Gasoline Demand in Saudi Arabia: Are the Price and Income Elasticities Constant?

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December 2019

Doi: 10.30573/KS--2019-DP81

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This publication is also available in Arabic.

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Key Points

Empirical estimations show that long-run income and price elasticities are not constant and are responsive to price and income fluctuations in the period considered.

The income elasticity of gasoline demand increased until 2014, peaking at 0.151, following growth in disposable income, before declining to 0.136 in 2017.

Aggregate car purchases increase when disposable income rises, causing a derived increase in gasoline demand, while consumers postpone new car purchases in periods of falling income. However, consumers do not stop driving when their disposable incomes fall, resulting in a less elastic response of gasoline demand to income.

Price elasticities sit in the range of -0.313 to -0.045, becoming less elastic when prices are low and vice versa. This pattern shows that consumers respond less to prices when prices are low but more when prices are high, perhaps reflecting their curtailment of unnecessary driving in times of high gasoline prices.

Summary

After the drop in international oil prices in 2014, oil-exporting countries started to launch new policies to develop their economies. It is important that policymakers involved in energy and economic development understand how economic agents respond to increased energy prices and how the latter affects the demand for different fuels. Saudi Arabia is the biggest oil exporting country and is currently undergoing many socioeconomic reforms. The success of these reforms requires accurate assessments of the country's energy indicators. The current paper investigates gasoline consumption, employing a time-varying coefficient cointegration approach. This approach allows us to analyze the varying responses of demand to income and price levels. The test for the long-run relationship concluded that there is a common trend. The empirical estimation used a time-varying coefficient approach and found the significant long-run time-varying income elasticity was less than 0.16. The long-run price elasticity was found to range between -0.31 and -0.05. Moreover, the speed of the adjustment coefficient is found to be -0.77, meaning that any short-run deviation can be corrected to the long-run equilibrium path in under 1.5 years. The estimation results revealed that income does not have a significant impact on gasoline demand in the short run. The estimated short-run price elasticity is -0.13.

The following policy insights can be derived based on the findings of the study:

- Periods of higher prices result in a higher negative impact on gasoline demand.
- Long-term price increases might cause demand to decrease severely.
- Short-run disposable income variations do not have a significant impact on gasoline demand.

This suggests that income support policies for the private sector, if required, should be designed considering their long-run impacts.

This study's conclusions can aid the successful implementation of energy price reforms and environmental policies. The statistically significant negative and time-varying effects of the domestic gasoline price is of particular use in this regard.

The growth path of gasoline demand, a key strategic fuel, has important implications for oil security, oil-related carbon emissions, and refinery investment (Dahl 2012). As such, understanding how fluctuations in income and gasoline prices could affect the demand for oil in Saudi Arabia allows policymakers to assess what drives gasoline demand over time and the likely future development of oil demand. This knowledge can help demand-side policymakers control oil demand more effectively through the use of measures such as tariffs and taxes, among other instruments. It can also help supply-side decision-makers develop more accurate data on the oil supply needed to meet the anticipated demand and plan refinery investment accordingly. Having a clearer picture of future oil demand could also help the Kingdom to develop the necessary carbon dioxide (CO₂) mitigation measures ahead of time, enable government entities to plan transportation services with more certainty, and help car manufacturers project their anticipated sales.

After the fall of global oil prices, many oil-rich countries deployed energy price reforms to raise government revenues, while encouraging more careful consumption of energy (see Gonand et al. [2019] for further discussion). The responses of economic agents in oil-exporting countries to changes in the international and domestic economic systems gives useful insights to domestic and international policymakers.

Regional and global stakeholders are currently looking to Saudi Arabia, the biggest exporter of oil, for insights into the possible development paths of their economies. A significant focus is placed on the impact of Saudi Vision 2030 (SV2030), and its various initiatives. For example, the number of female drivers in Saudi Arabia is projected to be around 3 million in 2020 (PwC 2018), following the lifting of the ban on women drivers in the country in 2018 as a part of the SV2030 women's empowerment policy. This might increase gasoline demand in the near future through direct and indirect channels (such as women driving). PricewaterhouseCoopers (PwC) (2018) also projects car sales will increase by 9% annually up to 2025, against the 3% annual increase between 2013 and 2017.

The analysis presented in this paper is of particular value for Saudi Arabia as it allows policymakers to quantify the impact of SV2030 targets and initiatives, including the possible impacts of price, income and population on energy demand. These initiatives include the Fiscal Balance Program (FBP), the National Transformation Program (NTP), and the energy price reforms (EPR). The Vision's goal of energy efficiency, for example, depends on having a clear picture of the numerical impacts of drivers on gasoline demand.

Some 15 papers have modeled gasoline demand in Saudi Arabia using fixed coefficient/elasticity approaches, i.e., they have assumed that the drivers of gasoline demand are constant over the periods analyzed. However, an investigation of time-varying properties of energy demand is worth considering; or, at the least, their stability should be tested. The government administers the domestic price of gasoline in Saudi Arabia, but it can be affected by international oil prices. Although the price of

gasoline in the Kingdom has been held constant in nominal terms for certain periods (i.e., 2002 to 2015), implying a negative growth rate in real terms, the price has fluctuated dramatically on several occasions.

