PEVs) in the United States (U.S.) suggest the subsidies cost $35,000 per additional PEV purchased. ***Measuring the Cost-Effectiveness of Clean Vehicle Subsidies*** cautions against assuming this figure should be used to calculate the cost of subsidizing PEVs when demand reaches millions or even tens of millions of units per year. Besides the effects of technological advances that may improve the competitiveness of PEVs relative to internal combustion engines, targeted policy design alone could halve the policy cost per additional PEV to near $16,000.

Regardless of their positions on climate change, governments across the world are motivated by air quality improvement to accelerate the turnover of older, higher-emitting vehicles and replace these with lower emission vehicles. ***Vehicle Retirement and Replacement Policy*** examines the economic efficiency of current policy designs in the U.S. It finds that incentivizing hybrid electric vehicles as the replacement choice in a 'cash for clunkers' or 'replace your ride' program delivers twice the value for money of incentivizing PEVs, in terms of additional vehicles replaced.

While technology pathways to lower greenhouse gas emissions from personal mobility are becoming clearer, the same cannot be said of freight transportation. KAPSARC has begun a research initiative, explained in the previous Quarterly, which focuses on the energy demand (particularly supplied by distillates such as diesel) in India, China and the Gulf Cooperation Council (GCC) countries. We held two initial workshops to secure research collaborations with institutions in these regions: ***The Future of Energy Demand for Freight Transportation***, conducted in China, and ***The Future of Transportation Energy Demand for Freight in Fast-Growing Economies***, held in India. The right data and a better

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knowledge of the trends that are shaping freight movement are prerequisite steps to understanding the primary determinants of rapidly rising oil consumption by these important, fast-growing economies. Economic development initiatives such as China's Belt and Road Initiative and the Indian Ocean Rim Association will affect both the domestic movement of freight in these countries and global patterns of trade. But demands to improve air quality mean that both India and China plan to use infrastructure investments to shift freight movement from road to other modes of transport, including rail. However, road-based transport is becoming increasingly energy efficient, has policy support and retains its door-to-door delivery advantage. The 'Uberization' of freight transport, for example, might lead to efficiencies through reduced empty run miles.

Focus on cross-border collaboration

GCC countries have installed a network of high-voltage transmission lines, known as the GCC Interconnector, which links the member states of Saudi Arabia, Bahrain, Kuwait, Oman, Qatar and the United Arab Emirates. The Interconnector has successfully improved the reliability of services for GCC countries but has not yet realized its full potential as a platform to fully integrate individual electricity systems. ***The Costs and Gains of Coordinating Electricity Generation in the Gulf Cooperation Council: Utilizing the Interconnector*** explores the potential economic gains that come from better integration. These gains amount to nearly $1 billion annually. This figure is in addition to the aggregate annual gains for the entire bloc of $41 billion from moving to prices that reflect the true costs of supply across the GCC. Such a move would eliminate the potential for 'subsidy exports' amounting to more than $2 billion for Saudi Arabia alone (based on current electricity and water pricing regimes in each of the member states).

Despite the economic arguments for integration of liberalized, integrated electricity markets in the GCC, the political momentum is less clear, favoring the current arrangement of using the GCC Interconnector to provide 'reliability' protection against outages or other shocks. The topic of regional integration was further discussed in a recent KAPSARC workshop ***Electricity Market Integration in the GCC and MENA: Imperatives and Challenges***, during which the participants identified the steps necessary to enable regional integration and the drivers of potential change.

Focus on China

China's energy demand has major implications for global energy markets. There has always been a gearing effect of small percentage changes to Chinese coal consumption – changes of just a few percent in either domestic supply or demand can swamp the global seaborne coal markets. However, China's demand for natural gas imports has now grown faster than many predicted with the campaign to 'make the skies blue.' Expectations of a liquefied natural gas (LNG) supply overhang into the long term were predicated on the relative costs of gas and coal as primary fuel sources. The fact that Chinese policy has overridden this assumption – tightening the LNG market – raises the question as to whether this could happen in India as well. Next quarter's research will include a detailed report on the Indian gas market, in collaboration with The Energy and Resources Institute in India.

Growth in China's natural gas import demand has intensified after last winter's gas shortages in its northern cities. China's 13th Five-Year Plan (2016-2020) endorses the use of natural gas to reduce

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coal consumption and achieve a cleaner energy mix. ***Economic Cycles and the Responsiveness of Natural Gas Demand in China's Residential Sector*** examines household natural gas demand, taking account of economic cycles, and provides insights into China's gas supply and demand balances. Income growth is clearly an important factor: households choose gas over coal as soon as they can afford to. However, the study finds that both environmental regulations aimed at suppressing coal consumption and government policies to foster natural gas accessibility by expanding infrastructure development are key drivers of gas demand growth. The former is already clearly visible while the latter is likely not far behind.

China has made significant progress in liberalizing its natural gas market, but certain key areas such as market access and pricing mechanisms remain heavily monopolized or controlled by the government. ***The Economic Impact of Price Controls on China's Natural Gas Supply Chain*** assesses how such distortions impact the market. It finds that lifting the price caps for regulated natural gas demand sectors could reduce total system cost by more than 4 percent and reduce the national average marginal supply cost by nearly 15 percent. The September 2015 paper *Economic Impacts of Debottlenecking Congestion in the Chinese Coal Supply Chain* found that improved rail infrastructure for coal shipments may have been due to lower global seaborne coal prices, making domestic coal available at lower cost on the Chinese coast. There is a similar case to be made that reducing the natural gas system costs and increasing market liberalization may put downward pressure on landed LNG prices where they compete with domestic supply or pipeline imports.

KAPSARC has been collaborating with the Energy Research Institute of China's National Development and Reform Commission for the past two years. Last quarter, we shared the joint report *Toward Economic Prosperity Through Industrial Energy Productivity Improvement*, which provided the background for a joint workshop in Beijing. ***Fostering Joint Leadership on Energy Productivity Transition in Saudi Arabia and China*** summarizes the insights from that workshop, during which Saudi and Chinese participants discussed the intended benefits of China's Belt and Road Initiative and Saudi Arabia's Vision 2030 plans. Of particular interest is China's deeper focus on its 'Green Belt & Road' initiative and Saudi plans to diversify both its energy system and the broader economy to create more sustainable, higher productivity growth.

China's increasingly public and proactive stance on climate change includes a commitment that its carbon dioxide (CO_2) emissions will peak before 2030. Its energy efficiency, clean energy technology, and carbon management initiatives support this. Carbon capture and storage (CCS) is a critical bridging technology. ***Policy Lessons from China's CCS Experience*** reviews and analyses Chinese CCS policies from the perspective of an adaptive policymaking framework, recognizing uncertainty as an inherent element of the policymaking process. The case study of progress in China points to how other economies with a high degree of government involvement, including Saudi Arabia, can support CCS development.

Trade policy has come back on the agenda in recent months. Petrochemical products, particularly plastics, contribute to a significant share of expanding and increasingly diverse trade flows between GCC countries and China. ***Potential Effects of Trade Liberalization on China's Imports of Plastics from the GCC*** identifies the potential for more than 10 percent growth in exports of polyethylene and

more than 5 percent growth for polypropylene. Chinese consumers also benefit from a $200 million-plus reduction in their costs. This is the benefit of a zero-tariff trade regime between the two blocs.

Focus on the sustainable use of hydrocarbons

Sustainability means more than just reducing the environmental footprint of an activity. The United Nations' Sustainable Development Goals include social and economic sustainability targets. KAPSARC has been leading a workstream in association with the World Economic Forum to help understand how the energy transition can be recognized as more than a zero-sum game. Current policy risks pitting three groups against each other: exporters of hydrocarbons, those countries wealthy enough to afford more rapid penetration of low emissions technologies, and developing economies that cannot afford the higher costs of renewable energy systems and still rely on fossil fuels.

Over the past year, stakeholders from these different communities have met. ***Understanding the Energy Transition*** summarizes the outcome of two workshops in the series. In its simplest form, the energy transition is characterized by changes in the global fuel mix, the rapid growth in renewable energy, emerging new transportation patterns and the rapid implementation of new energy technologies. There is a risk of a disorderly transition from increased price volatility, impacting the oil market in particular and the global economy more generally. The drivers for global energy demand growth remain firmly centered on China and India, and there could be a range of unexpected global consequences if their economies stutter. Low-cost legacy oil producers are well-placed to benefit from short-term price volatility, while investing in measures to retain value across the hydrocarbon chain gives them an opportunity for a sustainable economic future.

A low-carbon future does not inevitably mean a low oil and gas consumption future. When markets properly reflect the costs of greenhouse gas emissions, producers will adopt the most cost-effective way of decarbonizing their production. One such course is through enhanced oil recovery. ***Decarbonizing Oil – The Role of CO_2-Enhanced Oil Recovery*** summarizes the insights from a joint workshop co-hosted by KAPSARC and the International Energy Agency. Opportunities to lower the carbon intensity of oil production exist across the value chain with varying degrees of cost-effectiveness and mitigation potential. Unlocking these will require a level playing field that includes protections against trade leakages and avoids policies that 'pick winners.' If the 2°C climate goal is to be met, most projections require CCS as a policy component. Enhanced oil recovery through CO_2 injection may represent one of the most cost-effective paths to building scale in this sphere.

Finally in this quarterly update, we focus on the social and economic sustainability dimension of energy supply and demand. ***Identifying the Roadblocks for Energy Access*** is a case study developed jointly with Columbia University's Center on Global Energy Policy and the Fondazione Eni Enrico Mattei to look at energy access in Eastern Africa (defined here to include Burundi, Ethiopia, Kenya, Malawi, Mozambique, Rwanda, South Africa, Tanzania, and Uganda). Millions of inhabitants are currently living without access to electricity and clean cooking. Giant natural gas discoveries in the region could potentially be a driver for industrialization and economic growth. Reasons for low energy access vary but are tied mostly to the financial capacity of governments, inadequate revenues for utilities, tariffs being lower than costs, and a weak regulatory framework to implement energy policies.

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In July we will be hosting workshops on the ***Opportunity Costs of Oil for Saudi Arabia*** at our campus in Riyadh – a collaboration with the Baker Institute for Public Policy – and ***China's Policy Drivers of Future Energy Demand*** in Beijing – working with the Chinese Academy of Social Science. Our fall program of workshops includes events covering the potential for integration of Saudi Arabia into the global gas business, the medium- and long-term outlooks for oil and gas markets, the importance of 'model ready' data in research, and the future of transportation. We look forward to you joining us and deepening your engagement with the KAPSARC community.

Energy Workshops

July 2018

China's Policy Drivers of Future Energy Demand
Beijing, China, *July 23*

Opportunity Cost of Oil for Saudi Arabia
Riyadh, Saudi Arabia, *July 24*

September 2018

International Oil and Gas Market Outlook
Washington, DC, United States, *September 18*

October 2018

Nationally Determined Contributions
Paris, France, *October 3*

Integrated Approaches to Decentralized Electricity Transitions
Brussels, Belgium, *October 4*

The Value of Integrating Saudi Arabia into the Global Gas Market
Riyadh, Saudi Arabia, *October 15*

Model-Ready Energy Data
Riyadh, Saudi Arabia, *October 16*

Resilience in Energy Systems
Riyadh, Saudi Arabia, *October 24*

November 2018

Mobility/Transportation
Riyadh, Saudi Arabia, *November 6*

Energy Employment and Entrepreneurship
Riyadh, Saudi Arabia, *November 7*

Trade and Energy Transitions
Riyadh, Saudi Arabia, *November 26*

Models of CDMP for Energy Policy and Energy Markets
Riyadh, Saudi Arabia *November 28-29*

The Value of Saving Oil in Saudi Arabia

Jorge Blazquez, Baltasar Manzano, Lester C. Hunt and Axel Pierru

The instinctive answer to the question "What is the value of a barrel of oil saved in Saudi Arabia and instead exported?" is "The international market price." For oil saved from domestic consumption, this answer is incomplete for the following reasons:

- The rest-of-the-world demand for Saudi oil is not perfectly elastic, which impacts the revenues from exporting the oil saved.
- Domestic agents buy oil below the international price at a price set by the government, potentially leaving room for improving economic efficiency by saving oil.
- There are different ways to reduce the domestic consumption of oil.

