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Carbon emissions and oil consumption in Saudi Arabia

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ABSTRACT

This study attempts to analyze the effect of total oil consumption and oil consumption in the transport[2] sector on the environmental quality of Saudi Arabia over the period from 1971 to 2013. A structural time series technique is used in this study to expose the underlying energy demand trend (UEDT) for the total carbon emissions and carbon emissions from the domestic transport sector. The results reveal that the trend is nonlinear and stochastic both for carbon emissions and for carbon emissions from the transport sector. In both models, the elasticity of carbon emissions with respect to income and the square of income are positive and significant, which implies that there is a monotonically increasing relationship between carbon emissions and income in Saudi Arabia. The results further reveal that the elasticity of carbon emissions with respect to total oil consumption and transport oil consumption are positive and significant. The empirical findings of this study demonstrate that a growth in real income forces CO_2 emissions to grow, whereas the reverse is not true for both models.

Contents

1. Introduction

Over recent decades, Saudi Arabia has enjoyed rapid economic growth, which has led to a high per capita income. The vast petroleum reserves in Saudi Arabia and revenues earned from petroleum exports have led to considerable economic development. The oil sector in Saudi Arabia accounts for 47% of GDP, 90% of revenues and 90% of export earnings [25]. In addition to oil sector, others contributing factors in GDP of Saudi Arabia are expressed in Fig. 1. Domestic oil consumption in Saudi Arabia has increased drastically in the past four decades, from 0.41 million barrels per day (mbd) in 1970 to 3.07 mbd in 2013, and this oil consumption is one quarter of Saudi Arabian oil production [6]. Similarly, OPEC's oil consumption has increased sevenfold in 40 years, and this oil consumption constitutes one-quarter of production [12]. High

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[2] Oil consumption in the transport sector includes jet oil fuel consumption, gasoline consumption, and light fuel oil consumption.

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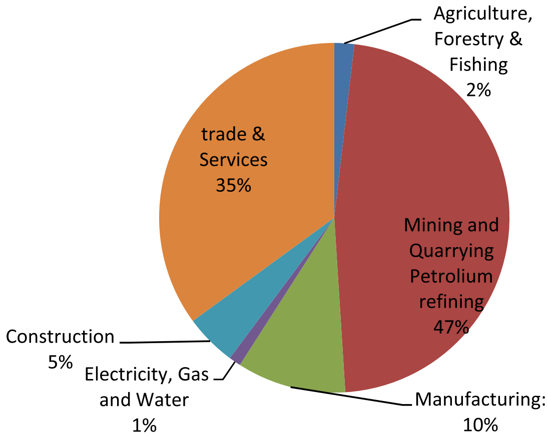

Fig. 1. GDP breakdown by Economic activity for year 2013.
Data source: SAMA (Saudi Arabian Monetary Agency) [25]

economic growth rates accompanied by high rates of population growth are continuously increasing pressure on the country's natural resources.

The high growth rate of domestic consumption of oil in Saudi Arabia has multiple effects at both national and international levels. On the international scene, the emergence of Saudi Arabia as a major consumer of oil will essentially affect Saudi Arabia's oil exports. That is, an increase in domestic consumption of oil will ultimately reduce Saudi Arabia's ability to supply enough oil to the international market. At the national level, because the Saudi Arabian economy depends largely on oil, the Kingdom has to address global environmental issues such as climate change. Increased domestic oil consumption is strongly linked to sustainable economic growth and to environmental degradation in Saudi Arabia. That is, high domestic oil consumption plays the dual role of providing the basis for economic activity and human well-being on the one hand while acting as the driving force for environmental degradation on the other hand. Oil production and exportation are indispensable for economic activities because Saudi Arabia is an oil dependent economy; at the same time, the production, processing and transportation of oil have strong implications for environmental quality. According to U.S Energy Information Administration [30] Saudi Arabia is the largest consumer of petroleum in the Middle East, particularly in the area of transportation fuels and direct crude oil burn for power generation. Similarly the BP Statistical Review of World Energy [6] argues that in 2013, Saudi Arabia was the world's 12th largest consumer of total primary energy, of which about 60% was petroleum-based. Lahan and Stevens [23] argue that Saudi Arabia's growing domestic demand of oil would threaten the country's ability to export to global markets. The finding of Alkhathlan and Javid [2] indicate that energy consumption (oil, gas, and electricity) leads to economic growth in Saudi Arabia in the long term and an increase in energy consumption could result in a deterioration of environmental quality by increasing the carbon emissions in the country. Narayan and Narayan [26] find a positive and statistically significant effect of income on carbon dioxide emissions in Saudi Arabia in the short-run and as well as in long-run.