However, in real terms, the domestic gasoline price has seen significant volatility. This includes a 48% and 38% increase in 1984 and 1988, respectively; a 29% decrease in 1992; a 72% and a 36% increase in 1995 and 1999, respectively; a 32% decrease in 2007, and a 55% increase in 2016. In 2016, the price increased by 55.25% and by 0.85% in 2017. The Saudi government announced an increase in the prices of electricity, fuel, and water at the end of December 2015, resulting in the nominal price for 91- and 95-octane gasoline increasing from 0.45 and 0.60 Saudi riyals (SAR) per liter to 0.75 and 0.90 SAR per liter, respectively (Apicorp-Arabia, 2018). In January 2018, the price of 91- and 95-octane gasoline increased again to 1.37 and 2.04 SAR per liter, respectively. Energy prices, including the domestic price for gasoline, will increase (or decrease) in accordance with international energy prices, which could help manage the domestic growth in gasoline demand. From January to March 2019, the price of the Kingdom's 95-octane gasoline decreased from 2.04 to 2.02 SAR per liter, following Saudi Aramco's announcement that "local prices of gasoline are subject to change, depending on price changes in the export markets" (Asharq Al-Awsat 2019). During this period, the price of 91-octane gasoline was unchanged at 1.37 SAR per liter.

Moreover, the absence of alternative transportation modes in Saudi Arabia (Algunaibet and Matar 2018) limits the scope of consumer responses to a price change. Algunaibet and Matar (2018) find that Saudi Arabian consumers' responses to these price changes are not constant.

Summary

Given the factors outlined above, one might expect price elasticity to change over time, responding to sharp price changes.

We use disposable income as an income proxy, which is taken from Hasanov et al. (2019), and measured in million Saudi riyals (SAR) at 2010 prices. Looking at the development path of the Saudi economy, the response of gasoline demand to changes in the disposable income level is most likely not constant in the long run. The Saudi economy witnessed periods of dramatic fluctuations between 1980 and 2017 (Hemrit and Benlagha, 2018). Between 1983 and 1988, Saudi non-oil gross domestic product (GDP) decreased by 5.49% annually, with 40% variation around the mean. From 1989 to 1995 this decrease moderated to 1.16% per year (except in 1990 and 1992). Non-oil GDP recovered gradually from 1996 to 2003, with annual growth of 0.51% (with 48% variation around the mean), due to the recession in Saudi Arabia's oil production and the movements in the international oil prices (Hemrit and Benlagha 2018). Non-oil GDP sharply increased to 5.4% between 2004 and 2011 (with 19% variation around the mean) as a result of economic diversification (Hemrit and Benlagha 2018). From 2012 to 2015, non-oil GDP growth in Saudi Arabia averaged 2.62% per annum, before declining to 1.84% in 2016 and 0.99% in 2017 (GaStat 2018), mainly due to the drop in international oil prices.

In addition, Scott (2012, 1721) concluded that agents “react more strongly to permanent than to temporary price changes.” It is important for policymakers to know whether economic agents' energy/gasoline consumption is responsive to income and price levels. Moreover, Bakhat et al. (2017) concluded that the price elasticity of gasoline demand increased

marginally in Spain during the financial crisis of 2008, whereas income elasticity reduced slightly. This shows the likelihood of a change in the responsiveness of elasticity to economic shocks.

As mentioned above, even in an environment of increased prices, some factors might increase demand by cancelling out the effect of price increases. This phenomenon needs to be investigated further through appropriate theoretical and econometric methods. As is well known, it is important for policymakers to understand the price effect, as it has implications for fuel tax policies and policies to mitigate environmental degradation caused by fossil fuels.

Given the development stages of the variables described above, the nature of price and income elasticities of gasoline demand in Saudi Arabia might not be constant, or at least their stability should be tested.

As discussed in Chang et al. (2014), ignoring the time-variable feature of the coefficient in the cointegration framework causes spurious regression results. Hence, from an econometric perspective, it is important to consider the varying nature of coefficients over time. Therefore, we believe it would be more appropriate to apply a method that can capture these variations, such as a time-varying coefficient cointegration method.

It should be noted that this method has not previously been considered in gasoline demand studies for Saudi Arabia.

In light of all the factors mentioned above, this study investigates possible time-varying effects of economic and demographic factors on gasoline demand in Saudi Arabia.

The study contributes the following insights to the literature:

To the best of our knowledge, this is the first study to have used the time-varying coefficient cointegration approach to assess the pattern of gasoline demand in Saudi Arabia.

Only a few papers have modeled the demand for gasoline demand in the Kingdom and other developing oil-rich countries. The pattern of gasoline demand found in this study can be used as a general pattern to understand gasoline demand in similar economies.

We consider disposable income to be a better measure of income than overall gross domestic product (GDP) or non-oil GDP when modeling gasoline demand in the Kingdom. This measure can also be used to model the demand for other sources of energy.

Estimating price and income elasticities could help decision-makers implement effective policies in the interests of achieving SV2030 targets.

The results of our empirical estimations revealed that income and price elasticities are time varying, ranging between 0 and 0.15 and -0.31 and -0.05, respectively.

The structure of the remaining part of the paper is organized as follows: section 2 reviews the related literature, section 3 summarizes the theoretical framework of the study; sections 4 and 5 discuss the methodology and give the data; section 6 details the study's empirical results; section 7 discusses the study's findings, and section 8 presents the conclusion.