This study analyses different policies that aim to reduce domestic consumption of oil in the long run and, thus, increase oil exports. The following policies are studied:

- Displacing oil by increasing the share of natural gas in electricity generation.
- Increasing the efficiency of natural gas power plants.
- Deploying renewable technology to displace oil.
- Increasing the administered price of oil.
- Implementing electricity efficiency programs.
- Increasing the fuel efficiency of the transportation sector.

To explore the long-run impact of these policies we develop a small open economy general equilibrium model for Saudi Arabia. In all the cases the increase in net public revenues resulting from these policies is transferred to households. The analysis of these policies leads to the following results:

- Policies designed to curb oil consumption positively impact households' welfare and help reduce Saudi carbon emissions. However, the costs of these policies and their impact on productivity are critical.
- The decrease of the international price of oil, due to the increase in oil exports, reduces the potential welfare gain from these policies.
- Policies aimed to increase energy efficiency have limited scalability and, consequently, the potential positive macroeconomic impacts are relatively small.
- The increase in administered oil prices has potentially the largest impact on domestic demand of oil, on carbon emissions and on oil exports. Although increases in energy prices harm households' welfare, the growth in net public transfers to households offsets this negative impact.
- Shifting power generation from oil to natural gas has a positive impact on the Saudi economy, even if the natural gas is imported.
- The gross welfare gains of energy efficiency projects, in electricity usage or transportation, are greater than those aimed at shifting from oil power generation to natural gas or renewables. However, energy efficiency projects tend to be more expensive than those to reduce oil in power generation.
- Welfare gains for all the policies studied range between a minimum of $6 and $56 per barrel of oil saved. These policies — excluding one that increases the share of natural gas in the generation mix — reduce the level of domestic carbon dioxide (CO_2) emissions by around 370 kilograms per barrel saved.

We simulate the increase in administered prices of gasoline and electricity in January 2018. The simulations show that this policy would increase oil exports by 724,000 barrels per day and welfare by $2.6 billion annually in the long run. It would also reduce CO_2 emissions by 97 million tons annually.

This study is part of a larger KAPSARC initiative to inform economic decision-making in Saudi Arabia with estimates for the opportunity costs of using domestic resources, especially oil and natural gas. More generally, the initiative will deliver a framework for evaluating public investment projects that takes into account the specific characteristics of the Saudi economy.

Download the paper

OPEC's Impact on Oil Price Volatility: The Role of Spare Capacity

Axel Pierru, James L. Smith and Tamim Zamrik

From *The Energy Journal, Vol. 39, No. 2, 2018*

Although oil market analysts frequently mention the influence of spare production capacity, as yet there has been no quantitative economic investigation of its size or impact. Our study fills this gap by assessing how effective has been OPEC's stated policy of maintaining a buffer capacity to stabilize the price of oil.

We build and estimate a model where OPEC's ability to dampen price volatility is limited by its inability to precisely estimate the size of shocks to oil demand and supply, as well as potential execution errors and constraints when implementing production decisions. Price stabilization is only possible if the magnitude of such errors is small relative to the size and persistence of shocks to the market. Using monthly data ranging from September 2001 to October 2014, we find that OPEC has the ability (at least in theory) to stabilize the price of oil. The same conclusion holds when we only consider Saudi Arabia, or the OPEC subgroup formed by its four GCC members ("OPEC Core").

An assessment of the actual impact of OPEC's use of spare capacity corroborates this conclusion. We evaluate the monthly prices that would have been obtained if OPEC had not used its spare capacity to offset shocks. As a result, depending on one's particular beliefs regarding the short-run elasticity of global demand, OPEC's impact may be viewed as large or small — but in all cases our analysis indicates that OPEC has at least partially offset shocks and stabilized the oil price during the past fifteen years. Under plausible assumptions regarding the elasticity of demand, OPEC's stabilizing influence appears to have been very substantial, perhaps reducing oil price volatility by as much as half.

Our analysis also suggests that Saudi Arabia has acted as a supplier of last resort and absorbed more shocks than the other OPEC members.

To the degree that OPEC wants to ensure the reliability of the global oil supply, the size of its buffer may at least indirectly be driven by the magnitude of global GDP losses caused by supply disruptions. From this perspective, we inquire whether the estimated size of OPEC's buffer (1.94 mmb/d for Saudi Arabia, 2.27 mmb/d for OPEC Core, and 2.64 mmb/d for OPEC) is large enough — or too large? To address this question, we first show that the value (to OPEC) of holding incremental spare capacity depends on:

- The parameters estimated from our model: existing size of the buffer, magnitude and persistence of shocks, and OPEC's estimation error.
- The losses that OPEC presumably incurs when the buffer is not sufficient to avoid production shortfalls; these losses reflect OPEC's displeasure or disutility due to the inability to pursue its optimum course.

By assuming that OPEC has behaved rationally – i.e., optimized the size of its buffer by equating marginal value and marginal cost – we are able to infer the implicit magnitude of losses that rationalizes OPEC's investment in spare capacity. After comparing this result to an independent estimate of global economic losses due to oil supply disruptions (derived from a well-known world macroeconomic model), we find that the estimated size of OPEC's buffer has been in line with global macroeconomic needs.

For instance, if monthly global demand is assumed to be relatively elastic in the short term (-5%), the losses that rationalize OPEC Core's buffer comprise some 40% of the estimated economic losses that potential supply disruptions would impose on the global economy. This does not imply that the buffer is too small, only that the OPEC Core may for whatever reason be motivated to address only a portion of the damage caused by oil shocks. The OPEC Core is but one piece of a much larger picture when it comes to neutralizing the impact of oil shocks. We are unable to say whether it is reasonable to believe that 60% of the burden of dealing with oil price shocks should be left to individual consumers, producers, government agencies, and multilateral organizations.

Our study has focused on the past. We do not overlook the strategic change within OPEC in late 2014 to rebalance the market, but that episode followed the end of our sample period. In any event, OPEC appears to have resumed its role in helping to stabilize the market, albeit at a lower price.

View the full article

An Estimation of the Drivers Behind OPEC's Quota Decisions

Philipp Galkin, Tarek Atalla and Ren Zhongyuan

The factors OPEC takes into consideration when determining output quotas, according to their press releases, include a broad range of macroeconomic and global oil market indicators. Research suggests that the priority and importance of these indicators tend to shift over time. The heterogeneity of OPEC member countries and the inherent collective action problem further complicate the group's decision-making process and make forecasting OPEC's output problematic.

The output of OPEC members may significantly deviate from assigned targets, partially due to OPEC's organizational complexities. Such deviations are driven by each member country's ability and willingness to produce, which are, in turn, determined by economic, political and industry-specific drivers and can be impacted by a variety of external shocks. 2017 saw a strong compliance record from OPEC, although the question of whether such performance can be sustained in the long run remains unanswered.

This study examines the major drivers behind OPEC's decision making and the compliance of individual member countries. This helps facilitate an understanding of OPEC's reaction to shifts in the oil market, and to provide insights into the organization's strategies and production behavior of its member countries. For this purpose, it applies a structural time series model to quantify causal links between two groups of variables:

1) OPEC production targets (quotas) and macroeconomic/global oil industry indicators.

2) The actual output of selected OPEC member countries and country-specific economic, financial political and industry indicators.

This modeling approach also accounts for the impact of unobserved components: one-off events or structural breaks that such factors as extreme weather or infrastructure disruptions may induce.

The first part of the analysis aggregates quarterly OPEC oil production targets from 2000 until the end of 2016. It finds that OPEC's quarterly targets are driven by crude oil price dynamics and other global oil market indicators. Global macroeconomics seem to have no quantifiable impact on quota decisions. The paper identifies the following factors and their effect on OPEC's quota targets:

- The oil price (represented by the OPEC Reference Basket) has a positive effect. An increase in price is likely to lead to quota increases.

- Crude oil inventories have a strong negative effect in the short run, attenuated in the long run.
- Spare production capacity has a negative effect.
- Global crude oil demand has a positive effect.
- Six-months global demand projection has a positive effect.
- Output by non-OPEC producers has a positive effect in the short run and a slightly negative effect in the long run.

The second phase of the analysis estimates the actual output of each of the eight OPEC members, including Algeria, Iran, Kuwait, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates and Venezuela, using quarterly aggregation over the same time frame. This analysis introduces country-specific independent variables that represent their available spare production capacity and economic, financial and political contexts. Other variables – assigned quota and combined compliance of other members – reflect individual member countries' responses to OPEC's group dynamics.

This analysis reveals that OPEC members cannot be treated as a homogenous group. They make production decisions for their own reasons. However, OPEC still plays a significant role in determining the oil production of its members, creating distinct intragroup interaction patterns.

The output of the Gulf Cooperation Council countries and Iran is largely driven by their OPEC membership, evidenced by the significant and positive impact of the assigned quota variable. These five countries also tend to demonstrate competitive behavior within the organization, as the combined compliance variable indicates: when all other member countries

overproduce, these countries tend to follow suit. The output of Algeria, Nigeria and Venezuela is not driven by OPEC dynamics but by the impact of economic, financial and political factors.

Saudi Arabia stands out among its peers due to the relatively low impact of the combined compliance on its oil production, and the highest coefficient for spare capacity variables among the group. The data indicate that it is driven to a greater extent than its OPEC peers to stabilize the market – results indicate lower involvement in competitive behavior compared to other member countries – as Saudi Arabia's production trend runs counter to that of the group when acting as a 'swing producer.'

Saudi Arabia's production behavior helps attenuate the external shocks that affect the output of other OPEC members. These shocks are generally country-specific and tend to occur more often than those that impact OPEC as a whole. This study captured a number of such shocks for each of the analyzed countries during the period under consideration. They tend to fall into two groups. The first includes international events that impact the country's oil production, such as the imposition and subsequent relief of sanctions by the European Union, the United States and the United Nations on Iran. The second group comprises domestic economic and political factors. Increased government interference, political instability, national strikes and an economic crisis in Venezuela, for example, have had a detrimental effect on its oil production. Other members can also increase their production between the OPEC meetings in response to global supply disruption. As a result, external factors (those not captured by major decision variables) impact the quota targets on limited occasions. They can either be classified as disruptions to the global oil market or a combination of market trends that trigger a synergetic effect leading to an exaggerated market response, fueled by speculative behavior.

This study covers OPEC target oil production levels from 2000 until the end of 2016. It concludes that it will be difficult for OPEC to continue its 2017 compliance record, given the strong competitive behavior between its members, and the number of members whose output is primarily affected by domestic political and economic conditions. The successful continuation of OPEC production quota compliance also depends on any agreements reached with non-OPEC producers, a framework not observed in this study.

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Measuring the Cost-Effectiveness of Clean Vehicle Subsidies

Tamara Sheldon and Rubal Dua

Many cities, states, and countries subsidize plug-in electric vehicles (PEVs) to help meet environmental goals such as reduced local air pollution and carbon dioxide emissions. Subsidies take various forms, including rebates, sales tax exemptions, and tax credits. Despite the prevalence of PEV subsidies, research into their cost-effectiveness and efficiency is limited. Furthermore, policymakers have not typically tested the effectiveness of these subsidies. Stated-preference research suggests that targeting 'marginal' consumers who are 'on the fence,' or could be nudged to purchase a PEV with a subsidy, can reduce the costs of such demand-side policies.

This study assesses the scope for reducing the costs of existing subsidies for PEV sales, through examining the feasibility of a more targeted approach. It also measures the impact of changes in vehicle offerings, specifically the driving range of battery electric vehicles (BEVs), on the potential costs of a fixed subsidy schedule. We employed a vehicle choice model for this purpose using nationally representative, revealed preference survey data of new vehicle buyers in the United States (U.S.). The study uses this model to make predictions for the market share of PEVs and fleet gasoline consumption under alternative subsidy policies. The study also used the demographics and attitudinal elements of the survey data to incorporate consumer heterogeneity into the vehicle choice model. We use the latter, which includes income, vehicle disposal type, geography, and vehicle miles traveled, to explore various subsidy policy designs.

