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Jointly reforming the prices of industrial fuels and residential electricity in Saudi Arabia

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ABSTRACT

The Saudi electricity sector currently buys fuel and sells electricity at prices administered by the government. In this analysis, we illustratively explore combining the reform of the fuel prices used in power plants with the implementation of alternative electricity pricing schemes for the households. Compared to the scenario replicating the year 2015, we find:

- The aggregate gain to the energy system could reach nearly $12 billion per year by raising both electricity prices to households and industrial fuels to reflect the cost of supply or international markets.
- Households would pay an additional $3 billion in electricity costs without any mitigation for the low-income households. However, Lifeline prices would halve this burden, while maintaining greater gains than deregulating fuel prices alone.
- The average electricity price paid under the lifeline scenario would be a more manageable 4.0 cents/kWh, versus an average marginal-cost price of 7.1 cents/kWh.

In the alternative electricity pricing scenarios we study, natural gas usage by the power utilities falls, allowing gas to flow to other industries, which would consume it to reduce their costs. We find the marginal values of natural gas falling at higher electricity prices, indicating that the supply of gas is becoming less constraining.

1. Introduction

The Saudi government increased domestic energy prices in 2016 to compensate for the lost revenue from international oil prices tumbling in recent years; an added benefit of raising these prices is the induced demand response for the various energy goods. Matar et al. (2016, 2017) have identified the economic benefits of reforming industrial fuel prices in Saudi Arabia without altering electricity prices. As the local government is currently exploring additional price reforms, this analysis aims to better understand the effects of reform by further incorporating end-use electricity prices.

Utilities in Saudi Arabia have received financial support from the government while keeping electricity prices low. They were provided fuels at low prices and had zero- to low-interest loans for building and maintaining facilities. Also, the government as a consumer has been willing to pay higher electricity rates to help the utilities meet their revenue requirements.

At present, metering does not allow the tracking of electric power by customer type for each hour of the day. We estimate household electricity demand using data from the Saudi Electricity Company (SEC); SEC is currently the sole operator of the transmission and distribution networks. However, it is difficult to reliably estimate hourly load profiles and hourly price elasticities for the other demand sectors. This study focuses on the residential sector, which constitutes about half of electricity demand. When data becomes available for other sectors, the analysis may be expanded to the rest of the market.

Past studies have estimated price elasticities of annual electricity demand for residential customers in Saudi Arabia (Atalla and Hunt, 2016). One of the interesting questions to ask, however, is what is the impact of changing prices on the hourly load curve profile? This is especially interesting if the price that will determine the shape of the load curve is based on the cost of generating and delivering the electricity. In an integrated view of the economy, the different load profiles and fuel costs will govern the technology choices of the power utilities; the technology choices will then determine the costs, and then the price.

To our knowledge, Bigerna and Bollino (2015) were the first to establish a set of own- and cross-price elasticities for electricity demand; they performed the estimation for Italy. Matar (2017) has computationally explored the effects of time-of-use pricing on

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households in the context of lacking data on hourly elasticities. He looked at several consumer behavior characteristics, and their impact on residential loads.

This analysis expands on previous studies by examining the reform of both input fuel prices and electricity prices that are charged to the households. In addition to the regulated and deregulated fuel prices in 2015, we examine the effects of four electricity pricing schemes for households: 2015 electricity pricing, dynamic pricing, average cost pricing, and what we call lifeline pricing. 2015 electricity pricing considers the same electricity prices charged to residential customers in the year 2015. The dynamic pricing scheme sets prices to the long-run marginal cost of delivering electricity; these costs are variable throughout the day. The average cost pricing sets the price as the annual long-run average cost by region (from here on, we will simply call these *marginal cost* and *average cost*, respectively). The lifeline pricing scheme sets a quantity that is consumed at a low flat electricity price, and further consumption is valued at the average marginal cost.

We perform the analysis in a steady, counterfactual 2015 year to examine the effects of different policies on the country's energy economy. In this framework, the capital costs of production units are annualized over their designed life. We identify a base case and show the effects of a fuel price reform scenario on the delivery cost of electricity, the technology mix for power generation, and assess its potential impact of reforming electricity prices for the households. The KAPSARC Energy Model (KEM) for Saudi Arabia is used as a tool to analyze different energy policy scenarios. The base case involves fixing energy prices to their values in 2015 and allowing the sectors to make decisions freely so as to replicate the year.