Environmental protection issues in Saudi Arabia are linked to natural resource development and domestic consumption of oil. In this study, we attempt to assess the effect of total oil consumption and oil consumption in the transport sector of Saudi Arabia on environmental quality over the period from 1971 to 2013. Having precise information on the relationship between environmental quality and domestic consumption of oil is essential from a policy point of view. Oil prices are extremely low in Saudi Arabia; therefore, this study will assist policy makers in planning the necessary strategies for meeting future domestic oil consumption and explore the potential for the market to realize energy conservation policy for protection of the environment domestically.

This study contributes to existing literature on oil consumption and carbon emissions in two ways. The first contribution of this study is to estimate the impact of total oil consumption and transport oil consumption on carbon emissions in Saudi Arabia. This analysis will help policy makers to identify the contribution of transport oil consumption in environmental degradation most polluted components of oil so that policy makers can take remedial measures in this sectors. A large number of studies probe the relationships among carbon dioxide emissions, real GDP and energy consumption in Saudi Arabia and the Middle East [for example, Mehrara [24], Sari and Soytas [27], Narayan and Narayan [26], [5], Alkhathlan et al. [1], Alkhathlan and Javid [2], Alshehery and Belloumi [3]]. None of these studies has investigated the effect of oil consumption on environmental quality. Therefore, this study focuses on the impact of oil consumption on the environment in Saudi Arabia.

The second contribution is that the study develops a structural time series modeling approach that has been used to take into account the underlying energy demand trend (UEDT). Hunt and Ninomiya [19], Hunt et al. [17,18], Dimitropoulos et al. [10] and Dilaver and Hunt [7,8] argue that the structural time series modeling (STSM) approach developed by Harvey [14,13] is the appropriate methodology to efficiently capture the effect of unobservable factors (trends in energy efficiency, technological progress and consumer preference).

We used annual data from 1971 to 2013 for analyzing oil consumption and environmental quality in Saudi Arabia. CO_2 emissions data were obtained from the BP Statistical Review of World Energy June [6] online database. The data for total oil consumption and oil consumption in the transport sector were obtained from the Energy Information Administration (EIA) and Saudi Arabian Monetary Agency. Transport oil consumption was calculated as the sum of Motor Gasoline, Aviation Fuels, and Gas Oil. Data on real GDP were obtained from World Development indicators.

2. Domestic oil consumption and carbon emissions in Saudi Arabia

Table 1 summarizes the levels and growth rates for the consumption of oil, real income, population and CO_2 emissions for Saudi Arabia and some industrialized economy over the period from 1971 to 2013. Because of strong economic and industrial growth, along with high population growth, total oil consumption in Saudi Arabia increased abruptly during the 1971–2013 period. In 2013, total oil consumption in Saudi Arabia was approximately 3.07 mbd, 7.5 times the level in 1971. The annual average growth rate in total oil consumption was 5.2% during the period 1971–2013. The 1970s witnessed the highest growth rate, with 7% annual growth. Oil consumption in the transport sector increased dramatically during the 1971–2013 period. In 2013, oil consumption in the transport sector was 1.3 mbd: 41% of total oil consumption and 61 times the level in 1971.

