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Efficient industrial energy use: The first step in transitioning Saudi Arabia's energy mix

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ABSTRACT

In Saudi Arabia, industrial fuel prices are administered below international prices and firms make decisions based on low energy prices, increasing domestic energy demand. This analysis explores alternative policies designed to induce a transition to a more efficient energy system by immediately deregulating industrial fuel prices, gradually deregulating fuel prices, and introducing investment credits or feed-in tariffs. It uses a dynamic multi-sector, mixed-complementarity model. Continuing existing policies results in a power system still fueled completely by hydrocarbons. The alternative policies result in a transition to a more efficient energy system where nuclear and renewable technologies become cost-effective and produce 70% of the electricity in 2032. Introducing the alternative policies can reduce the consumption of oil and natural gas by up to 2 million barrels of oil equivalent per day in 2032, with cumulative savings between 6.3 and 9.6 billion barrels of oil equivalent. The energy system sees a net economic gain up to half a trillion 2014 USD from increased oil exports, even with investments in nuclear and renewables. The results are robust to alternative assumptions regarding the value of oil saved and the growth in end-use energy demand.

1. Introduction

Oil consumption in Saudi Arabia has grown at an annual rate of 5% since the year 2000 [BP (2014)], raising concerns over the ability for the Kingdom to maintain future exports. For instance, Lahn and Stevens (2011) extrapolate future energy consumption and state that Saudi Arabia could become a net importer of oil in a little more than 20 years.

Constrained natural gas supply and low administered fuel prices offered to industry result in substantial quantities of oil consumed in electricity generation and industrial production. Low fuel prices have hindered the deployment of more efficient power generation and industrial technologies. Matar et al. (2015) show the potential economic gains that could have been realized in 2011 by deregulating the transfer prices of fuels among industrial sectors, or by introducing government credits to encourage investment in more efficient power generation capacity. They demonstrate that as much as 860 thousand barrels per day of crude oil could have been saved in 2011 through changes in electricity, water, and industrial production, leaving end-consumer prices of transportation fuels and electricity unchanged. Matar et al. (2015) also provide a background on Saudi energy consumption and the literature on energy subsidies and fuel price reform. This multi-period analysis extends those results by examining the consequences of alternative pricing policies on the energy system.

Few studies have investigated future energy consumption in Saudi Arabia. Mansouri et al. (2013) examined a move towards a future electricity generation mix in the Kingdom focused on solar photovoltaic (PV) and carbon capture and storage (CCS). Applying a life cycle assessment approach, they studied multiple scenarios where different combinations of CCS and PV deployment levels are imposed. Others, like Al-Saleh (2009) and Taleb (2009), have conducted survey methods to gauge the prospects for renewable technologies in the future Saudi power mix.

The analysis presented in this paper uses a multi-sector model to characterize the investment and operational decisions under various regulatory policies where transfer prices of fuels between sectors are not necessarily marginal costs or marginal values. The impact of fuel pricing policies on the energy system in inducing investment in more efficient power generation technologies is presented. The policy scenarios analyzed include deregulating transfer prices of fuels and introducing investment credits or equivalent feed-in tariffs. All policies maintain the current end-user prices for electricity and transportation

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fuels in real terms; this implies a slight shift in policy since the actual prices are fixed in nominal terms. The effects of various policies on the evolution of the power generation mix and fuel consumption through 2032 are analyzed using a multi-period version of the KAPSARC Energy Model (KEM). The economic gains attained from alternative policies are compared with the gains from a continuation of existing policies.

KEM incorporates the "baseline scenario" macroeconomic assumptions in Oxford Economics' global economic and industry models. The study explores the following cases:

- Continuing existing pricing policies,
- Immediate deregulation of fuel prices to industrial sectors,
- Phased deregulation of fuel prices to industry, and
- Combining incentives and small fuel price increases that capture many of the benefits of deregulation.

The next section provides a background on fuel pricing policies in the Kingdom. Section 3 details KEM, additional model features incorporated for this analysis, and data inputs. Section 4 describes the policy scenarios analyzed, followed by a discussion of the model results in Section 5.

2. The role of industrial fuel prices

In Saudi Arabia, administered prices of fuels lower costs in sectors that in turn sell their products at administered prices in order to support development objectives (by promoting economic diversification, or by providing electricity and water at low prices to the public). This, however, creates both a lack of economic coordination among sectors and inefficient choices within sectors. The equipment mix and fuel consumption rates in the large energy-consuming sectors reflect the low administered prices charged for fuels. Table 1 contains the transfer prices charged to the power, water desalination, and petrochemicals sectors.

