UNDERSTANDING THE DRIVERS OF ENERGY DEMAND IN SAUDI ARABIA: A STRUCTURAL TIME SERIES ANALYSIS

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Overview

Understanding the drivers of energy demand is critical to policymakers' economic plans; moreover, Greening et al. (2007) states that "being able to understand and predict with reasonable accuracy changes in industrial energy consumption is an important task" (p. 1). However, empirical work on industrial energy demand is still sparse, particularly for the Gulf Cooperation Council (GCC) countries.[1] This paper therefore attempts to help fill this gap by econometrically modelling manufacturing energy demand in Saudi Arabia – an economy that has experienced rapid growth in energy demand and is going through an economic transformation and diversification, driven to some extent by the Saudi Vision 2030 (2016) programme.

In almost all economies, the end-use sectors consuming the largest shares of final energy include residential, transport, industry, and commercial. Many studies have modelled energy demand in the residential and transport sectors, but as observed by Bernstein and Madlener (2015), econometric studies of industrial energy demand and estimated elasticities remain scarce. One explanation for this suggested by Greening et al. (2007) is that that modelling industrial energy demand is relatively difficult given that different firms consume different fuels in different processes to produce a wide range of goods and services – heterogeneity that can lead to aggregation issues.

Nevertheless, some studies have attempted to model energy demand in the industrial (or manufacturing)[2] sector using a range of energy types, specifications, and econometric methodologies. However, unlike for the residential and transport sectors, there are still relatively few published studies for the manufacturing sector. Moreover, as far as we are aware, there are no earlier attempts to model econometrically a causal relationship for manufacturing energy demand in Saudi Arabia, which is undertaken here to estimate the key energy demand elasticities and quantify the contributions of the key drivers.

Methodology

Following, for example, Hunt et al. (2003), Dimitropoulos et al. (2005), and Dilaver and Hunt (2011) the Structural Time Series Model (STSM) is employed to estimate an aggregate manufacturing energy demand function for Saudi Arabia based on the following general specification:

$$e_t = \alpha_1 e_{t-1} + \alpha_2 e_{t-2} + \gamma_0 p_t + \gamma_1 p_{t-1} + \gamma_2 p_{t-2} + \theta_0 y_t + \theta_1 y_{t-1} + \theta_2 y_{t-2} + \beta_0 SF_t + \beta_1 SF_{t-1} + \beta_2 SF_{t-2} + UEDT_t + \varepsilon_t \quad (1)$$[3]

where e_t is the natural logarithm of energy demand; y_t is the natural logarithm of real value added; p_t is the natural logarithm of the real weighted energy price; SF_t is a structure variable measured as the ratio of energy intensive exports to total non-oil exports; and ε_t is a random error term – all in year t. The coefficients γ_0, θ_0, and β_0 capture the short-run impact of the real price, value added, and structure, respectively (with γ_0 and θ_0 giving the short-run impact price and income elasticities, respectively). The steady-state coefficients $\Gamma = \frac{\gamma_0+\gamma_1+\gamma_2}{1-\alpha_1-\alpha_2}$, $\Theta = \frac{\theta_0+\theta_1+\theta_2}{1-\alpha_1-\alpha_2}$, and $\mathrm{B} = \frac{\beta_0+\beta_1+\beta_2}{1-\alpha_1-\alpha_2}$, capture the long-run effect of the real price, value added, and structure, respectively (with Γ and Θ giving the long-run price and income elasticities, respectively). The $UEDT_t$ is the stochastic underlying energy demand trend estimated using the STSM as follows:

$$\mu_t = \mu_{t-1} + \delta_{t-1} + \eta_t\ ; \qquad \eta_t \sim NID\ (0, \sigma_\eta^2) \quad (2)$$

$$\delta_t = \delta_{t-1} + \xi_t\ ; \qquad \xi_t \sim NID\ (0, \sigma_\xi^2) \quad (3)$$

where μ_t and δ_t are the level and slope of the UEDT, respectively. η_t and ξ_t are the mutually uncorrelated white noise disturbances with zero means and variances σ_η^2 and σ_ξ^2, respectively. The disturbance terms η_t and ξ_t determine the shape of the stochastic trend component. Where necessary the condition of normality of the auxiliary residuals (irregular, level, and slope residuals) can be satisfied by irregular, level, and slope interventions. These interventions give information about important breaks and structural changes at certain dates with the estimation period. In the presence of such interventions, the UEDT can be identified as:

$UEDT_t = \mu_t +$ irregular interventions + level interventions + slope interventions.

The estimation strategy involves estimating Equations (1), (2) and (3) by a combination of maximum likelihood and the Kalman filter and then eliminating insignificant variables and adding interventions but ensuring the model passes an array of diagnostic tests until the preferred parsimonious model is obtained. The software package STAMP 8.30 is used for the estimation of the preliminary preferred model below.