The results of this study suggest that the existing federal subsidy structure accounted for only 17 percent of PEV sales in the 2015 model year. This would mean that the cost of existing incentives per additional PEV purchase is very high, at around $35,601, with the cost per gallon of gasoline saved at $8.18 per gallon. A more targeted approach to subsidy policy design would give policymakers the scope to improve the impact and reduce the costs of these subsidies. This research shows that, in every simulation, the most cost-effective scenario is to limit subsidies to lower-income individuals: those with annual incomes under $70k. Such a scenario would mostly restrict subsidies to those consumers who would not have otherwise purchased a PEV (85-95 percent of subsidy dollars) and would account for around 30 percent of PEV sales. The policy cost per additional PEV would be limited to around $16,000, and the cost per gallon of gasoline savings would fall to $3.55 per gallon. Furthermore, the cost reductions from an improvement in the driving range of BEVs by 100 miles could equal those of a targeted subsidy. This study predicts that targeted subsidies, combined with an improvement in vehicle range, would limit the policy cost per additional BEV to $9,712 and the cost per gallon of gasoline to $2.41 per gallon.

A real-world example of targeted subsidy design is California's Replace your Ride pilot program that restricts subsidies to low-income consumers. However, it is important to note that such targeted subsidy designs have the potential to distort the used car market. Appropriate measures would have to be put in place to avoid such unintended consequences.

Targeted subsidy designs will differ depending on their goal. Policymakers could restrict subsidies to low-income individuals if the aim is to maximize PEV market share. Alternatively, if their goal is to minimize gasoline consumption, policymakers might limit subsidies to individuals who dispose of a large conventional vehicle, who reside in rural or farming areas, or who drive more than 2,000 miles per month.

Current U.S. federal policy subsidizes the purchase of PEVs on a sliding scale relative to their battery capacities. This study finds that maintaining this approach for purchases of BEVs would increase their sales. Policies that do not subsidize according to battery capacity would result in greater plug-in hybrid electric vehicle (PHEV) adoption. Thus, given policymakers' goal of encouraging the development of longer-range batteries for BEVs, they are likely to continue assigning larger subsidies to BEVs. However, the level of reduction in gasoline consumption is the same in both the cases, with a slightly lower marginal cost when BEVs and PHEVs are equally subsidized. Thus, if the policy goal is to minimize local air pollution and greenhouse gas emissions at lower near-term cost, there is no benefit in prioritizing one technology over the other.

Download the paper

Vehicle Retirement and Replacement Policy: Assessing Impact and Cost-Effectiveness

Tamara Sheldon and Rubal Dua

Vehicle retirement and replacement programs provide incentives for households to replace used, fuel-inefficient vehicles with new, fuel-efficient vehicles. For example, the 2009 United States (U.S.) 'cash for clunkers' program, formally known as the Car Allowance Rebate System, offered households a rebate of $3,500 to $4,500 towards the purchase of a new, fuel-efficient vehicle when they scrapped their older vehicle. Limited research to date on the program's cost-effectiveness and efficiency suggests that such subsidies did not lead to substantial additional sales. This was because everyone participating in the program was given the subsidy, including those who would have traded up to a lower emissions vehicle even without the subsidy.

The 2018 KAPSARC paper (Sheldon and Dua 2018) highlighted the fact that policymakers might increasingly adopt targeted subsidy designs to improve the cost-effectiveness of such demand-side policies. Targeted subsidy designs are aimed at 'marginal' consumers who are still deciding or who could be persuaded by a subsidy to purchase a plug-in electric vehicle (PEV). Those findings were based on simulating counterfactual targeted subsidy policies, using a vehicle choice model, estimated using real-world data in which all PEV buyers received the same subsidy. In this paper, a difference-in-difference framework measures the impact and cost-effectiveness of an existing targeted subsidy policy. That is, the simulation-based findings of the previous paper are validated in this study using real-world data involving a targeted subsidy policy.

In particular, this study explores the effectiveness of California's integrated vehicle retirement and replacement incentive program – the Enhanced Fleet Modernization Pilot Program – more commonly known as 'Replace Your Ride' (RYR). This program provides support to low-to-moderate income households in disadvantaged Californian communities to replace their older vehicles with cleaner ones. RYR offers targeted subsidies based on three criteria: household income (relative to the poverty line, which accounts for household size); geography (neighborhood air quality); and type of replacement vehicle (i.e., internal combustion engine vehicle, hybrid electric vehicle or plug-in electric vehicle). The program currently operates in two districts with relatively poor local air quality: the South Coast air quality management district and the San Joaquin Valley air pollution control district. The overarching goal of RYR is to help low-income families retire and replace their older vehicles with newer, cleaner vehicles and thus reduce greenhouse gas emissions and local air pollution in areas which have relatively poor air quality.

This paper estimates the cost-effectiveness of the RYR policy in terms of promoting additional clean vehicle sales. The policy's impact on clean vehicle sales is identified using a difference-in-difference strategy. It involves comparing changes in new PEV and hybrid sales between eligible and non-eligible households before and after the implementation of RYR.

Results show that purchases by eligible vehicle buyers under the policy accounted for at least 54 percent of battery electric vehicles, 44 percent of plug-in hybrid electric vehicles and 78 percent of hybrid vehicles (HEVs). In other words, these sales would not have taken place without the RYR subsidy. The RYR program's efficiency in promoting additional clean vehicles sales is higher than other demand-side policies – 17 percent has been recorded for the U.S. federal PEV subsidy policy and 7 percent for California's Clean Vehicle Rebate Program (CVRP). In terms of cost-effectiveness, RYR, with a per additional PEV cost of less than $17,600, is more than 1.5 times more cost-effective in promoting PEV adoption than CVRP. Within RYR, comparisons across technology suggest that the HEV subsidy is 1.35 to 2.1 times more cost-effective than the PEV subsidy. In terms of per additional gallon of gasoline saved cost, the HEV:PEV subsidy cost-effectiveness ranges from 0.83 to 1.31. Despite HEVs lower fuel economy, the HEV subsidy remains as cost-effective as the PEV subsidy because of the higher percentage of additional HEV sales and the lower subsidy amount for HEVs compared with PEVs.

Using geography and income-based subsidy designs similar to RYR, i.e., targeting low-to-moderate income households living in zip codes with low current adoption of fuel-efficient vehicles, policymakers have the scope to improve the impact and cost-effectiveness of vehicle retirement and replacement programs.

Download the paper

The Future of Energy Demand for Freight Transportation: The Impact of China and India

Workshop brief

The economic growth in China and India during the last two decades has led to a significant increase in their freight transportation energy demand, with major implications for the global fuel markets. Among the fundamental forces driving this change is both countries' entry into the global production and trade system, which has transformed them into economic powerhouses and major exporters of manufactured goods and services to the international market. Rapidly rising income, growing domestic markets supported by the enthusiastic participation of the population, and active government policies have further boosted economic growth and fostered domestic prosperity. This has led to increased demand for raw materials, energy commodities, intermediate goods and final products that are moved by ships, trucks and trains – and this ultimately translates into demand for oil, accounting for nearly half of global transportation energy demand growth in the last ten years.

As the Chinese economy cools down and settles into a new normal rate of growth, while the world economy continues to recover from the financial crisis, what does the future hold for Chinese and Indian freight transportation energy demand? Three trends point to potential strong growth in freight transportation:

> Although China's economic transition in recent years has been focused on slowing down infrastructure development and reducing excess industrial capacity domestically, the country's Belt and Road Initiative, with its emphasis on infrastructure investment, may have substantial implications for freight transportation.

> In the meantime, the Indian economy has continued its strong growth in recent years. This is expected to boost manufacturing and construction sector growth, potentially generating strong demand for freight movement.

> At the micro level, the latest trends in consumer behavior, such as online shopping, with the corresponding demand for lighter and faster product delivery, will increasingly change the way goods are currently moved between producers, distributors and end-users, and may also lead to greater freight distribution demand.

Offsetting these trends, technology innovations in the freight transportation sector, such as the 'Uberization' of freight mobility, could potentially result in substantially improved logistics efficiency and energy savings through reduced empty run miles.

To generate insights into the potential impacts of these new trends will require new approaches. While policymakers

and researchers have largely focused on personal mobility and urban infrastructure, freight transportation research has received much less attention and has suffered from limited data availability, especially in countries like China and India, and this ultimately affects policymaking. Consequently, understanding the gaps in freight transportation data, together with the use of new methods such as data collection using information and communication technologies to address the gaps, will assist policymakers to better comprehend the disruptions that may occur in global fuel markets.

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The Future of Transportation Energy Demand for Freight in Fast-Growing Economies

Workshop brief

India and China are both pursuing strategies to shift modes of freight transportation, to increase the energy efficiency in the movement of goods, relieve traffic congestion and meet emissions reduction objectives. Transport represents the largest oil-consuming sector, with motor gasoline and diesel the predominant fuels of choice. Reforming this sector is a priority for both countries, to enhance their energy security and reach their decarbonization goals. Currently, freight in India and China is dominated by road-based transport, creating intensive regional road use. Indian national highways only make up an estimated 2 percent of all its roads but account for 40 percent of the country's traffic. Trucks in India and China are also often over-loaded, leading to the fast deterioration of road infrastructure. Around 48 percent of rail lines in India and around 65 percent of rail lines in China are electrified. Shifting freight from road to rail in both countries could help reduce road congestion and energy intensity.

Effecting such a shift requires a thorough understanding of urban and regional transport infrastructure and the policy ecosystem. Inefficiencies in policy execution can impede the development of new infrastructure.

Since mobility is a derived demand, the economic and geographic composition of demand within a country will affect how and what products are moved. With increasing economic development, the industrial economy is moving from low value-added goods to high value-added goods, creating demand for efficient and timely freight movement.

A lack of flexibility in the rail system could make it less competitive and less reliable than road transport. The increasing fuel efficiency of trucks goes some way to addressing emissions reduction in the short term, with new, more fuel-efficient, fleets being used for long haul.

Road freight has increased in India and China at the expense of rail. This is due to rail capacity constraints, first and last mile delivery issues, structural changes in economies and isolated policymaking. Trying to curb escalating domestic transportation energy consumption while meeting the rising demand of freight mobility represents a major challenge for policymakers. China's rail system had limited freight capacity when its economy began to strengthen. This limited capacity, combined with a lack of new infrastructure development, resulted in rail becoming a bottleneck to economic growth. The movement of goods, including bulk commodities, were shifted to road transportation, leading to the latter's significant growth. India has anticipated a high growth of freight mobility since its economic development began to accelerate in recent years. To accommodate this, it built dedicated rail freight corridors to connect raw materials in exporting regions with major production and consumption centers. However, the uncompetitive pricing of rail and the lack of efficient intermodal connectivity has caused the share of rail in India's freight industry to remain limited. This report offers insights into India and China's freight policies and infrastructure for other fast-growing economies at different stages of economic development.

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The Costs and Gains of Coordinating Electricity Generation in the Gulf Cooperation Council: Utilizing the Interconnector

David Wogan, Frederic Murphy and Axel Pierru

Countries in the Gulf Cooperation Council (GCC) have installed a network of high-voltage transmission lines, known as the GCC Interconnector, which links the member states of Saudi Arabia, Bahrain, Kuwait, Oman, Qatar and the United Arab Emirates. The Interconnector is envisioned as a platform to facilitate coordinated electricity generation among the GCC countries to support the ongoing reform initiatives. The Interconnector was completed in 2011 and has maintained system reliability through enabling the in-kind exchange of electricity among GCC member states.

Given the interest in restructuring domestic electricity sectors and ongoing demand growth, it is useful to examine the potential savings from the greater use of the Interconnector to lower costs and improve the efficiency of electricity generation and transmission in the region. Only countries that benefit from non-emergency transmission have incentives to engage in trades. As such, for the GCC countries to engage in non-emergency transmission, all countries have to benefit.

This paper measures the gains and losses of alternative approaches to trading. It establishes a baseline using the existing policies of each country in 2015 and examines the consequences of transmitting electricity through the Interconnector, using electricity costs based on the existing fuel subsidies. This gives an estimate of the magnitude of fuel subsidies that would be exported through electricity sales. This analysis sets fuel prices equivalent to world prices and runs two scenarios with and without using the Interconnector for non-emergency power flows, to estimate the largest potential economic benefit from using the Interconnector.