With respect to size of the economy and population, Saudi Arabia's oil consumption is much higher than the advance industrialized countries. Saudi Arabia consumes more than three million barrels oil per day that is higher than the consumption of, the advance industrialize countries Germany and Canada. German population is three times the population of Saudi Arabia and an economy is about six times as larger as the economy of Saudi Arabia. Japan, an industrialized country with more than four time population and economy nearly nine times as large as the economy

Table 1
CO_2 Emissions and consumption of oil, 1971–2013.

	Variables names	1971	2013	% Growth 1971–2013	Average annual % growth				
		Level	Level		1971 2013	1971 1979	1980 1989	1990 1999	2000 2013
Saudi Arabia	Total oil (mbd)	0.41	3.07	647.8	5.2	6.9	4.36	4.84	5.1
	Transport oil (mbd)	0.03	1.3	3525.7	9.5	27.1	7.1	3.9	5.2
	CO_2 emissions (mt)[a]	66.1	632	856.3	5.8	7.2	6.4	4.2	5.2
	CO_2 emissions from transport oil (mt)	3.29	122.5	3623	9.9	28.3	8.5	2.74	5.6
	Population (millions)	5.8	28.8	375.7	3.8	5.3	5.4	2.3	2.8
	Real income (billions)[b]	60.5	520.6	760.8	5.4	14.5	−0.61	3.1	5.5
Germany	Total oil (mbd)	2.77	2.38	−17.86	−0.26	2.2	−2.4	0.89	−1.12
	CO_2 emissions (mt)	1056.4	842.8	−20.2	−0.49	1.25	−1.14	−1.53	−0.37
	Population (millions)	78.2	80.6	2.95	0.07	−0.01	0.08	0.42	−0.13
	Real income (billions)	1365	3161.9	124.6	1.99	3.1	1.9	2.2	1.17
Japan	Total oil (mbd)	4.3	4.5	6.2	0.49	4.1	−0.76	1.3	−1.5
	CO_2 emissions (mt)	857.1	1397.4	56	1.2	2.5	0.57	1.7	0.53
	Population (millions)	104.3	127.3	20.5	0.46	1.17	0.6	0.28	0.03
	Real income (billions)	1582	4784.5	202.4	2.6	4.7	4.4	1.5	0.94
Canada	Total oil (mbd)	1.51	2.38	57.7	1.2	3.1	−0.74	1.58	1.1
	CO_2 emissions (mt)	371.4	616.7	66	1.28	2.9	0.98	1.27	0.54
	Population (millions)	21.6	35.1	62.4	1.2	1.4	1.2	1.1	1.0
	Real income (billions)	417.4	1319.3	216.1	2.8	4.3	2.9	2.4	2.2
China	Total oil (mbd)	0.75	10.7	1324.2	7.4	14.5	2.6	6.7	6.6
	CO_2 emissions (mt)	749.7	9524.3	978	6.2	7.8	5.2	3.3	7.8
	Population (millions)	818.3	1357.4	61.4	1.2	1.89	1.45	1.14	0.57
	Real income (billions)	118.3	4864	4010.1	9.1	6.1	9.7	10	9.8
U.S.A	Total oil (mbd)	15.2	18.9	24.1	0.64	2.6	−0.54	1.21	−0.2
	CO_2 emissions (mt)	4682.8	5931.4	616.7	0.59	1.52	0.31	1.25	−0.27
	Population (millions)	205.1	316.1	52.2	1.01	1.03	0.93	1.23	0.89
	Real income (billions)	4333.8	14,450.3	233.4	2.86	3.6	3.1	3.2	1.9
World	Total oil (mbd)	47.9	91.3	90.75	1.67	3.92	0.29	1.53	1.3
	CO_2 emissions (mt)	15,463.9	35,094.4	126.9	2.02	3.1	1.4	0.94	2.5

Data source: World Bank [29] BP statistical review of world energy, June 2014. Energy Information Administration (EIA), Saudi Arabian Monetary Agency (Annual Report 2014).

[a] mt stand for Million tonnes carbon dioxide.
[b] Real income is GDP (constant 2005 US$).