Literature Review

This section presents an overview of gasoline demand studies for Saudi Arabia. We consider time series and panel studies because of the limited number of time series studies. Table 1 details the reviewed studies and all other relevant information. As the table shows, in papers published after 2012, the long-run price elasticity of gasoline demand ranges from -0.5 to -0.1. These papers use GDP as an income measure. Algunaibet and Matar (2018) employ a cost-minimization (monetary and non-monetary [time budget] costs) approach and find that price elasticity is not constant, changing around -0.1, depending on the magnitude of the price change. This conclusion is in line with earlier studies such as Gately (1992), which states that the responses of consumers to changes in gasoline prices vary depending on how significant these price changes are. Manzan and Zerom (2010) and Gillingham (2011) come to the same conclusion, finding higher responses to higher gasoline prices and lower responses when prices are lower. Although Algunaibet and Matar (2018) concluded that the gasoline price elasticity is not constant for Saudi Arabia, they did not investigate the varying nature of elasticity over time.

According to the same studies mentioned above, the response of gasoline demand to income measures differs across studies, ranging from 0.55 to 1.10. Only Atalla et al. (2018) used non-oil GDP as an income measure in addition to overall GDP and estimated the demand elasticities with respect to GDP and non-oil GDP to be 0.15 and 0.62, respectively.

Among the recent studies mentioned above, the short-run elasticities are only reported in Arzaghi and Squalli (2015) and Atalla et al. (2018). The short-run price elasticity is around -0.1 for both studies, while Arzaghi and Squalli (2015) estimated the short-run income elasticity to be 0.16 and Atalla et al. (2018) found it to be insignificant.

The overall conclusion from the reviewed studies can be summarized accordingly:

None of the studies considered the time-varying nature of the coefficients. We would have liked to review papers investigating gasoline demand in oil-exporting or oil-rich countries that employ time-varying techniques. However, to the best of our knowledge, no such studies exist. We therefore review two studies which employed the same econometric approach as this study. Park and Zhao (2010) and Neto (2012) studied gasoline demand modeling using time-varying cointegration coefficient techniques for the United States and Switzerland, respectively. Their findings were more relevant to this study than the studies using fixed coefficient estimation methods alluded to previously. As the aforementioned two studies concluded that coefficients are time-varying, results obtained using fixed coefficient methods are spurious due to the omitted variable bias issue, as discussed in Chang et al. (2014).

The long-run income elasticity values range from 0.6 to 1.1, while the range for price elasticity is -0.5 to -0.1.

Only two recent papers report short-run elasticities.

No econometric study uses the data set covering the post-2015 period when the Kingdom initiated its energy price and fiscal reforms.

There are only four recent studies on gasoline demand, and they mainly incorporate panel data analyses, with only one a time series study.

The points listed above emphasize the need for an individual country case study, employing different

econometric techniques and using the most recent data. This study aims to address this need.

Table 1. Summary of reviewed studies.

Study	Country (group)	Period	Study type	Methodology	Price elasticity		Income elasticity	
					SR	LR	SR	LR
Totto and Johnson (1983)	OPEC	1970-1979	T	MOLS	n/a	-0.09 [*]	n/a	1.02 [*]
Al-Sahlawi (1988)	Saudi Arabia	1970-1985	T	OLS	-0.08	-0.67	0.11	0.92
Al-Faris (1992)	Saudi Arabia	1970-1990	T	OLS/PAM	-0.08	-0.30	0.02	0.07
Eltony (1994a)	GCC	1975-1989	P	CFE/PAM	-0.11 to -0.09	-0.13 to -0.11	0.21 to 0.41	0.23 to 0.48
Eltony (1994b)	GCC subgroup	1975-1989	P	CFE/PAM	-0.04	-0.05	0.28	0.33
Eltony (1996a)	GCC	1975-1993	P	CFE/PAM	-0.11	-0.17	0.31	0.48
Eltony (1996b)	GCC subgroup	1975-1993	P	CFE/PAM	-0.04	-0.05	0.38	0.43
Al-Faris (1997)	Saudi Arabia	1970-1991	T	OLS/PAM	-0.09	-0.32	0.03	0.11
Al-Sahlawi (1997)	Saudi Arabia	1971-1995	T	OLS/PAM	-0.16	-0.80	0.30	1.50
Chakravorty et al.(2000)	Saudi Arabia	1972-1992	T	OLS/PAM	-0.08	-0.52	0.10	0.66
Dahl (2012)	120 countries, including Saudi Arabia	Different time intervals	T and P	Review of previous studies	n/a	-0.09 [*]	n/a	1.02 [*]
Al Yousef (2013)	GCC	1980-2010	P	Panel FMOLS & DOLS	n/a	-0.36 to -0.28 [*]	n/a	0.55 to 0.56 [*]
Burke & Nishitaten (2013)	132 countries, including Saudi Arabia	1995-2008	P	PPOLS	n/a	-0.5 to -0.2	n/a	0.95 to 1.10
Arzaghi and Squalli (2015)	32 fuel-subsidizing countries including Saudi Arabia	1998-2010	P	FE and RE/PAM	-0.05	-0.25	0.16	0.81
Atalla et al. (2018)	Saudi Arabia	1981-2015	T	STSM	-0.10 ^g -0.09 ^{ng}	-0.15 ^g -0.09 ^{ng}	ins	0.15 ^g 0.62 ^{ng}

Notes: OPEC= Organization of the Petroleum Exporting Countries; T=time series; OLS=ordinary least squares method; MOLS=modified OLS; FMOLS=fully modified OLS; DOLS=dynamic OLS; PAM=partial adjustment model; P=panel; CFE=country fixed effects; FE=fixed effects; RE=random effects; STSM=structural time series model; GCC=Gulf Council countries; PPOLS=pooled panel OLS; SR=short-run; LR=long-run."*" means that the reported coefficient is for Saudi Arabia; "g" and "ng" stand for elasticities with GDP and non-oil GDP, respectively; ins= insignificant.