This analysis finds that domestic fuel subsidies are the key barrier to economic regional electricity exchanges from which all the member countries benefit. In the absence of subsidy removal across the region, other GCC countries would purchase low-priced electricity generated with subsidized fuels, and Saudi Arabia would export $2.2 billion (in real 2015 United States dollars) annually in subsidies-by-wire.

The bulk of the annual economic benefit results from removing fuel subsidies of $41 billion. The economic gain increases by nearly $1 billion annually when coupling subsidy removal with electricity exchange. Nearly 33 terawatt hours, or over 5 percent, of GCC electricity production would be exchanged at market prices.

Substantial investment would accompany these exchanges. More efficient combined-cycle gas turbines and utility-scale photovoltaics would replace over 50 percent of existing capacity at a cost of $7.3 billion. A significant aspect of the capacity shift is the replacement of electricity/water cogeneration plants, with water production switching to reverse osmosis.

The thermal cogeneration plants in make the electricity systems inflexible because of the need to produce water. Retiring the cogeneration plants and replacing them with combined-cycle and reverse osmosis plants increases the flexibility of the national grids and allows them to take advantage of the interconnection.

These results highlight the potential to increase the efficiency and reduce redundancy in the existing GCC electricity and water systems and achieve substantial gains through increased coordination. Since the GCC countries are unlikely to fully deregulate electricity production, this paper examines scenarios that eliminate cross-border subsidies while maintaining fuel subsidies for domestically consumed electricity. These scenarios balance economic efficiency with social goals. The result is costlier than not having coordination.

As with previous KAPSARC studies, the important lesson is that moving from current highly regulated systems to a more market-based approach on a piecemeal basis can increase costs without the proper sequencing of policy changes. The Interconnector can provide substantial economic benefits. However, the conditions must be right for these benefits to be realized.

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Electricity Market Integration in the GCC and MENA: Imperatives and Challenges

Workshop brief

A number of power systems around the world have combined to form regionally integrated electricity markets in order to achieve efficiency, reliability and environmental objectives. Beyond the physical interlinking of national grids, the concept has gained little traction in the Gulf Cooperation Council and Middle East and North Africa regions to date. However, a renewed political commitment to regional integration has revived interest among the countries in these regions. With rising power demand and growing financial pressure, the development of a regional electricity market has the potential to offer many benefits to the participating countries, both in the short run and long run. The design and development of an integrated electricity market in these regions will require an understanding of a range of economic, regulatory and policy challenges. The key highlights follow.

For decades, resource-rich countries in these regions have been providing energy subsidies with the aim of social protection and redistribution of the hydrocarbon wealth among their citizens. While subsidized retail tariffs have their own implications for the sector's performance, subsidized fuel for power generation has made the task of integrating electricity markets especially difficult because of concerns about implicit wealth transfer in cross-border electricity trading. Removing supply-side price distortions through effective price reform measures will be necessary for the development of an effective and viable regional electricity market. Until such time, the option of facilitating electricity trading at market-determined prices could be explored in the short run by developing an acceptable regulatory approach. However, benchmarking and transparency of fuel prices will remain contentious issues.

Promoting competition in wholesale and retail electricity markets through open access is an essential element of the market liberalization process. However, due to the single/principal buyer model predominating in the electricity industry in the regions, open access and third-party sales are either not allowed or are only loosely defined. The following measures would be required to improve market liquidity, both within and across borders, and develop a competitive marketplace, reaping the benefits of load and time differences: the implementation of open access together with fully-supported, fair, transparent and common regulatory rules for access to and pricing of grid services in the region. Major barriers to the implementation of open access exist in exclusive long-term power purchase contracts, including the fear of losing the revenue base to cross-subsidize other low paying customers.

Liberalization of the electricity market is underway in a number of countries in the region, but local priorities have shaped its pace and design rather than regional objectives. International experience suggests that electricity market integration is a dynamic transition process which takes time to mature, but where both 'liberal' and 'nationalistic' approaches can however co-exist. Thus, initiating structural reforms may be desirable but not a prerequisite to market integration. A market design that facilitates the development of a regional market while at the same time allowing countries to undertake reforms at their own pace is required. Experience shows that making liberalization a precondition for developing a regional electricity market has not succeeded in the past.

While electricity as a product can be differentiated over time, the existing trading portfolio of the Gulf Cooperation Council Interconnection Authority is largely characterized by long-term transactions. By contrast, the day-ahead market accounts for the majority of traded volume in a number of power pools in Europe, Australia and the United States. Development of the short-term market needs to be encouraged to take advantage of regional load diversity. Inducing competition, reflecting the value of electricity at shorter operational timescales and rewarding flexibility can be the guiding principles for future market design. Restrictions and/or delays in achieving electricity price and volume approvals from multiple agencies have discouraged the emergence of a short-term market for cross-border electricity trading.

Institutional arrangements for cooperation and coordination in formulating and aligning necessary regulatory frameworks should be explored. Both top-down strategies, such as the European Union's vision of creating a pan-European integrated market, and bottom-up strategies like aligning or creating common market rules/regulations, will be required to integrate markets. Moreover, effective integration will also require coherent system operation practices and coordination at two levels: horizontal, between system operators, and vertical, as with a system operator dealing with both market participants and governments.

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Economic Cycles and the Responsiveness of Natural Gas Demand in China's Residential Sector

Noha A. Razek

Determining which factors drive the growth in gas demand is difficult because of data limitations and the non-convergence of short-term fluctuations to a long-term equilibrium. As a result, we use an unobserved components model to estimate the responsiveness of residential demand for natural gas in urban China to changes in income and natural gas prices (i.e., estimate income and price elasticities. This made it possible to account for technological progress and periodically changing administered prices.

The Chinese economic cycle estimated here includes both the surge in economic growth in the early 2000s, and the decrease in the rate of growth and aggregate consumption due to investment slowdown since 2013. The cyclical components separating the two effects of China's five-year plans were modeled. These two effects reflect movements around both a steady state irrespective of economic growth and fluctuations around a growth trend.

During the sample period 2001 to 2014, the value of price elasticity is approximately -0.52 and the estimated value of income elasticity is not statistically different from unity, which suggests that natural gas for urban consumers tends to be a normal economic good that provides a high quality standard of living. That means it is neither regarded as a necessity nor a luxury good, reflecting the substitutability of natural gas. Demand for natural gas for heating purposes (cooking, water and space heating) is affected by changes in income and price. Coal is cheaper, so residents may choose it over natural gas. In urban areas with the relevant infrastructure, households will opt for natural gas; in other locations, coal use is the only possible choice. As more natural gas infrastructure is constructed, households will shift to natural gas. For those with access to natural gas, as their income increases, their consumption of gas for cooking and water heating will increase and/or they will move to larger accommodation where their consumption of gas for space heating will increase accordingly.

It is observed that the positive cyclical effect starting in the early 2000s, possibly triggered by the long-term plan of the 8th National People's Congress that resulted in an increase in urbanization and infrastructure development, contributed to higher natural gas consumption. The estimated midterm cycle reflects the 1999 trough in China's economic cycles and the peak in 2012, which is in line with the economic slowdown that started in 2013. China's natural gas consumption declined following economic slowdowns in 2014 and 2015. This is in line with concerns over low consumption, investment and income

growth as well as share of labor in income, discussed at the 18th National Party Congress in 2012.

This demonstrates that the model reasonably represents China's economy and residential demand for natural gas in urban areas. Accordingly, this derived cycle can also be considered as a business cycle indicator, which shows that information based on five-year plans and economic cycles is key to understanding China's economy and natural gas market potential.

The main findings of the research are:

- Natural gas is a normal yet substitutable economic good for urban households.
- The estimated midterm cycle suggests that China reached an economic cycle peak around 2012. This aligns with concerns, discussed during the 18th National Party Congress, over economic slowdown which likely contributed to the decrease in natural gas demand.
- Infrastructure investment to increase natural gas accessibility is essential for increased demand.

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The Economic Impact of Price Controls on China's Natural Gas Supply Chain

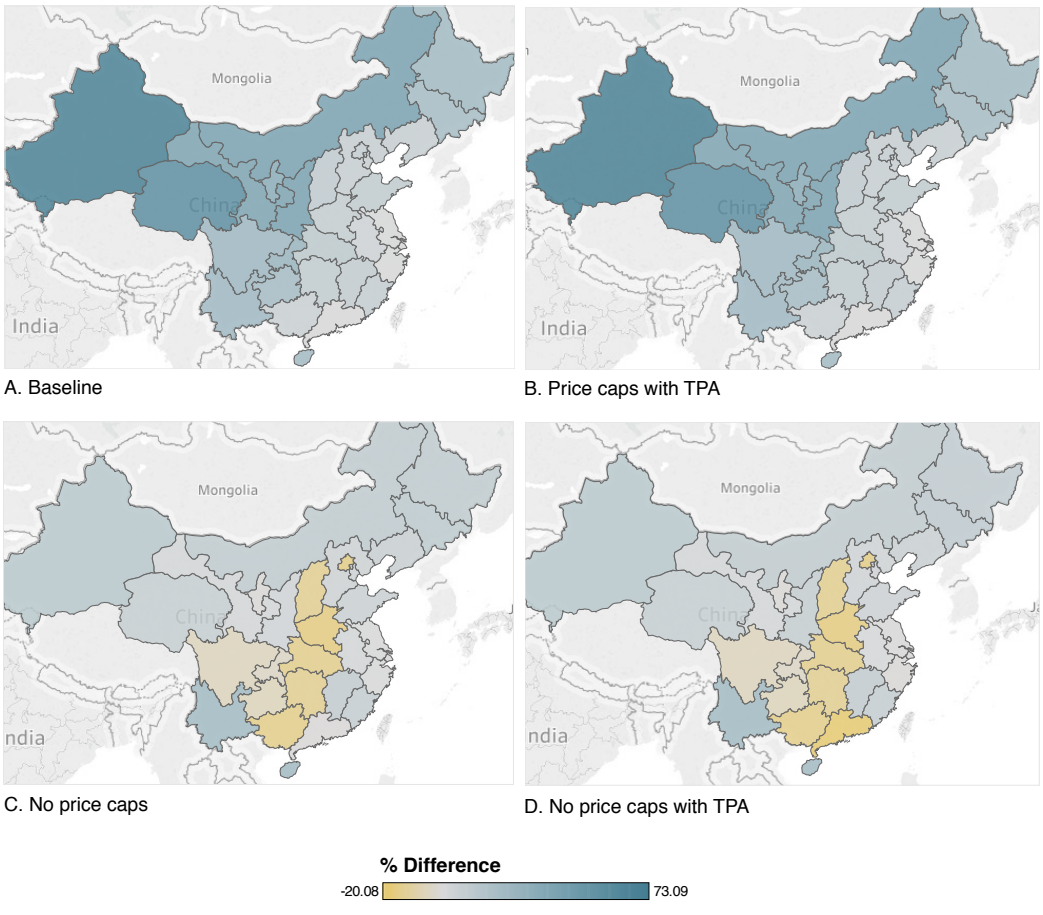
Bertrand Rioux, Philipp Galkin, Frederic Murphy, Axel Pierru, Artem Malov, Felipe Feijoo Palacios, Yan Li and Kang Wu

Reforming the pricing mechanism and ensuring efficient third-party access to infrastructure have been the top priorities of China's policy agenda for the natural gas industry. While prices for unconventional gas supplies and liquefied natural gas (LNG) imports have been largely liberalized (settled by sellers and buyers through negotiations), certain consumer groups (commercial and residential demand, small industrial users) and modes of delivery (pipeline) are still subject to fixed prices or price caps. These price distortions incentivize profit-maximizing firms to alter their operational, logistic and investment strategies to avoid supplying gas at capped prices, leading to the cross-subsidization of lower-priced regulated demand sectors, with higher tariffs charged in deregulated markets. Limited access to midstream infrastructure further distorts logistics patterns and leads to a suboptimal market structure and a less efficient resource allocation nationally.