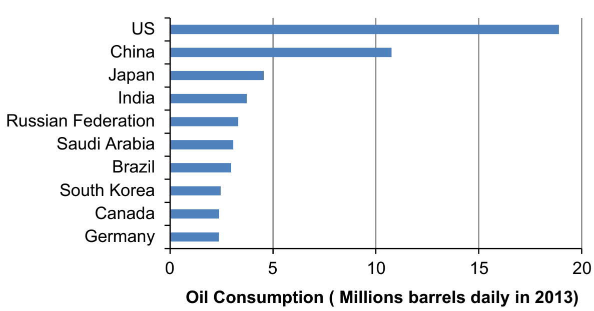

Fig. 2. Top ten oil consuming countries in the world (2013).
Source: BP Statistical Review of World Energy June 2014

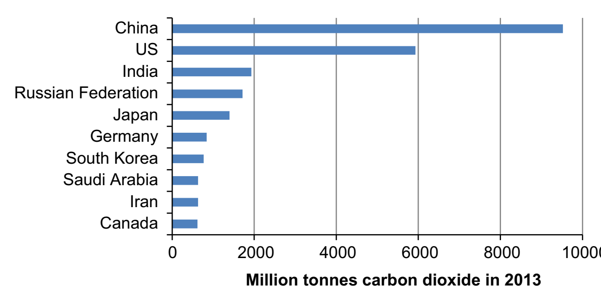

Fig. 3. Top ten CO_2 emitting countries in the world (2013).
Source: BP Statistical Review of World Energy June 2014

of Saudi Arabia, consumes oil (4.5 mbd), slightly more than the oil consumption of Saudi Arabia (3.07 mbd) (See Table 1). Table 1 also depict that decades wise growth rate of oil consumption and CO_2 emissions in Saudi Arabia is higher than the decade wise growth rate of oil consumption and CO_2 emission in Germany, Japan, Canada, and U.S.A. The Saudi Arabian economy is an oil-based economy and comprises energy intensive sectors such as the industry, building and transport sectors, but the extremely high rate of oil consumption is surprising because Saudi Arabia is not a highly industrialized economy. Saudi Arabia is the major oil-consuming economy in the Middle East because of the highly subsidized prices. Fig. 2 reflects that, Saudi Arabia is the 7th largest oil consuming country in the world, even its rank above the industrialized countries like Germany, Canada and South Korea.

In Saudi Arabia, environmental protection issues are strongly related to the energy and oil consumption behavior of Saudi Arabian citizens. Total oil consumption is growing rapidly in Saudi Arabia, and primary energy consumption per capita is 6.8 t of oil equivalent toe in 2009, four times higher than the world average. Total energy consumption has been growing at an average of 5.8% per year since 1990, and it tripled between 1990 and 2009.

The final and primary energy intensities rose by 2.3% per year on average between 2000 and 2009, and CO_2 intensity has risen by 2% per year since 2000 [28]. Despite the Saudi Arabian government's increasing its efforts to protect Saudi Arabia from various environmental threats, CO_2 emissions from liquid fuel consumption reached 291,053.5 kt, and CO_2 emissions from transport oil consumption reached 109.2 million metric tonnes (mmt), in 2011; these figures are, respectively, 13.8 and 33.2 times the 1971 levels.