[1] Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates (UAE)
[2] Note that although not technically the same the terms 'manufacturing' and 'industrial' are used interchangeably in this abstract for the sake of brevity.
[3] A two-year lag is chosen to capture any possible dynamic effects, since it is seen as a reasonable length given the data set being used

Preliminary Results

Initial estimation suggests that following the estimation strategy outlined above the preferred equation is given by:[4]

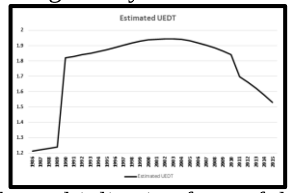
$\widehat{e_t} = -0.429^{***}p_t - 0.193^{**}p_{t-2} + 0.689^{***}y_t + 0.853^{***}SF_t + 0.846^{***}SF_{t-1} + \widehat{UEDT}_t$;

$\widehat{\Gamma} = -0.62$, $\widehat{\Theta} = 0.69$, & $\widehat{\mathrm{B}} = 1.70$; $UEDT_t$: Level interventions for 1990 and 2011 required.

se= 0.04; $r_{(1)} = -0.13$; $r_{(2)} = -0.10$; $r_{(3)} = -0.10$; Box-Ljung:$Q_{(5,3)} = 1.74$; Het: $F_{(7,7)} = 2.47$;

Norm$_{(res)}$: $\chi^2_2 = 4.00$; Norm$_{(Irr)}$: $\chi^2_2 = 0.23$; Norm$_{(Lvl)}$: $\chi^2_2 = 1.43$; Norm$_{(Slp)}$: $\chi^2_2 = 2.14$;

Failure: $\chi^2_7 = 6.47$; Estimation Period 1986-2015.

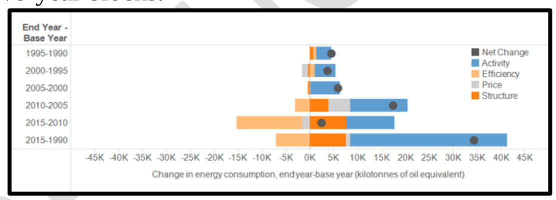


Decomposition analysis using the Logarithmic Mean Divisia Index (LMDI) method was applied to the multiplicative form of the estimated econometric equation, given by:

$$\widehat{E_t} = GVA_t^{\,0.689} P_t^{\,-0.429} P_{t-2}^{\,-0.193} * \exp(0.853SF_t) * \exp(0.846SF_{t-1}) * \exp\left(\widehat{UEDT_t}\right) \quad (4)$$

yielding the following seven drivers of the change from a reference year 'r': $\Delta E_{GVA_t} = w_i \ln\left(\frac{GVA_t^{\,0.689}}{GVA_r^{\,0.689}}\right)$, $\Delta E_{P_t} = w_i \ln\left(\frac{P_t^{\,-0.429}}{P_r^{\,-0.429}}\right)$, $\Delta E_{P_{t-2}} = w_i \ln\left(\frac{P_{t-2}^{\,-0.193}}{P_{r-2}^{\,-0.193}}\right)$, $\Delta E_{SF_t} = w_i \ln\left(\frac{\exp(0.853SF_t)}{\exp(0.853SF_r)}\right)$, $\Delta E_{SF_{t-1}} = w_i \ln\left(\frac{\exp(0.846SF_{t-1})}{\exp(0.846SF_{r-1})}\right)$, and $\Delta E_{UEDT} = w_i \ln\left(\frac{\exp(\widehat{UEDT_t})}{\exp(\widehat{UEDT_r})}\right)$. Which, by combining the two price terms and the two SF terms can be reduced to the four drivers: an activity effect, a price effect, a structure effect, and an efficiency effect and is illustrated in the chart for five-year blocks.

Preliminary Conclusions



This paper is, to the best of our knowledge, the first to model industrial energy demand in Saudi Arabia econometrically and quantify the relative importance of the drivers of its growth. The estimated model reveals long-run output and price elasticities of 0.69 and -0.62, respectively. Decomposition analysis reveals that the activity effect was the primary (mainly positive) driver of industrial energy demand growth over the last several decades. The structure effect being another major (mainly positive) driver, as energy intensive Saudi manufacturing expanded. In contrast, energy prices, which had not changed significantly, played a limited (negative and positive) role given the limited change in prices. Finally, the efficiency effect played a noteworthy (negative) role from 2004 onwards helping to reduce industrial energy demand and may continue to play an even bigger role if the government were to introduce further energy efficiency initiatives.

Saudi Arabia has recently entered a period of substantial economic and social change through Vision 2030 (Saudi Vision 2030, 2016). Part of this vision involves energy price reform, the deregulation of energy prices to make the energy market more competitive. Further gradual price reform for industrial fuels is expected over the coming years as energy prices rise towards international benchmarks. Energy price reform thus carries the potential to mitigate the rapid growth in industrial energy consumption. In fact, if both economic output and fuel prices were to double (holding all else fixed), then the estimated model would predict about a 7% increase in industrial energy demand, as higher prices lessen the impact of higher output. Furthermore, the inclusion of the structural factor in the estimated model suggests that Saudi Arabia could increase its industrial energy productivity substantially by moving away from energy-intensive manufacturing towards higher value added output. Moreover, the estimated UEDT from the mid-2000s onwards is downward sloping with a negative derivative, suggesting that there is scope for an increasing role for energy efficiency improvements in reducing industrial energy demand in the Kingdom.

In summary, the econometric results presented in this paper give a deeper understanding of the impact of prices, output, economic structure, and energy efficiency on Saudi industrial energy consumption, while the decomposition results reveal what have been its primary drivers over the last several decades. These results should help policymakers anticipate the evolution of industrial energy demand and formulate appropriate policies.

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[4] Note, * represents significance at the 10% level, ** at the =5% level and *** at the 1% level.