This paper is organized as follows: first, we give a brief overview of residential electricity prices and its use in Saudi Arabia. Then we detail the approach we took and the scenarios we analyze. In the fourth section, we provide the impact of the different scenarios on the electricity costs output from the model as a first set of results. Section 5 describes our approach to devising own- and cross- price elasticities for households in Saudi Arabia, and how they are used with demand. The subsequent sections and sub-sections provide our results, discussion, and concluding remarks.

2. Residential electricity prices and consumption by households in Saudi Arabia

Electricity tariffs, before the most-recent reforms that came into effect in the beginning of year 2016, started at 1.33 cents/kWh for the first 2 MWh consumed, and progressively increased to 6.93 cents/kWh for every unit consumed beyond 10 MWh in a billing period. The most recent price changes in 2016 did not significantly alter household prices. The two lowest consumption brackets, which constitute the majority of consumers, were not changed (Electricity and Co-generation Regulatory Authority (ECRA) (2011, 2016)).

Table 1 displays the average regional prices paid by season for households; for the year 2015, the average electricity price paid country-wide was 2.09 cents/kWh. The price is understandably higher in the summer when there is high space cooling demand.

Table 1
Average electricity price paid by households by region and season in cents per kWh (source: SEC).

	Eastern operating area	Central operating area	Western operating area	Southern operating area	Saudi Arabia as a whole
Summer	2.31	2.48	2.20	2.03	2.31
Winter	1.71	1.75	1.63	1.42	1.65
Spring and fall	2.26	2.10	1.97	1.83	2.05
Year	2.21	2.21	2.00	1.82	2.09

The average household in Saudi Arabia consumed about 24 MWh of electricity in the year 2014 (SEC; World Energy Council, 2017). That is the third highest consumption per household globally, after the 38 and 32 MWh for Kuwait and Qatar, respectively. The high levels of consumption in these countries is partially due to historically low prices. For instance, the residential price of electricity in Kuwait was near zero cents/kWh in 2014 (Fattouh and Mahadeva, 2014).

The Saudi government has introduced higher efficiency standards to compensate for the effects of historically low prices. In 2013, the Saudi Standards, Metrology and Quality Organization established new standards for air conditioners, increasing their minimum energy efficiency ratio (EER). The government further mandated that all new residences must be thermally insulated to be connected to the grid. Matar (2016) previously investigated the effects of higher residential efficiency on the Saudi energy economy, with a particular focus on the power sector. The hourly demand curves would have differing shapes as a result of efficiency measures, so projecting demand for multi-period analyses would have to consider these effects and not just a uniform scale factor.

Domestic energy consumption would also benefit in the coming years from technological improvements that are independent of prices. For example, the advent of less costly light-emitting diode lightbulbs, or more energy efficient televisions, will have an effect on overall energy consumption. Others, like Manne et al. (1995), have formally adopted these ideas using the autonomous energy efficiency improvements index.

Higher electricity prices incentivize customers to purchase more efficient equipment in the long term, such as air conditioners, and improve home insulation to cut their electricity bills. Higher prices can also nudge customers into conservation such as modifying thermostat settings and turning off lights when not needed.

3. Analysis approach and scenario descriptions

We apply KEM for Saudi Arabia to study the economic effects of reforming electricity prices charged to the households. KEM is a technology-rich model of the major energy producing and consuming sectors in Saudi Arabia. The model consists of six sectors: upstream fuel production, power generation, water desalination for municipal purposes, refining, petrochemicals and cement. It considers a range of power generation technologies, heat rates, transmission and distribution losses, and costs of equipment and operation. KAPSARC (2016) provides a detailed description of KEM. Even if our focus is on the power sector, it is worth noting that the model runs all six sub-models together.

All six sectors' decisions are taken into account when studying different pricing policies; this can be viewed as taking a system-wide perspective. When fuel prices are reformed, for example, the decisions of the whole energy system in KEM contribute to the performance of the electricity sector. This is especially pertinent with the utilization of the limited supply of natural gas. More gas would make it to one sector if there is less demand for it in others.

KEM is run in a long-term 2015 year to study the policies' impact on the country's energy economy. In this single-year framework, the capital costs of plants are annualized over their life time to consider the costs in the long run; annualized capital costs and operational costs can then be properly compared for one year. The data used to calibrate the model to the year 2015 is predominantly detailed by Elshurafa and Matar (2016); however, updated power plant cost and thermal efficiency data are referenced in Appendix A. Moreover, hourly residential loads are estimated for all combinations of regions, seasons, and day types using consumption data from SEC.

We test several electricity pricing schemes, with the base case defined as the scenario that replicates the actual decisions of 2015. Although the model includes all of the capital stock available in 2015,