To estimate the magnitude of such distortions and potential gains from liberalization reforms, we developed a single-period equilibrium model that provides a short-term perspective on China's gas market. Key model output elements include total production, domestic liquefaction, pipeline and LNG imports, average marginal cost (weighted by provincial demand), and total systems cost. The model is formulated as a mixed complementarity problem and represents the profit-maximizing behavior of price-taking suppliers – three large national oil companies (NOCs) and smaller fringe suppliers – with some market segments subject to price caps. The model is calibrated to simulate the structure of China's provincial natural gas supply market in 2015. Scenarios include lifting the price caps and providing all market players with equal access to pipelines and regasification infrastructure.

We find that lifting the price caps for regulated natural gas demand sectors in 2015 would have resulted in a 14 percent reduction in marginal supply costs and decreased the total system cost by 4.7 percent or $1.4 billion. These efficiency gains primarily occur as a result of optimized logistics – reduced domestic liquefaction and LNG trucking – and import patterns,

Difference between marginal cost and city gate price caps



as market participants no longer prioritize more expensive delivery pathways to target unregulated market segments.

The impact of eliminating price controls is magnified when all market players are granted access to midstream infrastructure. These two initiatives combined could have saved $2.2 billion (7.6 percent of total cost) and reduced the average spot prices across provinces by 16 percent. Opening the market eliminates the use of domestic LNG to skirt the price caps and lowers the marginal cost of supply. In some central provinces, the resulting price declines lead to prices below the government-enforced price cap, increasing the competitiveness of natural gas in the provincial fuel mix. Increased flexibility in logistics induces competition among import sources and facilitates the penetration of cheaper pipeline imports to central and even eastern provinces. The impact of third-party-access reform, on its own, is less pronounced: the spot prices record minimum changes, and total cost savings are below $1 billion.

The current regulatory environment facilitates the regionalization of China's gas market and favors the LNG industry, both its imported and domestic liquefaction segments. Conversely, the proposed reform initiatives tie segregated regional markets together through optimized logistics patterns and increase the competitiveness of pipeline imports. In a highly concentrated environment where a particular NOC dominates many regional markets, such reforms will likely alter the competitive landscape significantly and could face opposition from major players. The potential for the players to exercise market power is an aspect of the market not addressed in this study.

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Fostering Joint Leadership on Energy Productivity Transition In Saudi Arabia and China

Workshop brief

China's Belt and Road Initiative (BRI) could be an important catalyst for achieving Saudi Arabia's economic transformation goals in terms of fostering a stronger collaborative relationship. The focus of the Chinese government on green development within the BRI may also offer an opportunity to improve the production and use of energy efficient, resource efficient and renewable energy technologies in the Kingdom's infrastructure and development projects.

For example, China has the world's largest energy service company (ESCO) market, valued at $56 billion in 2016. Saudi Arabia recently formed a $500 million super ESCO focused on public buildings. There is rich potential to extend the Kingdom's approach to industrial energy efficiency, which accounts for over 50 percent of energy consumption in both countries.

China is also the world's largest producer and installer of renewable energy (RE) technologies. Saudi Arabia has a target to build 9.5 gigawatts (GW) of RE capacity, or 10 percent of generation, by 2023 and recently outlined plans for up to 200 GW by 2030. The National Renewable Energy Program eProcurement Portal offers a gateway to participate in the Kingdom's RE transition.

Saudi Arabia is the world's largest exporter of basic petrochemical polymers, while China is the largest importer and consumer. Demand for polymers is expected to increase by around 3.5 percent year-on-year during the next decade. The historical model of development and trade in this area has focused on basic materials being sent from the Kingdom to China where they are transformed into a range of higher value products. There is a strong desire in the Kingdom to move from simply being a source of cheap feedstocks, to encourage greater local production of some of these value-added products. Research and collaboration can play an important role in helping chart pathways towards mutually beneficial opportunities which avoid potential trade risks or conflicts.

Setting energy productivity or intensity targets and using energy productivity as a strategic narrative can help policymakers integrate a range of economic and energy policy objectives. The goal of energy productivity, to maximize value from the energy system, economically, socially and environmentally, can also appeal to a wide range of stakeholders. China has had a long experience setting such targets. Their adoption in Saudi Arabia could help provide investors with clearer signals and increase certainty around long-lasting energy investments.

Industrial energy efficiency financing, petrochemical trade and investment, renewable energy, district cooling and energy access are all areas identified as having potentially high benefits for research and collaboration.

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Policy Lessons From China's CCS Experience

Xiaoliang Yang, Wolfgang Heidug, and Douglas Cooke

Carbon capture and storage (CCS) is a potential bridge to a zero-carbon future for fossil fuel-dominated economies like China. Scenarios show that China will not achieve long-term carbon dioxide (CO_2) emissions reduction without CCS. For CCS to mature and be deployed at scale requires a series of policy instruments combining technology push and market pull. This paper analyzes the status of CCS development in China and proposes an 'adaptive' policy framework tailored to the Chinese situation. It allows for policy learning in response to the uncertainties and opportunities inherent in the technology maturation process; a feature that static technology roadmaps do not provide.

CCS in China has made significant progress as a result of substantial research and development funding over the last decade. Key achievements in this period include developing and piloting all main CO_2 capture technologies (pre-combustion, post-combustion, and oxy-combustion), assessing CO_2 storage potential in the Chinese subsurface, and demonstrating the country's first fully-integrated CCS project. China is now ready to start industrial-scale, sector-specific demonstration with the aim of having the technology available around 2030. Storage-focused CO_2-enhanced oil recovery can make an important contribution to achieving this objective.

This paper sheds light on the policy instruments needed to achieve short- and long-term CCS development in China. It argues that China has an opportunity to promote domestic CCS projects through leveraging its proven capability to mobilize capital grants for major infrastructure investments. Alternative policy options, such as portfolio standard programs or tax incentives, require consensus building and coordination among various ministries, which are time-consuming and may not be appropriate for this phase of CCS demonstration.

Economy-wide carbon pricing measures could also be implemented to complement and reinforce more specific sectoral incentives for the deployment of CCS. Such measures should be driven by market-based instruments that provide incentives for CO_2 reduction, irrespective of the technology employed. Possible options include incorporating CCS in the planned national emission trading schemes, or a carbon tax on atmospheric CO_2 emissions. This paper frames the discussion within an adaptive policymaking framework. It uses the notion of 'policy gateways' to ensure that CCS policymaking incorporates feedback from implementation experience, specifying policy gateways that are relevant for the Chinese CCS context.

China's experiences of CCS development also provide a useful context for exploring how an adaptive policy framework could be applied to support CCS and other clean energy technology development. There are some similarities to Saudi Arabia in terms of the extent of the government's role in the economy, which might lead to similar capabilities in mobilizing public resources for industry development.

Download the paper

Potential Effects of Trade Liberalization on China's Imports of Plastics From the GCC

Philipp Galkin, Carlo Andrea Bollino and Rami Shabaneh

Bilateral trade between the Gulf Cooperation Council (GCC) countries and China has been expanding rapidly since the turn of the century. In 2016, China accounted for 12 percent of the GCC's imports, making it the largest exporter to the region. The GCC countries also heavily rely on China as one of their major export markets. Still dominated by energy fuels, their exports to China are becoming increasingly diversified as the GCC producers strive to convert parts of their vast petroleum reserves into higher value-added products. In particular, plastics currently amount to about 7 percent of total GCC exports to China, or 30 percent of non-energy exports.

Increase in trade flows under tariff reduction scenarios (%)

HS code	Product name	Trade flow	Increase in trade under preferential tariff rates				
			5.2%	3.9%	2.6%	1.3%	0%
390110	Low density polyethylene	Total imports	0.2	0.5	0.7	1.0	1.3
		GCC imports	2.1	4.2	6.4	8.7	11.1
390120	High density polyethylene	Total imports	0.6	1.3	1.9	2.5	3.2
		GCC imports	2.2	4.4	6.8	9.2	11.6
390210	Polypropylene in primary forms	Total imports	0.1	0.2	0.3	0.4	0.5
		GCC imports	1.2	2.5	3.8	5.1	6.4

Developing trade and investment ties between the GCC and China called for institutional arrangements beyond the World Trade Organization (WTO) framework to further enhance economic cooperation. The GCC-China Free Trade Agreement (FTA) negotiations started in 2004 and, after several years of suspension, resumed in 2015. One of the major stumbling blocks in the negotiation process has reportedly been the issue of liberalizing petrochemical trade. Protecting its domestic producers, China proved to be reluctant to set forth significant concessions on import duties. Conversely, the GCC countries sought a preferential trade regime since the development of their petrochemical industries has been primarily driven by exports, with China representing a major global demand destination.

Understanding the potential effect that various liberalization scenarios for the petrochemicals trade can have on the major stakeholders may help to facilitate progress toward finalizing the FTA negotiations. This study aims to assess such effects through the following steps:

- Estimating the impact of tariff reduction and the elimination of non-tariff barriers on the bilateral trade flows of three major plastics, classified according to the six-digit harmonized system (HS) 2012 code:
  - 390110 – polyethylene with a specific gravity of less than 0.94 (including low-density polyethylene (LDPE) and linear low-density polyethylene (LLDPE) – together referred to as LDPES);
  - 390120 – high-density polyethylene (HDPE) (a specific gravity of 0.94 or more).
  - 390210 – polypropylene (PP).
- Assessing the consequences for the parties involved:
  - Opportunities for the GCC exporters (as a block and by country).
  - Net welfare gains for China and the impact on its consumers and domestic producers.
- Evaluating the feasibility of trade liberalization scenarios based on market developments and the estimated impact on key stakeholders.

This study develops and estimates a dual stage model of import demand functions and applies it to selected petrochemical products, to quantify the trade creation and trade diversion effects that occur as a consequence of trade liberalization. It first models total petrochemical imports into China. Second, it models import flows among competing exporters: the GCC and the rest of the world. This design allows for an estimation of import demand and import substitution price elasticities, and a simulation of alternative tariff reduction scenarios.

We find that the price sensitivities and the structural composition of total Chinese imports differ significantly across products. The coefficients for import demand elasticity, which drives the trade creation effect, range from -0.29 for PP to -1.19 for HDPE. The dispersion of import substitution elasticities, which define trade diversion, is less pronounced with the smallest coefficient of -0.86 recorded for PP and the largest (-1.41) for LDPES.

Consequently, the reduction or elimination of Chinese import duties would potentially have a significant positive impact for plastics exporters in the GCC. The analysis in this paper

suggests that Saudi Arabia and the United Arab Emirates (UAE) would be best positioned to take advantage of such a scenario. These countries would be able to capture most of the gains in PP and HDPE segments, and Qatar could substantially increase its LDPES exports to China. This study estimates that if China dropped its import tariffs to zero, the annual increase in imports for the three major plastics would be $193 million from Saudi Arabia, followed by $134 million for UAE, $54 million for Qatar and $28 million for Kuwait, based on average 2016 import prices.

Reducing import tariffs would impact Chinese domestic producers through a trade creation effect: More efficient (cheaper) imports would partially replace less efficient (more expensive) domestic production. Domestic HDPE production seems to be most vulnerable to foreign competition. A zero percent tariff rate on GCC imports would result in a 3.2 percent increase in total HDPE imports, compared to a 1.3 percent increase for LDPES and a 0.5 percent increase for PP. On the other hand, liberalizing imports would allow Chinese consumers to benefit from reduced tariffs – estimated at $256 million per annum – and create a $6.3 million net welfare gain for the country.

Download the paper

Related papers:

Towards Economic Prosperity Through Industrial Energy Productivity Improvement

How to Achieve Economic Prospertiy Through Industrial Energy Productivity Improvement

Coal in Asia: The Challenge for Policy & the Promise of Markets

Support for a Carbon Tax in China: A CDMP Simulation Using KTAB

The Effect of PTAs on Energy Trade From Chinese & Exporters' Perspectives

Understanding the Energy Transition

Workshop brief

Barely a few years since the phrase 'energy transition' entered the mainstream lexicon, it is becoming clear that conventional economic models are inadequate for deconstructing the complexity surrounding the future trajectory of global energy, the impacts of decarbonization and the required response by governments and corporations. KAPSARC's energy workshop series aims to provide insights by bringing together a range of experts from government, the private sector and academia.