Currently, Saudi power generation capacity is composed almost entirely of conventional thermal plants fueled by crude oil, refined oil products, and natural gas. The Joint Oil Data Initiative (JODI) (2014) states that direct use of crude oil approached 900 thousand barrels per day in July 2014, or about 9% of the country's total production, the vast majority of which was used for power generation.

3. Overview of KEM

KEM is a partial equilibrium model representing the upstream, power, water, refining, petrochemicals and cement sectors in Saudi Arabia. The model is formulated as a mixed-complementarity problem (MCP) that captures the administered fuel prices that permeate the Saudi energy economy. A standard optimization approach cannot be used because administered prices are different from marginal costs. Prior to modeling of administered prices in MCPs, the only approach to finding a regulated equilibrium was treating an optimization model as an embedded sub-model and iterating with a complex set of calculations, see Greenberg and Murphy (1985). As explained in Murphy et al. (2016), an MCP formulation can directly represent important aspects of regulations and price controls. Matar et al. (2014) explains how this is done. The power and water sectors meet exogenous demand for electricity and water at their least cost, given the prices and equipment costs they see. The remaining sectors are export-oriented and meet domestic demand while maximizing profits from exports. The sectors covered and the flows of energy are shown in Fig. 1.

Table 1
Transfer prices for fuels paid by the power, water, and petrochemicals sectors.
[Source: Council of Ministers Resolution No. 55 and Electricity & Co-generation Regulatory Authority (ECRA, 2014)].

Methane and ethane	0.75 USD/MMBtu
Arab light	4.24 USD/bbl
Arab heavy	2.67 USD/bbl
Diesel	0.65 USD/MMBtu
Heavy fuel oil 360cst	0.36 USD/MMBtu

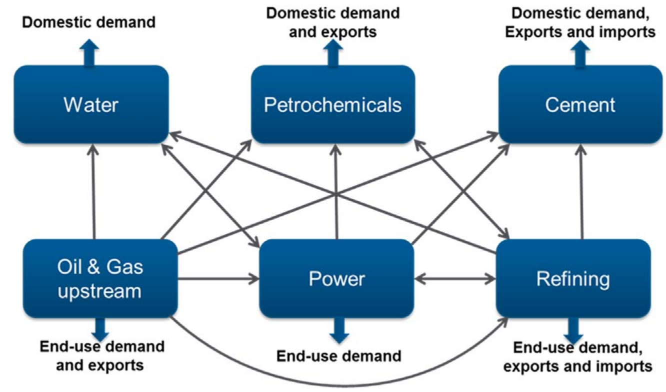

Fig. 1. The sectors represented in KEM and the major flows among the sectors.

The version of KEM used here is an extension of the model described in Matar et al. (2015). The central difference is that this version is a multi-period model that represents the impact of alternative energy policies over time, while the previous version is a single-period static model that examines the long-run consequences of policies without examining transition issues.

A technique called recursive dynamics is used to find the equilibrium for all years through the forecast horizon of 2032 (described in Appendix A). This method is a compromise between assuming full information, with capacity added optimally through the model's horizon, and the myopia of the single-period model.

As detailed by Matar et al. (2014, 2015), the model is calibrated to data for the year 2011, but also includes partial data for 2012 through 2014. The years 2012–2014 are treated as part of the forecast period because of the incomplete data. The planning for power generation expansion begins in 2015 and includes plants already under construction, which are listed in Appendix B. The data includes aggregate capacities for power, water, other industrial process technologies, and reported demands.

The Oxford Economics Global Economic (GEM) and Global Industry (GIM) models generate a set of consistent macroeconomic assumptions that we use in defining our scenarios. Projected demands beyond the calibration year are calculated using the GEM and GIM outlooks. Appendix C gives an overview of the assumptions common to all policy scenarios. Appendix D details the assumptions made for technology costs.

For specific details about how different sectors are represented in the model, see Matar et al. (2014, 2015). Additional developments and technologies introduced in the multi-period version of the model used in this paper are described in Appendix E. All price results are expressed in real 2014 dollars.

4. Policy scenarios analyzed

Policy choices analyzed in this paper focus on fuel-pricing policies, feed-in tariffs, and levels of investment credits. In all scenarios, existing electricity prices to all sectors are maintained, including the price of electricity transferred between the power and desalination sectors. Residential electricity prices and gasoline prices are unchanged in all scenarios. Higher residential and transportation efficiency standards have been enforced since 2013 or will be implemented in the near term. These standards will have long-term effects on the shape of the load curves and the magnitude of the peak loads and will also affect future