Functional Specification for the Gasoline Demand Model

Following Dahl and Sterner's (1991) preferred model, and Burke and Nishitatenno (2013) and Atalla et al. (2018), this study models per capita gasoline demand as a function of the real gasoline price and the per capita real income. The relationship used for modeling purposes can be formulated as follows:

$$mgp_t = \alpha_0 + \alpha_1 di_t + \alpha_2 rp_t + \varepsilon_t \quad (1)$$

Where mgp_t , $incp_t$ and rp_t are per capita gasoline demand, per capita real income, and real gasoline price, respectively. All variables are in logarithmic form. α_1 and α_2 are parameters to be estimated, and ε_t is an error term. Since all the variables in (1) are in logarithmic form, α_1 and α_2 can be interpreted accordingly as income and price elasticities, and we expect positive and negative signs for them from the econometric estimations. Since the behaviors of the right-hand variables of

equation (1) can change over time, the responses of gasoline demand to these changes will likely differ. The changes in the variables might be due to new socioeconomic policies, structural changes, or shocks to the economy, among other factors. One disadvantage of models like (1) is that, according to Chang et al. (2014), they are unable to capture the variability of elasticity over time, which might result in misrepresentative parameter estimations if the parameters are indeed not constant. One way to address this issue is to use time-varying estimation methods, which consider the parameters to be functions of time. Taking this into account, equation (1) can be reformulated as follows:

$$mgp_t = \alpha_0 + \alpha_{1t} di_t + \alpha_{2t} rp_t + \varepsilon_t \quad (2)$$

The current study makes use of specification (2) to model the gasoline demand relationship.

Econometric Methodology

Equation (2) can be estimated using different approaches, such as the time-varying coefficient cointegration approach as used by Park and Zhao (2010) for United States (U.S.) gasoline demand modeling, and the Kalman filter technique as used by Arisoy and Ozturk (2014) for electricity demand modeling in Turkey. The current study uses the time-varying coefficient cointegration approach (TVC) proposed by Park and Hahn (1999) and applied in many empirical studies (Chang and Martinez-Chombo 2003; Park and Zhao 2010; Mikayilov et al. 2017, 2018, inter alia). The TVC method has some advantages. For example, taking into account the variable nature of coefficients, the method nests the fixed coefficient case. It also allows researchers to test whether the coefficient is time-variant or not, as well as to test the existence of the long-run relationship among the variables of interest. Moreover, the model is not sensitive to stationary regressors (Chang et al. 2014). The TVC method is described briefly here. See Park and Hahn (1999) and Chang et al. (2014) for a more detailed description.

The TVC method by Park and Hahn (1999) can be summarized as follows:

1. It defines the coefficient(s) as a function of time, approximating it (or them) in Fourier flexible form (FFF). FFF expresses the function (coefficient) as a linear combination of polynomials and pairs of periodic functions. It can be expressed as follows:

$$\alpha_{kt} \left(\frac{t}{T} \right) = \theta_0 + \sum_{i=1}^p \theta_i \left(\frac{t}{T} \right)^i + \sum_{i=1}^q [\theta_{p+2i-1} \cos \left(2\pi i \frac{t}{T} \right) + \theta_{p+2i} \sin \left(2\pi i \frac{t}{T} \right)] \quad (3)$$

Where t is the time trend, T is the number of observations, p is the number of polynomials and q is the number of trigonometric pairs.

2. It uses the ordinary least squares method and the chosen specification, estimates the equation for different pairs of p and q , and, based on the Schwarz information criterion (SIC), chooses optimal p and q .
3. It transforms the data using the formulas below:

$$x_{kt}^* = g_k \left(\frac{t}{T} \right) \otimes x_t^* \quad (4)$$

Where $x_t^* = x_t - \Lambda_2 \Sigma^{-1} w_t$,

and

$$y_t^* = y_t - \left(g_k \left(\frac{t}{T} \right) \otimes \Lambda_2 \Sigma^{-1} w_t \right)' \alpha_k - (0, \omega_{12} \Omega_{22}^{-1}) w_t \quad (5)$$

Where, g_k is the vector of polynomials and trigonometric pairs, which can be written as below:

$$g_k = \left(1, \frac{t}{T}, \left(\frac{t}{T} \right)^2, \dots, \left(\frac{t}{T} \right)^p, \left(\cos \left(2\pi \frac{t}{T} \right), \sin \left(2\pi \frac{t}{T} \right) \right)', \right. \\ \left. \left(\cos \left(4\pi \frac{t}{T} \right), \sin \left(4\pi \frac{t}{T} \right) \right)', \dots, \right. \\ \left. \left(\cos \left(2q\pi \frac{t}{T} \right), \sin \left(2q\pi \frac{t}{T} \right) \right)' \right)' \quad (6)$$

$\otimes$ stands for kronecker product; t, T, p, q is the same as defined above; x_t is a vector of explanatory variables, while y_t is a dependent variable; $(\cdot)'$ stands for transpose; $w_t = (u_t, (\Delta x_t)')'$, where u_t represents the residuals from the OLS estimation with the optimal p and q values and Δ is a difference operator;

$$\Omega = \sum_{l=-\infty}^{\infty} E(w_i, w_{i-l}'), \quad \Sigma = \sum E(w_i, w_i'),$$

$$\Lambda = \sum_{l=0}^{\infty} E(w_i, w_{i-l}'),$$

Ω_{ij} (or ω_{ij}) and Λ_{ij} (or δ_{ij}). $\Lambda_2 = (\delta'_{12}, \Lambda'_{22})$.