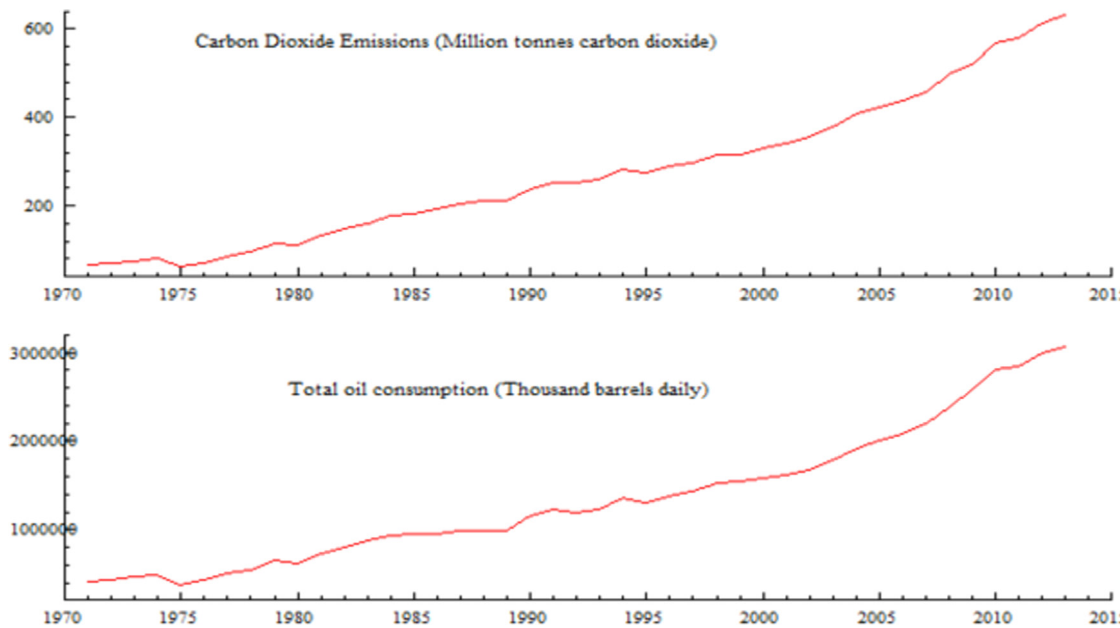

Fig. 4. Total oil consumption and CO_2 emissions (1971–2013).

It is evident that CO_2 emissions from transport oil have grown faster than total oil consumption and transport oil consumption (Table 1). Regarding CO_2 emissions, Saudi Arabia is among top ten countries of the world and stay at the 8th largest CO_2 emitting country in the world (Fig. 3).

Fig. 4 depicts a continuous rising trend of oil consumption and CO_2 emissions during the period from 1971 to 2013. The data indicate that the increasing oil consumption trend, both in total oil consumption and oil consumption in the transport sector, causes high carbon emissions, which adversely affect the environment.

3. Econometrics analysis

Structural Time Series Models (STSMs), also called unobserved components models, provide a flexible way of analyzing time series data. These models represent the observed series as a sum of explanatory variables and suitably chosen components such as a stochastic trend component, μ and a random irregular term [16]. Using the STSM approach, one can estimate a non-linear UEDT, but deterministic time trends are not ruled out (see, for example, [15,11,7-9]).

Recently, several studies have used the STSM approach for energy modeling. Dilaver and Hunt [7,8] used the STSM approach to predict the industrial electricity demand, aggregate electricity demand, and residential electricity demand in Turkey. Amarawickma and Hunt [4] used the STSM technique and other econometrics techniques to predict electric demand in Sri Lanka. Javid and Qayyum [22] used STSM approach to examine relationship between electricity consumption and economic growth over the period from 1972 to 2012. Hunt et al. [17,18] used the STSM approach to analyze the aggregate energy demand for various sectors by using quarterly data over the period from 1972 to 1997. They conclude that in energy demand modeling, stochastic and seasonal trends play an important role. Hunt and Ninomiya [19] studied the demand for oil in the transport sector in Japan and in UK and they concluded that the stochastic trend is more suitable than the deterministic one.

Therefore, STSM methodology, along with an autoregressive distributed lag (ARDL) model, is used in this study to analyze the impact of total oil consumption and transport oil consumption on carbon emissions.