Energy scenarios published by a wide range of organizations including, inter-alia, the International Energy Agency, OPEC, the World Energy Council and BP reflect the complexity of the energy transition and the multiplicity of possible outcomes and impacts. As awareness of the complexity of the energy transition increases, many scenarios are raising the number of possible pathways, a phenomenon that serves to reduce, rather than increase, clarity.

Research recently undertaken suggests that some of the drivers of the transition, hitherto regarded as key, might not be as powerful as originally anticipated, either in terms of accelerating the transition or in decarbonizing the fuel mix. A case in point is electric vehicles (EVs) that, irrespective of the speed of uptake, are now viewed as having a heavy lifecycle carbon footprint and resulting in a relatively low net displacement of oil. A fleet of 100 million EVs would reduce oil demand growth by less than 2 million barrels per day. Continued improvements in the fuel efficiency of the internal combustion engine (ICE), allied with hybrid technologies, could extend the life of traditional ICE vehicles. Potentially more disruptive trends in oil demand for transportation include the increased use of natural gas as a fuel in shipping and trucking, and consumers opting out of car ownership altogether.

The power sector will be the key battleground in an emerging inter-fuel war. Renewables will increasingly meet the growing demand for electricity across the globe, with natural gas continuing to offer flexibility despite limited decarbonization benefits. Exposure to electricity becomes a major risk at the generation or load ends of the chain. Coal remains firmly entrenched even if its market share falls. Much will depend on the desire of policymakers in key consuming countries such as India and China to cut back on current plans to build new coal-fired plants or even to retire existing units.

India is expected to overtake China as the main driver for primary energy demand growth. There is a risk that an economic downturn in either India or China could have a major impact on global demand growth, as most of it comes from these two countries.

Changing demand patterns for some petroleum products, notably diesel, could require a major reconfiguration in the global refining industry. Diesel is under pressure in multiple markets for many reasons: in Europe due to particulate emissions; in India due to the electrification of railways; in distributed power generation from the expansion of power grids; in trucks from electricity and liquefied natural gas; and in passenger vehicles from electricity and, potentially, hydrogen.

The changing fuel mix, especially in transportation, will raise fiscal challenges in countries that rely on oil consumption taxes and in countries that are resource holders. Many of the latter are already pursuing strategies to diversify their economies while working to secure a sustainable market for their resources.

Meanwhile, in the short to medium term, there is a risk of a disorderly transition caused by disrupted markets and price volatility, as corporations and financial markets weigh up the perceived investment risk in the hydrocarbons sectors and delay supporting necessary investments in maintaining production capacity. Low-cost legacy oil producers, such as those in the Gulf Cooperation Council that are prepared to continue investing, are expected to reap windfall revenue that they could reinvest in securing a sustainable future for their economies.

Download the paper

Decarbonizing Oil: The Role of CO_2-Enhanced Oil Recovery (CO_2-EOR)

Workshop brief

Under the Paris Agreement's 'well below 2 °C' climate target, countries have committed to work towards development paths that, over time, become carbon neutral. Of the key emitting sectors, carbon dioxide (CO_2) emissions from transportation are the most challenging to reduce cost-effectively. According to the International Energy Agency Reference Technology Scenario, CO_2 emissions in this sector could reach 14 billion tonnes by 2050. Storage-focused CO_2-EOR can help to cost-effectively reduce the carbon footprint of oil use in the transport sector and support other decarbonization options. The life cycle of greenhouse gas emissions associated with a barrel of oil range from around 400 to 900 kilograms (kg) CO_2 equivalent, and depend on a wide range of factors. CO_2-EOR can effectively lower the carbon intensity of oil production across the value chain. While wider concerns persist about the petroleum industry using CO_2-EOR to extend fossil fuel use, oil and gas will continue to be major contributors to energy supply for decades to come. It is essential, therefore, to reduce the carbon intensity of petroleum supply in order to benefit the climate.

Currently, EOR projects use about 80 million tonnes of CO_2 per year, almost all of which becomes permanently trapped in oil reservoirs. Of this number, about 20 million tonnes are captured from a variety of activities such as natural gas processing, ethanol and fertilizer production, and – notably – power generation and steelmaking. While virtually all of these activities take place in the United States, the potential for CO_2-EOR storage outside North America is significant and currently estimated to correspond to an economic storage potential in the order of 40 gigatonnes of CO_2.

Conventional CO_2-EOR operations use about 300 kg of CO_2 per incremental barrel of produced oil. These projects look to optimize their return on investment rather than maximize CO_2 storage. However, CO_2-EOR can be configured to co-exploit hydrocarbon production and storage. The amount of CO_2 that can be stored via 'advanced' CO_2-EOR practices will be determined by reservoir characteristics, wells and infrastructure design, operating choices and economic variables. These variables include the oil and CO_2 prices the operator can obtain from hydrocarbon production and for CO_2 storage. Additionally, the availability of CO_2 is a critical barrier for large-scale EOR deployment and plays a key role in determining how much CO_2 is stored during the EOR process.

The value proposition for CO_2-EOR may be different in different countries. While the emissions reduction objective may be

driving CO_2-EOR deployment in some countries, in other countries the selling point for CO_2-EOR could be to free up natural gas that would otherwise be reinjected, job creation, or the effective use of domestic hydrocarbon resources. Regulatory requirements, technological capabilities and the supply-price relationship between oil and carbon dioxide also influence the decision to invest in EOR. Policy interventions that improve the positioning of storage-focused EOR within oil and gas investment portfolios are necessary. Pricing carbon dioxide emissions would provide an important stimulus for CO_2-EOR and would encourage investment in developing new alternative technologies with lower emission profiles or costs. Other options for incentivizing CO_2 storage include investment tax credits, storage credits, tax exemptions on dedicated bonds, master limited partnerships, environmental performance standards, fuel carbon intensity limits and fuel economy standards. Policy instruments such as the European Union's fuel directive and the low carbon fuel standard in California have encouraged the increased use of alternative fuels and ensured compliance with declining carbon intensity obligations. The Carbon Offsetting and Reduction Scheme (CORSIA), about to be implemented by the International Civil Aviation Organization, will provide a market mechanism to offset emissions growth from international air transport. CO_2-EOR schemes might be eligible for CORSIA as a compliance mechanism.

Download the paper

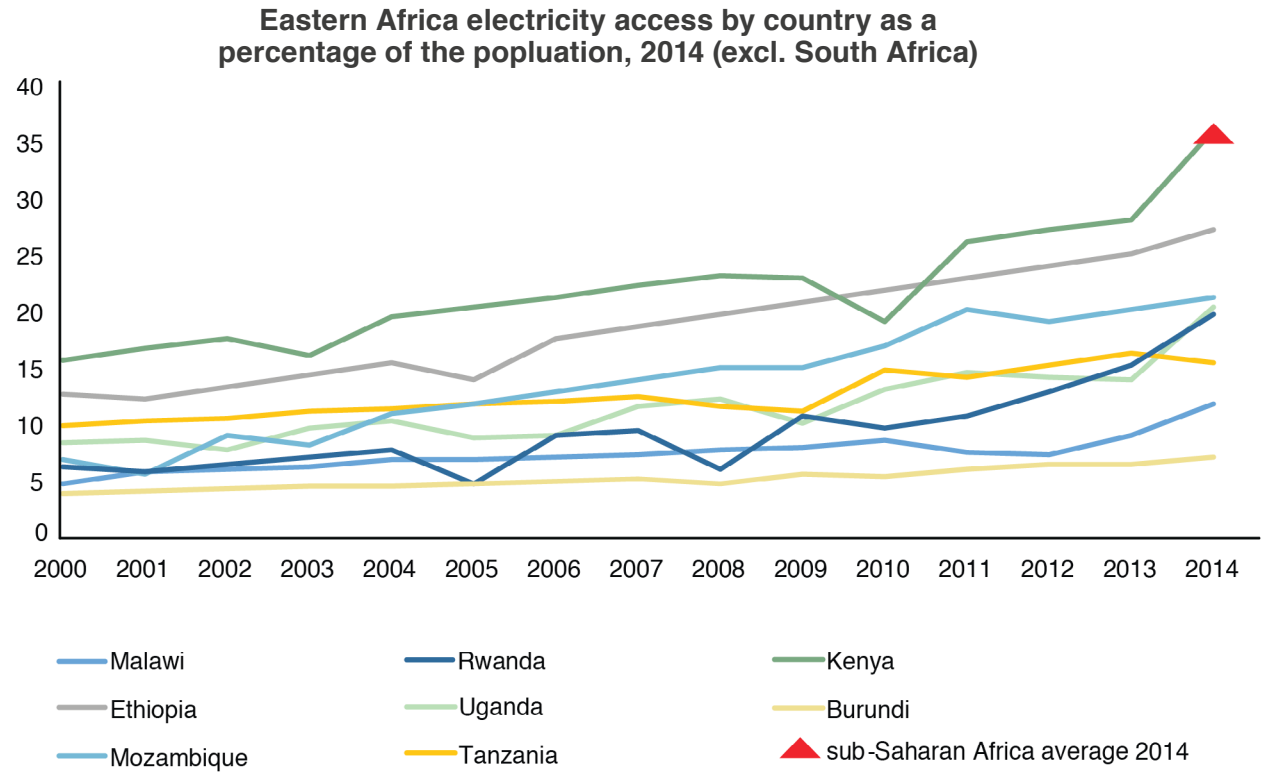
Identifying the Roadblocks for Energy Access: A Case Study for Eastern Africa's Gas

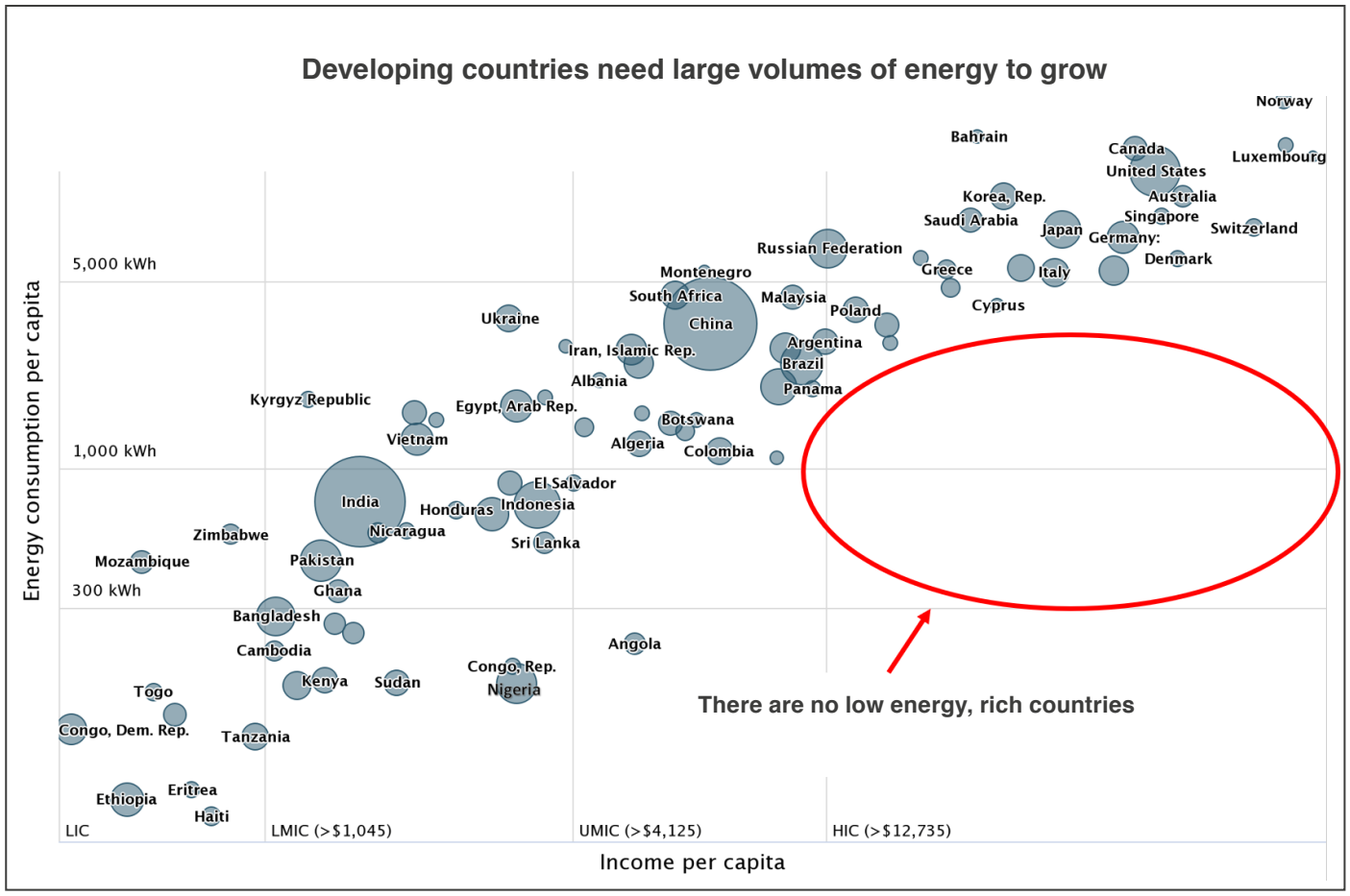
Rami Shabaneh, Anne-Sophie Corbeau and Fernando Tomas Nhantumbo