α_k is a vector of coefficients from the OLS estimation with the optimal p and q values.

4. It uses transformed data to estimate the equation below:

$$y_t^* = x_{kt}^{*'} \alpha_k + \varepsilon_{kt}^* \quad (7)$$

5. It tests for cointegration using the variable addition test (VAT) (Park 1990). The VAT test is a Wald test and is defined below:

$$W_T = \omega_*^{-2} \left(\sum_t (\hat{\varepsilon}_{kt}^*)^2 - \sum_t (\hat{\varepsilon}_{kt}^{*s})^2 \right) \quad (8)$$

Where $\hat{\varepsilon}_{kt}^*$ represents the residuals from equation (7), and $\hat{\varepsilon}_{kt}^{*s}$ represents the residuals from equation (7) augmented with additional trend polynomials.

$\omega_*^2 = \omega_{11} - \omega_{12} \Omega_{22}^{-1} \omega_{21}$, calculated using the variances from the first step OLS estimation.

The null hypothesis of VAT tests is that “all coefficients of the additional trend variables are jointly insignificant,” referring to the existence of a cointegration relationship (Park 1990).

6. It tests the TVC for significance (Park and Hahn, 1999). This a χ^2 -test with $p+2q$ degrees of freedom. The null hypothesis states that all the varying coefficients are jointly insignificant, which can be expressed as follows:

$$\theta_1 = \theta_2 = \dots = \theta_{p+2q} = 0 \quad (9)$$

The alternative is “at least one of the coefficients is significant,” stating the significance of the TVC method (Park and Hahn 1999).

The next section briefly describes the data employed in the empirical estimations.

The study uses annual data from 1980 to 2017. This period includes Saudi Arabia's gasoline price reforms implemented at the end of December 2015, among other SV2030-related policies.

The final demand for motor gasoline, excluding biofuels in transport (motor gasoline per capita [MGP]) is in million liters. Data from 1980 to 2016 is from the International Energy Agency (IEA 2018). Data for 2017 was obtained using the 2017 growth rate from the Joint Organisations Data Initiative Oil (JodiOil 2018).

Some studies have used total GDP or non-oil GDP as an income measure to investigate gasoline demand in Saudi Arabia. However, this study uses disposable income (DI) because, according to the System of National Accounts (SNA), national disposable income (NDI) is income that can be saved or spent on goods and services, including gasoline (European Commission et al. 2008). Since NDI data for Saudi Arabia is not available for the entire period 1980-2017, we have substituted it with private disposable income (PDI) (NA 2017) as PDI represents a substantial portion of NDI. Second, in resource-dependent countries like Saudi Arabia, the government transfers some part of its resource revenues to the private sector, which in turn contributes to DI and can affect gasoline

demand. DI is taken from Hasanov et al. (2018) and measured in million SAR at 2010 prices. We also used non-oil GDP as an income measure, but the results obtained through using this measure were not as relevant to this study as the results obtained from PDI.

RP (real price) is the weighted average real gasoline price in SAR per liter. Price data is taken from the updated gasoline price data used in Atalla et al. (2018), prepared by KAPSARC researchers. Further details of this data can be found in Atalla et al. (2018).

Population data is used to convert gasoline demand and disposable income data into per capita terms. Population data is taken from the United Nations database (UN 2017).

We also included a pulse dummy (pd1989) in empirical estimations to catch the sharp drop in gasoline demand in 1989, taking 1 in 1989 and 0 otherwise.

Table 2 provides the descriptive statistics of employed variables for the three periods, i.e., the entire sample and the two stages of Saudi Arabia's economic development, as described by Hemrit and Benlagha (2018).

Table 2. Descriptive statistics of the variables.

	Mean			Standard deviation			Coefficient of variation, %		
	1980-2017	1980-2008	2009-2015	1980-2017	1980-2008	2009-2015	1980-2017	1980-2008	2009-2015
<i>MGP</i>	0.67	0.60	0.90	0.14	0.06	0.06	21	11	7
<i>DI</i>	24.75	20.65	37.30	9.22	5.87	4.34	37	28	12
<i>RP</i>	0.63	0.67	0.47	0.26	0.29	0.03	41	43	6

Notes: MGP is in thousands of liters, DI is in thousands of riyals, RP is in SAR/Liter. MGP and DI are in per capita terms.

Figure 1. Plots of variables.

Figure 1. Plots of variables.

As Table 2 shows, average per capita income and gasoline demand are lower in the relatively weak economic period of 1980-2008 than in the next stage of economic growth (2009-2015). The latter period is more stable, with smaller variations around the mean. However, the mean values for the entire period are larger than those in the relatively weak economic development period and smaller than those in the stable economic development phase. This reflects the impact of shocks to the economy.