Improving access to reliable, modern energy is among the highest priorities of Eastern African countries' economic growth plans and energy strategies. In particular, developing access to electricity – including in rural areas – is the cornerstone of most strategies. On average, only 35 percent of the population in sub-Saharan Africa has access to electricity; lower than any region in the world including developing Asia, the Middle East and Latin America. In the group of nine Eastern African countries considered, only South Africa and Kenya are above this average, while most countries have a rate below 20 percent. This implies that the majority of the population still has to meet its primary demand for cooking and lighting from unsustainably harvested biomass. The process of fuel collection is also time-consuming and comes at the expense of education and income generation (IEA 2006, 419).

The paradox is that, against this bleak demand picture, Eastern Africa is endowed with large energy resources ranging from oil, gas, uranium and coal to a variety of renewable energy sources, including solar, hydro, wind and geothermal. In theory, these resources should be sufficient to meet a large part of the region's energy needs, contributing not only to the development of power generation but also to that of other sectors such as the industrial and transportation sectors. However, as of 2017, most of these resources are largely underdeveloped, except for coal and uranium in South Africa and some hydro potential.

Low electricity access finds its roots in many issues, including a slow development of power capacity due to lack of investments, high technical losses and theft, difficulty covering the cost of electricity for utilities, high electricity tariffs in some countries, and the poor financial health of utilities. This is compounded by specific issues experienced in each region, such as low incomes, the large size of the countries, the remoteness of some energy resources from demand centers, and high rural populations. Energy efficiency also poses a challenge: on the supply side from low-efficiency power plants, and on the demand side from issues such as inefficient transport fleets and industrial processes. Deployment of prepaid meters to households has increased electricity access in Eastern Africa. Almost all countries in the region have programs in place to





support this initiative. It makes it easier for utilities to collect revenue, reduces connection costs and manages demand for consumers.

While industries linked to the agriculture sector (agro-processing) have an important role in many countries, the transport and industrial sectors are also key drivers of the economic development of Eastern Africa. These sectors need energy to develop. The total energy use in transportation in all nine countries accounts for only 10 percent of their total energy consumption. Africa's road infrastructure is quite underdeveloped. Under 20 percent of roads are currently paved, and many roads are in poor condition. Thus public and non-motorized transport are widely used. Some energy strategies of the countries studied suggest plans to expand mass transportation, including trains and buses. However, these initiatives may face some of the challenges experienced by countries trying to improve electricity access, including limited financial capacity and the need to implement policies to satisfy all stakeholders. Meanwhile, natural gas discoveries may open the door to industrial development.

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Related papers:

Third-Party Access to Regasification Terminals: Adapting to the LNG Markets' Reconfiguration

Growth, Investment and the Low-Carbon Transition: A View From Saudi Arabia

Curbing Carbon Emission: Is a Carbon Tax the Most Efficient Levy?

Towards More Pragmatic Global Climate Goals and Policies

Enhanced Oil Recovery and CO2 Storage Potential Outside North America: An Economic Assessment

02 // Viewpoint

The $200 billion annual value of OPEC's spare capacity to the global economy

By Adam Sieminski, KAPSARC President

Rising international oil prices and increased geopolitical uncertainty have put OPEC's spare production capacity back into the spotlight. KAPSARC's recent peer-reviewed collaborative study in the Energy Journal by authors Axel Pierru, James L. Smith, and Tamim Zamrik finds that OPEC's spare capacity reduces oil price volatility and generates between $170 and $200 billion of annual economic benefits for the global economy.

Investments in spare capacity provide value to the economy because deploying the production held in response to disruptions saves costs that result from price volatility. This value can be calculated by subtracting the gross domestic profit (GDP) losses that the world would expect to suffer even after deploying the spare capacity buffer from the expected losses without the buffer. The expected losses depend on the buffer size, the magnitude and persistence of the shocks, and on the global GDP losses incurred when there are production shortfalls.

For many years analysts have judged oil market stability by considering the level of excess production capacity maintained almost exclusively by OPEC. The production and delivery of oil to the market is subject to frequent disruptions, whether from conflicts, natural disasters, labor strikes, port closures, or political sanctions. In addition, demand can be affected by other factors such as the general state of the global economy. The rigidity of demand and supply magnifies the impact of any disruption, and restoring equilibrium to the market often requires sharp price movements, especially in the short term.

These sharp movements and the financial risk premium associated with volatility impose costs on the global economy if they are not dampened through mechanisms including the release of strategic stocks held by major oil importers, redirection of oil tankers to fill geographical imbalances, or increases in production from OPEC spare capacity. Historical examples where OPEC has used its spare capacity to stabilize the market include increasing members' production to meet the unexpected buildup of global oil demand from 2003-2004, and to compensate for the collapse of Libya's oil production following the uprising of 2011.

Figure 1 shows the change in monthly 'effective' spare capacity reported by the International Energy Agency (IEA) since 2001. OPEC's spare capacity amounted to 3.24 million barrels per day in June 2018, with world oil demand forecast to reach 100 million barrels per day by the end of the year. Saudi Arabia has held, on average, 70 percent of OPEC's total spare capacity since 2001.

The study uses monthly data to build and estimate a model to analyze a 'counterfactual' scenario — comparing what would have been the outcome if OPEC had not deployed spare capacity to the actual outcome observed in global oil markets. The model describes how OPEC maintains a buffer of spare capacity that it uses to offset perceived shocks to global oil demand and supply. The analysis of OPEC's behavior recognizes that the economic, industrial or geopolitical information necessary to accurately judge the size of such shocks is never fully available, which limits OPEC's ability to

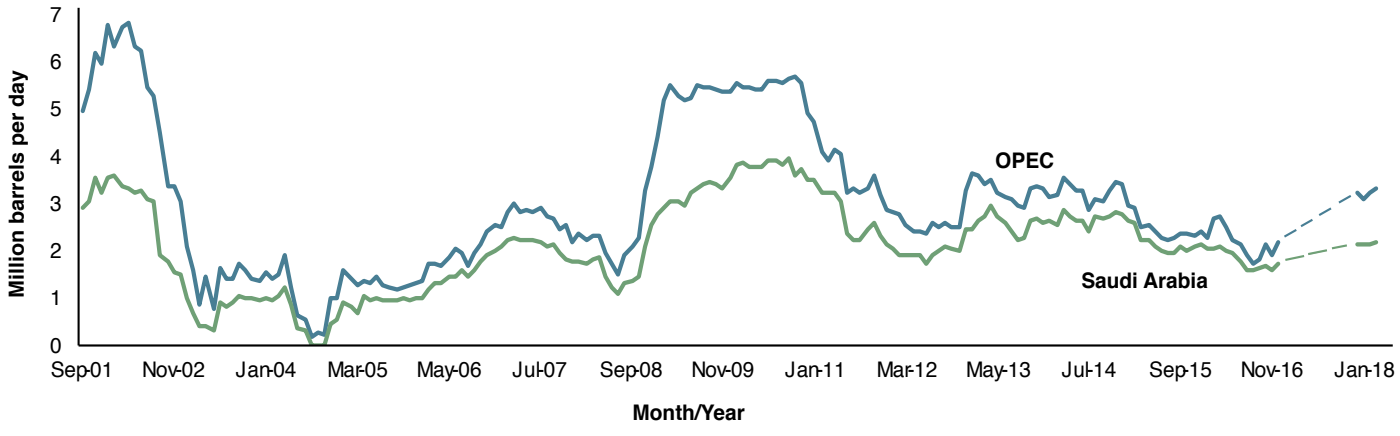

Figure 1. OPEC's effective spare capacity.

Source: IEA Monthly Oil Market Reports

Note: IEA did not report data from January to November 2017.

stabilize the price of oil. In addition, the model accounts for OPEC's logistical constraints and compliance levels.

The counterfactual scenario is based on estimates of the monthly oil prices that would have prevailed from 2005 to 2014 had OPEC not used its spare capacity to offset shocks. These hypothetical prices are compared to the prices historically observed. There is no consensus on how price responsive global demand is. The study examines the effects of a range of monthly price elasticity estimates. Figure 2, based on a monthly price elasticity of -1 percent, is representative of the type of impact that OPEC's spare capacity policy has had. The analysis indicates that OPEC had a substantial stabilizing influence, perhaps reducing oil price volatility by as much as half. The same conclusion holds when the analysis only considers Saudi Arabia, or the four GCC members of OPEC collectively. Indeed, the analysis finds that Saudi Arabia has played a greater role in offsetting shocks than all other OPEC members combined.

The study also examines the magnitude of spare capacity. This is especially relevant given that the absolute level of spare capacity is now less than it was two decades ago, despite oil demand having grown by 25 percent. To estimate the desired size of the buffer, the study attempts to consider all possible shocks and their respective likelihoods, and then compare the value of spare capacity to the cost of building it. The 'right size' is when the cost of adding a marginal barrel per day of capacity is equal to the GDP loss that would arise without that additional barrel of capacity. The analysis confirms that OPEC's buffer, estimated at 2.64 million barrels per day (1.94 million barrels per day for Saudi Arabia), has been in line with global macroeconomic needs.

Spare capacity is only one piece of a much larger picture in terms of neutralizing the negative impact of oil shocks. By maintaining costly inventories, individual consumers, producers, government agencies, and multilateral organizations also shoulder part of the burden of dealing with oil price shocks. This has not been entirely altruistic because spare capacity has a value to the holders: production from the buffer is typically put on the market when prices are high.

The recent emergence of shale oil as the world's marginal producer, with a development lead time measured in months, has made non-OPEC supply much more reactive to price. By contributing to market stability, shale oil is capturing a share of the historical value of spare capacity for the world economy and reducing the incentive for OPEC members to invest in maintaining the cushion. However, shale oil is also subject to potential logistical constraints, such as those currently limiting its expansion in West Texas. Furthermore, it does not suffice to rapidly offset unanticipated shocks of large magnitude. As such, it does not provide sufficient protection for the world economy and OPEC spare capacity still provides value in stabilizing oil markets.

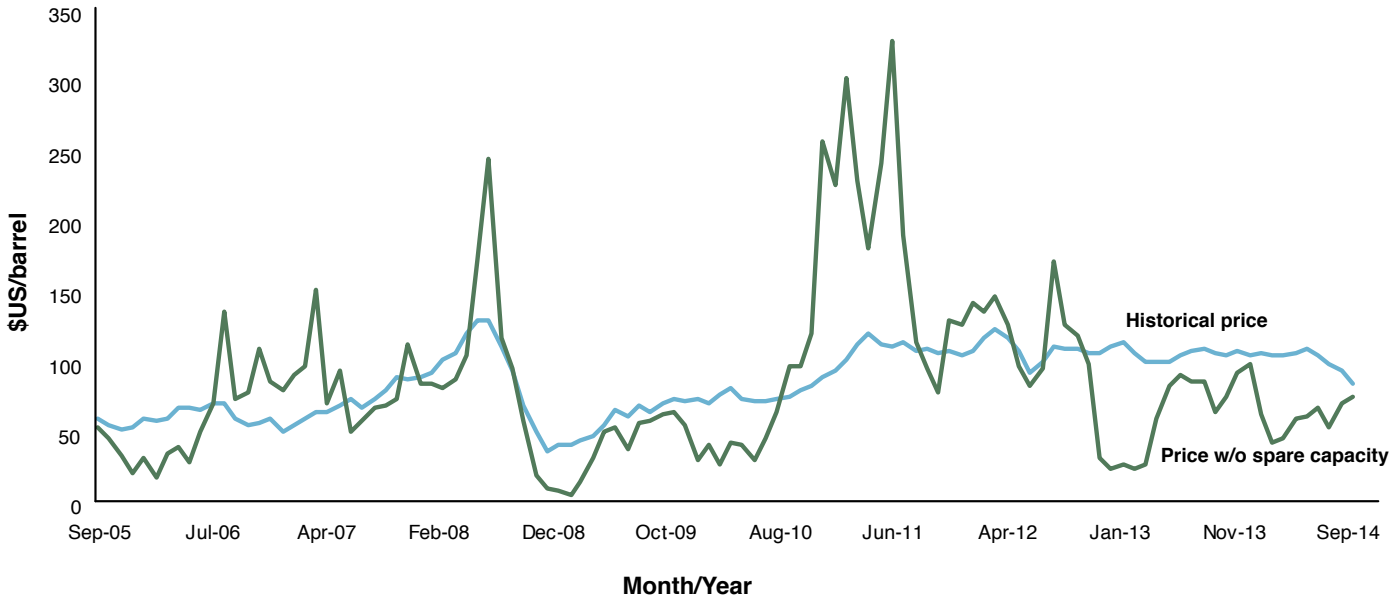

Figure 2. Spare capacity reduces oil price volatility.

Source: Estimates from authors: OPEC's Impact on Oil Price Volatility: The Role of Spare Capacity; The Energy Journal, Vol. 39, No. 2, April 2018; Axel Pierru, James L. Smith, and Tamim Zamrik.

Note: Price with no spare capacity policy assumes -1% monthly price elasticity for global demand.

This commentary is based on a KAPSARC research project initiated in late 2016, resulting in the April 2018 publication of the paper 'OPEC's Impact on Oil Price Volatility: The Role of Spare Capacity' in The Energy Journal, Vol. 39, No. 2, 2018.

03 // OpenKAPSARC

Our Tools and Datasets

A core part of our mission at KAPSARC is to equip stakeholders with the models, tools and data to make the most educated and informed decisions possible.

We have invested in the development of several analytical platforms, some of which have resulted in tools and datasets that we are now making available through our website. The model codes can be downloaded, and any data that are not proprietary to third parties can be downloaded and reused freely. The current key platforms are:

KAPSARC Energy Data Portal

This easy-to-use data portal is a source of critical energy data, enabling users to better understand energy, the economy and policies. We focus on identifying key energy information sources from Saudi Arabia, the GCC, India, China and Eastern Africa, as well as selected global energy data.

The energy datasets cover 16 themes: crude oil and refined products, natural gas, coal, renewable and alternative fuels, nuclear, electricity, water, transportation, industry, residential, agriculture, environment, economy, demography, trade, and policies. The datasets can be exported in CSV, JSON, and Excel formats or accessed using API for use in mobile and web applications.

KAPSARC Energy Model for Saudi Arabia (KEM-SA)

KEM-SA has been developed to understand the dynamics of Saudi Arabia's energy system. It is a partial economic equilibrium model that characterizes some of the major energy producing and consuming sectors in the country. The sectors represented are electric power, petrochemicals, refining, water desalination, upstream oil and gas, and cement production.

Each sector is contained within its own sub-model and acts as an agent that makes decisions on fuel usage, investment and technology to minimize its costs or maximize its profit. The model is being expanded to include more sectors from the demand-side of the economy.

KAPSARC Global Energy Macroeconometric Model (KGEMM)

KGEMM is a domestic policy analysis tool that captures the interactions between the Kingdom of Saudi Arabia and global economies. Unlike commonly available models, KGEMM takes into account the importance of the energy sector in the Kingdom and the growing significance of the domestic economy as a driver of domestic demand and, hence, available oil exports.

This easily customizable macro-econometric model covers the real, monetary, fiscal, external energy and labor sectors of the Kingdom's economy. It allows stakeholders to evaluate different policy scenarios such as energy price reforms, fiscal policy changes and the impacts of different oil price regimes.

KAPSARC Toolkit for Behavioral Analysis (KTAB)

This toolkit comprises a suite of building blocks for analyzing collective decision making processes (CDMPs). These can include political bargaining, commercial negotiation and any multi-stakeholder issue where an understanding of how each player's attempts to maximize their own positions drives the ultimate settlement (or not). The software for each type of CDMP is available and we are building a library of illustrative applications to help users understand the limits and benefits of this type of analysis.

KAPSARC Vehicle Fleet Model

This scenario model enables policymakers to explore the incremental user cost implications of different passenger car powertrain technology choices. The context for the analysis is a future where today's low-carbon powertrain technologies are fully developed and manufactured at scale. Driving behavior input is based on today's data. However, provision is made in the model for behavioral change scenarios to be tested.

Aimed at simplicity and transparency, the model does not include all the detailed complexity of the problem but aims to adequately capture the main factors that influence the incremental user cost of different passenger car powertrain mixes. It has also been designed to make it easy for the user to improve and update the input to the model as new evidence becomes available.

Other platforms/ datasets

We have built a data transformation team that serves our internal research needs but will also increasingly release curated data resources to all our stakeholders. These resources will grow over time in the breadth of their scope and their area of coverage.

For more information email

datasource@kapsarc.org

KAPSARC Solar Photovoltaic Toolkit

This toolkit and dataset are intended for any individual or institution interested in the solar photovoltaic (PV) industry and its cost trends. It compiles capital costs and levelized cost of energy (LCOE) data for PV technology by year and country, and presents the data in an interactive manner. In addition to the interactive dataset, the raw dataset is provided in Microsoft Office Excel should the user wish to perform his/her own post-processing. An LCOE analyzing tool, specifically tailored for solar PV technology, accompanies this toolkit, enabling the user to acquire the LCOE using the capacity factor or solar irradiation.

KAPSARC India Renewable Energy Policy Atlas

We have developed a web-based energy policy reference tool that systematically describes energy sector policies. This tool, also of use to external researchers, is intended to facilitate a better understanding of policy instruments and track evolution of policies from draft to enactment worldwide.

KAPSARC has released part of this research in its Solar Policy Atlas, which provides specific, state and national level coverage of policies in India. It presents a policy landscape using large numbers of policy design elements that are relevant in different geographies to gain holistic insights into policy frameworks and make comparisons between them. Each policy design element has a comprehensive description and is intended to improve the understanding of the subject at national and state levels.

KAPSARC develops economic frameworks to reduce the overall costs and environmental impacts of energy supply, increase the value created from energy consumption and achieve effective alignment between energy policy objectives and outcomes.

We collaborate with leading international research centers, public policy organizations, and industrial and government institutions, freely sharing our knowledge, insights and analytical frameworks.

04 // Team News

Growing Our Global Team

In the last quarter, our Research team welcomed the following members:

Dr. Anvita Arora

Anvita is the program director of the Transport and Urban Infrastructures program. She is an architect and transport planner whose current areas of research at KAPSARC include smart cities, electric vehicles and freight mobility.

Previously, she was the managing director and CEO of Innovative Transport Solutions, where she led over 40 applied research and planning projects for clients including the United Nations Environment Programme, World Bank, Asian Development Bank, and the Department for International Development. Dr. Anvita holds a doctorate in transport planning, a master's degree in urban planning with a specialization in transportation, and a bachelor's degree in architecture.

Guodong Sun

Guodong is a research fellow in the Transport and Urban Infrastructure program. He holds a doctorate in engineering and public policy from Carnegie Mellon University, a master's degree in systems engineering and a bachelor's degree in thermal turbomachinery from Tsinghua University.

Previously, Guodong was a faculty member of the State University of New York at Stony Brook, and the founding executive director of the New York Energy Policy Institute. His current research is focused on the resilience of energy infrastructure and the innovation processes of large-scale complex technology systems.

Abdullah Aldayel

Abdullah is a research analyst in the Market and Industrial Development program. He recently graduated from King Fahd University of Petroleum and Minerals with a Bachelor of Science in petroleum engineering.

Abdullah previously completed an internship with Halliburton Technology Center in Dhahran, Saudi Arabia.

Eric Williams

Eric is a research fellow in the Energy Demand, Efficiency and Productivity program. He holds a master of arts degree in law and diplomacy in development economic and international environmental policy from the Fletcher School, Tufts University and a bachelor's degree in economics and political science from the University of Kentucky.

Previously, Eric was an economist with the North Carolina Utilities Commission, and a consultant at the Organization for Economic Cooperation and Development. He was also previously a doctoral student at Duke University studying energy systems modeling. His former roles have included energy/environmental economist at the International Atomic Energy Agency, and co-director of the Climate Change Policy Partnership at the Nicholas Institute for Environmental Policy Solutions at Duke University.

Cian Mulligan

Cian is a senior research associate in the Energy Demand, Efficiency and Productivity program. He holds a master's degree in economics from Tilburg University, and a bachelor's degree in economics and social studies from Trinity College. He is due to complete his doctorate in 2018.

Previously, Cian worked as an energy analyst in Vienna and was the editor of Intereconomics: Review of European Economic Policy.

Nawaz Peerbocus

Nawaz is a research fellow in the Energy Transitions and Environment program. Before joining KAPSARC, he was chief economist at the Saudi Electricity Company where he led the strategic transformation project and advised on strategic planning issues. Prior to SEC, Nawaz was director of market strategy at Enbala and senior economist at the Ontario Independent Electricity System Operator. He holds a master's degree in economics.

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KAPSARC is searching for talented and open-minded thinkers to add to our growing research and business management teams.

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About KAPSARC

Our Mission

To advance the understanding of energy economics and act as a catalyst for dialogue, charting a path to better welfare for societies, locally and globally.

Our Values

We strive to combine creativity and rigor in our research and operations.

We achieve results with effective teamwork and collaboration.

We seek to maximize positive societal impact.

About Us

Affordable, sustainable energy underpins the growth of a country's economy and the well-being of its citizens. Yet effective energy policy is one of the greatest challenges for governments and other stakeholders globally.

KAPSARC was founded as a global non-profit institution for independent research into the economics of energy. It seeks to understand the complex intersections between energy economics and energy policy, technology and the environment with the objective of contributing to societal wellbeing and prosperity.

From our base in one of the world's most important energy-producing regions, KAPSARC develops economic frameworks to reduce the overall costs and environmental impacts of energy supply, to increase the value created from energy consumption and to better understand energy policy such that policy objectives and outcomes are better aligned.

We collaborate with leading international research centers, public policy organizations, and industrial and government institutions through workshops, joint papers and the development of open-source datasets and tools, freely sharing our knowledge, insights and analytical frameworks.

KAPSARC studies topics of global scope with a particular focus on the Kingdom of Saudi Arabia, the Gulf Cooperation Council countries, China and India.

Research Initiatives 2018

1. **Productivity and Economic Diversification in Saudi Arabia**
2. **Energy and Economic Vulnerability**
3. **Evaluation of Public Investment Projects: The Opportunity Costs of Oil and Gas in Saudi Arabia**
4. **Future of Transportation and Fuel Demand**
   - Freight Movement
   - Personal Mobility
5. **Future of Global Oil Markets**
6. **Future of Natural Gas Markets Including Potential Saudi Linkages to Global Markets**
7. **Regional Energy Markets: GCC Market Integration and Policy Drivers of Demand in China and India**
8. **Electricity Sector Transitions**
9. **Climate Change Policies and Governance**
10. **Models, Data and Tools**
    - KGEMM model for policy analysis in the Kingdom
    - KEM model for policy analysis in the Kingdom
    - KTAB toolkit - models of collective decision-making processes
    - Energy data portal and web apps