Contrarily, since gasoline price is a policy tool for policymakers, socio-politic tool for leaders and necessary good for consumers, the real price of gasoline has a higher average value with higher variation in 1980-2008, and a smaller mean value with less variation during the stable economic period, 2009-2015.

Figure 1 demonstrates the historical path of the variables in logarithmic form and their growth rates.

Empirical Results

We tested the variables for unit root using an augmented Dickey-Fuller test (ADF) (Dickey and Fuller 1981); Table 3 presents the results. As can be seen from the table, all the variables are integrated of the first order.

Having all the variables integrated of the first order, we can move to the investigation of the long-run relationship.

We treated coefficients of both variables, income and price, as time-varying. In accordance with our methodology, we first chose the optimal values for p and q .

Both coefficients of income and price are found to be time-varying, as depicted below. Based on the

SIC, the optimal values are found to be $p=2$ and $q=2$ for the income coefficient and $p=1$ and $q=2$ for the price coefficient.

After making transformations (4) and (5), we estimate equation (7) with the transformed data. In the next step, we tested variables for cointegration relationship using a VAT test; the results are given in Table 4. Comparing the test statistics and critical values in Table 4, we can see that the test value is smaller than the 5% critical value but higher than the 10% critical value. As we have a small number of observations, and a VAT test relies on asymptotics and concludes long-run co-movement at a 5% significance level, we conclude that there is a cointegration relationship at a 5% significance level.

Table 3. The ADF unit root test results.

	Variables	Level	k	First difference	k
Intercept	mgp_t	-0.029	0	-2.667*	1
	rp_t	-1.976	0	-4.553***	0
	di_t	-0.211	0	-5.076***	0
Intercept and trend	mgp_t	-2.957	2	-5.508***	0
	di_t	-2.016	0	-5.950***	0
	rp_t	-1.697	0	-4.616***	0

Notes: Maximum lag order is set to two and the optimal lag order (k) is selected based on Schwarz info criteria; ***, and * indicate a rejection of the null hypotheses at the 1% and 10% significance levels, respectively. The critical values are taken from MacKinnon (1996).

Table 4. Cointegration test results.

Variable addition test			
Distribution	Result	Critical values	
Chi-square	test statistics	1%	13.18
$df=4$	9.47	5%	9.49
		10%	7.78

Notes: df = degree of freedom. df is 4 as we used four trend variables for the VAT test.

Empirical Results

Having established a long-run relationship, we then test whether or not the estimated income and price coefficients are time-varying. The test statistics and critical values are reported in Table 5. Table 5 shows that the test statistics are higher in all critical values, which means we can reject the null hypothesis of the insignificance of the coefficients. We therefore conclude that the coefficients of the income and price variables are indeed time-varying.

Table 6 presents the long-run results. The corresponding time-varying income and price elasticities are illustrated in figures 2 and 3, respectively.

The time-varying income elasticity depicted in Figure 3 takes values from 0.00 to 0.15, ignoring negative values before 1993.

Table 5. Significance test for TVCs.

Income Coefficient			
Test Statistics	Critical values		
	1%	5%	10%
441.45	16.81	12.59	10.65
Price Coefficient			
Test Statistics	Critical values		
	1%	5%	10%
151.97	15.09	11.07	9.24

Notes: For the income coefficient $p=2$, $q=2$, $df=p+2q=6$; for the price coefficient ($p=1$, $q=2$, $df=p+2q=5$); p is the number of polynomials, and q is the number of trigonometric pairs in the TVC specification.

Table 6. Long-run estimation results

		FC	Polynomials (p=2)		Trigonometric pairs (q=2)				
		1	$\frac{t}{T}$	$(\frac{t}{T})^2$	$\cos(2\pi\frac{t}{T})$	$\sin(2\pi\frac{t}{T})$	$\cos(4\pi\frac{t}{T})$	$\sin(4\pi\frac{t}{T})$	
Corresponding coefficients									
Income	€ (intercept)	θ_0	θ_1	θ_2	θ_3	θ_4	θ_5	θ_6	
	coefficients	-7.742	-0.027	0.213	-0.094	0.022	-0.040	0.022	-0.013
	p-values	(0.000)	(0.724)	(0.558)	(0.766)	(0.461)	(0.105)	(0.004)	(0.263)
Price	coefficients	0.013	-0.347		0.030	-0.189	0.042	-0.084	
	p-values	(0.914)	(0.119)		(0.339)	(0.032)	(0.076)	(0.041)	

Notes: FC = fixed coefficient, which is the coefficient of the variable without a TVC; p-values are in parenthesis. We also included pulse dummy (dp1989) taking 1 in 1989 and 0 otherwise.

Figure 2. Time-varying income elasticity.

Figure 3. Time-varying price elasticity.

Empirical Results

As Figure 3 shows, the time-varying price elasticity ranges between $[-0.31, -0.05]$.

We employed the general-to-specific strategy for the short-run estimation (see Campos et al. [2005] inter alia). The only difference between the current short-run equation and conventional ones is that the error correction term in our specification comes from the specification with a time-varying coefficient. In other words, it is the residual from the model where the coefficients are time-varying (Eq. [2]). Table 7 gives the final short-run specifications based on

the test results (the general unrestricted model and test results are not reported here to save space but they are available from the authors upon request). The final specification passes the diagnostic tests for residuals and the RESET misspecification test, reported in Table 7.

Figures 4-5 show the plots of the recursive residuals, the cumulative sum control chart (CUSUM) and the CUSUM of squares tests. As the figures show, all test results are in favor of the short-run final specification.

Table 7. Short-run final specification.

variables	ect_{t-1}	$d(incp_{t-1})$	$d(rp_t)$	$d(mgp_{t-2})$	$d(dp1989)$
coefficients	-0.766		-0.126	0.241	-0.103
p-values	(0.000)		(0.000)	(0.000)	(0.000)
	SE of regression	R-squared	Log likelihood	df	k
	0.017	0.888	97.392	30	5
	LM test	White test	JB test	RESET test	
	0.313	1.748	2.240	0.135	
	(0.854)	(0.155)	(0.326)	(0.716)	

Notes: ect=error correction term; SE of regression=standard error of regression; df=degree of freedom; k=number of observations; LM test=Breusch-Godfrey serial correlation LM test (lags=2); White test= White test for heteroskedasticity; JB test=Jargue-Bera goodness-of-fit test; RESET test=Ramsey RESET test for misspecification.

Figure 4. Plot of recursive residuals.

All the estimated parameters of the short-run have the expected signs and are statistically significant. The statistical significance and magnitude of the speed of adjustment coefficient indicate the stability of the long-run relationship. The magnitude of the speed of adjustment coefficient allows us to

conclude that any short-run deviation from the long-run relationship is expected to correct back in over a year. The contemporaneous price change has a meaningful sign and is statistically significant, and no income changes survive.

Empirical Results

Figure 5. CUSUM and CUSUM of squares tests for stability.

Discussion of the Findings

The results of the estimated coefficients are, by and large, similar to the findings of previous studies. The last five studies (after 2012) found the long-run price elasticity to be in the range of $(-0.50, -0.10)$, and our finding is within this interval, taking values from the $(-0.31, -0.05)$ interval. It is worth noting that Dahl (2012) concludes that for static models, long-run gasoline price elasticity range from -0.11 for middle-income economies with low gasoline prices to -0.33 for high-income countries with higher gasoline prices. Controlling for publication bias, Havranek et al. (2012) concluded that the average long-run price elasticity is -0.31 regardless of whether high- or low-income countries are considered.

The estimated income elasticities in the last five studies range from 0.55 to 1.10 . Our results for income elasticity vary from 0.00 to 0.15 . Havranek and Kokes (2015) reviewed the previous studies, controlling for publication bias, and found that the average long-run income elasticity is 0.23 . In this regard, based on the initial observations in this paper and the comparison of the findings in previous studies, this study's estimation results seem relevant.

The income elasticity illustrated in Figure 2 depicts the growth of Saudi Arabia's economy, from its recession in the early 1980s to its expansion until 2014, before it declined again from 2014 as it absorbed the effects of the collapse of global oil prices. The income elasticity values in the figure are, on average, in line with the findings of Havranek and Kokes (2015). The period represented in Figure 2 resembles the conventional behavior of agents of developing countries, with income elasticity increasing in accordance with the country's increasing per capita income level (Chang et al. [2016], *inter alia*). The change in income elasticity also indicates the impact of events such as the 1986

and 2014 oil price drops, and factors influencing elasticity at different income levels (Chang et al. 2014). For example, during periods of relatively low income, the elasticity value is also relatively low. The slightly negative values for income elasticity from 1983 to 1993 shown in Figure 1 are possibly associated with Saudi Arabia's significant economic slowdown during this time: the country's GDP continuously declined from 1981 to 1985 and non-oil GDP declined from 1984 to 1987 while gasoline consumption declined from 1987 to 1989.

For comparison, Figure 6 plots the time-varying income elasticity against disposable income and government transfers to the private sector, both in per capita terms (on a normalized scale). As can be seen, the varying elasticity levels can be explained by changes to disposable income and government transfers. During the recession of 1983-1988, both disposable income per capita and government transfers declined. The relationship between income elasticity and government transfers follows the same pattern. As the recession weakened from 1989 to 2003 government transfers increased, with income elasticity also increasing. During the gradual economic recovery from 1996 to 2003 disposable income elasticity continued to increase; oil prices also increased from 1999 to 2000.

During the Kingdom's rapid economic development from 2004 to 2011 both the growth of disposable income per capita and government transfers increased, although the former was negatively affected by the 2009 global financial crisis. It is clear from Figure 3 that the increase in income elasticity was also higher in 2004-2011 than in 1996-2003. Disposable income growth and government transfers increased until 2012, respectively, before declining; the same was true for income elasticity, with a lagged response.

Discussion of the Findings

Figure 6. Comparison of income elasticity in different periods, with per capita income and government transfers (normalized scale).

Figure 7 plots the time-varying price elasticity and real gasoline price data using a normalized scale. As can be seen from the figure, price elasticity moves in the opposite direction to the domestic price of gasoline. When the price of gasoline spiked sharply in 1988, price elasticity decreased to its lowest value (-0.31) in the period studied. Price elasticity began to increase the following year, following the decline in the gasoline price. The increase in the price of gasoline in 1995 by 72%, and its continued increase until 2002, is associated with the decline in the price elasticity until 2003. The gasoline price has declined in real terms since 2003, with the 2007 Royal decree further accelerating this decline. The downward trend in the domestic price of gasoline continued until 2015, while price elasticity increased until 2012. Price elasticity started to decline again as the gasoline price dropped in 2012. The Kingdom's energy price reform of 2016 increased the domestic price of gasoline, and price elasticity further declined.

Scott's (2012) finding that agents react more strongly to permanent price changes than temporary ones is evident from Figure 7: During the five-year periods of consecutive price increases (1984-1988 and 1997-2001), price elasticity fell to -0.31 in 1988 and -0.15 in 1999. However, though the gasoline price increased in 1995 by 72%, the price elasticity did not change significantly. This can be explained by the fact that the domestic price of gasoline declined in 1994 and 1996. The continued drop in gasoline prices in 2004-2011 saw price elasticity peak in 2011. The last gasoline price increase in 2016 also negatively impacted price elasticity. This could be due to a) the gradual decrease in the growth rate of the price of gasoline, and b) the cut in government transfers. This finding allows us to conclude that a sharp increase in the domestic price of gasoline after a period of permanent price increases, or followed by income 'shrinking' policies, might result in sizeable changes in price elasticity in responses to this increase.

Figure 7. Time-varying price elasticity and gasoline price (normalized scale).

Lastly, the error correction model estimations show that income does not have a statistically significant impact on gasoline demand, replicating the findings of Atalla et al. (2018). The insignificant impact of income on gasoline demand in the short run in the case of Saudi Arabia might be caused by the following factors: first, the saturation effect of driving. The unavailability of different transportation modes in Saudi Arabia makes driving a necessary good, which is bounded above (see Chang and Hsing, 1991, *inter alia*). Second, Saudi Arabia is the fifteenth largest car market in the world, regularly renewing its car park (Motory 2015). Furthermore, as in other Gulf countries, luxury cars are very popular (Krane and Majid 2018). These cars are modern and are mainly fuel efficient, resulting in less gasoline consumption. Third, historically, the domestic price

of gasoline has been very low. As such, the ability of consumers to purchase gasoline has been irresponsive to whether their incomes have been increasing or decreasing in the short-run.

The estimated short-run price elasticity is -0.13. It is worth noting that Havranek et al. (2012), reviewing the previous studies, concluded that the average short-run price elasticity of gasoline demand is -0.09, which is close to our finding.

Additionally, similar to Scott (2012), we found that price elasticity is more responsive to the permanent shocks/price changes. Our findings also support those of Gately (1992), in that high gasoline prices result in larger price responses, and low gasoline prices result in smaller responses.

Conclusion

After the drop in international oil prices in 2014, oil-exporting countries started to launch new policies to develop their economies. It is important that policymakers involved in energy and economic development understand how economic agents respond to increased energy prices and how the latter affects the demand for different fuels. Saudi Arabia is the biggest oil exporting country and is currently undergoing many socio economic reforms. The success of these reforms requires accurate assessments of the country's energy indicators. The current paper investigates gasoline consumption, employing a time-varying coefficient cointegration approach. This approach allows us to analyze the varying responses of demand to income and price levels. The test for the long-run relationship concluded that there is a common trend. Empirical estimation results using the TVC approach showed a significant long-run time-varying income elasticity of less than 0.16, which mainly increased before 2014. The long-run price elasticity was found to range between (-0.31, -0.05). The income elasticity shown in this study is slightly smaller than those estimated in studies published after 2012, which range from 0.55 to 1.10. One reason for the difference between this study and previous studies could be our consideration of the time-varying nature of elasticities, something not considered in previous studies. Another reason might be the use of different measures of income in previous studies. The long-run price elasticity is within the range (-0.1, -0.5) of findings of recent studies. Moreover, the speed of adjustment coefficient is found to be -0.77, meaning that any short-run deviation can be corrected to the long-run equilibrium path in under

1.5 years. Short-run estimation results revealed that income does not have a significant impact on gasoline demand in the short-run. Atalla et al. (2018) also came to this conclusion. The estimated short-run price elasticity is -0.13, almost the same as the findings of the two most recent studies (Arzaghi and Squalli 2015; Atalla et al. 2018).

Gasoline price increases when prices are already high cause larger negative impacts on gasoline demand. Policymakers may consider how this finding can inform energy efficiency measures: Price increases in higher price regimes could produce energy efficiency gains by curtailing gasoline demand.

Consecutive long-lasting price increases might cause demand to decrease severely. This finding could be useful for policymakers, depending on their objectives. For example, if they wish to increase energy efficiency, they could gradually increase prices over the long term.

The short-run income variations do not have a significant impact on gasoline demand. This suggests that income support policies for the private sector, if required, should be designed considering their long-run impacts.

Overall, the insights mentioned above can aid the successful implementation of energy price reforms and environmental policies. The statistically significant negative and time-varying effects of the domestic gasoline price are of particular use in this regard.

Acknowledgements

The authors would like to thank Fatih Karanfil, Walid Matar, Anwar Gasim and Olivier Durand-Lasserve for their valuable comments and suggestions, which helped improve the quality of the paper. The views expressed in this paper

are those of the authors and do not necessarily represent the views of their affiliated institutions. We also thank the attendants of the 21st Dynamic Econometrics Conference and Sir David F. Hendry for their valuable comments.

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About the Project

This research investigates gasoline consumption in the case of oil-exporting country, Saudi Arabia, employing a Time-varying Coefficient Cointegration approach to the data from 1980 to 2017. The conclusion of the study can be useful in successful implementation of energy price reforms and implementation of environmental policies.

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