3.1. The structural time series model (STSM)

The STSM approach incorporates unobservable trends and irregular components that are permitted to vary stochastically over time

$$CO_2 = \alpha + \beta LY_t + \gamma LOC_t + \delta LY_t^2 + \varepsilon \tag{1}$$

where CO_2 is the amount of carbon emissions, LY is the logarithm of GDP, LOC is the logarithm of total oil consumption, and LY^2 is the square of log[GDP]

$$CO_2 = \alpha + \beta LY_t + \gamma 1 LTROC_t + \delta LY_t^2 + \varepsilon \tag{2}$$

where CO_2 is the amount of carbon emissions from transport, LY is the logarithm of GDP per capita, $LTROC$ is the logarithm of transport oil consumption, and LY^2 is the square of log[GDP] per capita

3.2. Trend component

The UEDT component, μ_t, is assumed to have the following stochastic process

$$\mu_t = \mu_{t-1} + \beta_{t-1} + \eta_t \quad \eta_t \sim NID(0,\ \sigma_\eta^2) \tag{3}$$

$$\beta_t = \beta_{t-1} + \xi_t \qquad \xi_t \sim NID(0,\ \sigma_\xi^2) \tag{4}$$

Eqs. (2) and (3) represent the level and the slope of the trend, respectively, and η_t and ξ_t are the mutually uncorrelated white noise disturbance with zero means and variances σ_η^2 and σ_ξ^2, respectively. For more detail on STSM methodology, please see Dilaver and Hunt [7–9].

3.3. ARDL model with a stochastic trend

The dynamic autoregressive distributed lag model (ARDL) specification has been used for estimation

$$A(L)CO_2 = B(L)Y_t + C(L)OC_t + D(L)Y_t^2 + \mu_t + \varepsilon_t \tag{5}$$

where $A(L)$ is the lag operator $1-\lambda_1 L - \lambda_2 L^2$, $B(L)$ is the lag operator $1+\varphi_1 L + \varphi_2 L^2$, $C(L)$ is the lag operator $1+\theta_1 L + \theta_2 L^2$, CO_2 is the natural logarithm of per capita Carbon emissions in Saudi Arabia, Y_t is the natural logarithm of real GDP per capita, OC_t is the natural

Table 2
Estimated coefficients and diagnostic tests.

Total oil consumption and carbon emissions		Transport oil consumption	
Variables	Estimated coefficients	Variables	Estimated coefficients
Outlier 1984	0.04 (5.09)	Outlier 1984	−0.09 (−3.35)
Level break 2009	−0.03 (−3.05)	Level break 1980	−0.39 (−10.25)
Level break 1990	−0.04 (−3.65)	*LY*	0.39 (2.37)
Level break 1986	0.03 (3.30)	LY_{t-2}	0.28 (2.41)
Outlier 1991	−0.02 (−2.57)	LY^2	0.431 (2.26)
LY	0.098 (2.94)	*LTRP*	1.11 (12.9)
LY_{t-2}	1.23 (16.59)		
LY^2	0.04 (12.88)		
LTO	0.87 (42.03)		
Estimated hyper-parameters			
$\sigma^2_\xi x10^{-5}$	1.74	$\sigma^2_\xi x10^{-4}$	2.17
$\sigma^2_\eta x10^{-5}$	4.05	$\sigma^2_\eta x10^{-4}$	0.000
$\sigma^2_\mu x10^{-5}$	1.55	$\sigma^2_\mu x10^{-4}$	4.43
Nature of trend	Local level trend	Smooth trend model	
Diagnostics			
Standard error	0.09	Standard error	0.04
Normality	0.05	Normality	0.54
Kurtosis	1.15	Kurtosis	0.48
Skewness	0.41	Skewness	0.05
H (10)	0.74	*H* (11)	0.76
r (1)	−0.11	*r* (1)	−0.10
r (6)	0.17	*r* (6)	0.02
DW	2.03	*DW*	2.04
Q (6, 4)	5.11	*Q* (6, 4)	1.82
R^2	0.99	R^2	0.99
R^2 *d*	0.98	R^2 *d*	0.92

Normality (corrected for Bowman–Shenton), kurtosis and skewness are error normality statistics.
Normality is distributed as $\chi^2(2)$, and kurtosis and skewness are distributed as $\chi^2(1)$.
H (9) is the test of heteroscedasticity, approximately distributed as *F*(9,9).
DW is Durbin Watson statistic for first-order autocorrelation;
r (1) and *r* (6) are the serial correlation coefficients at the 1st and 6th lags, respectively.
Q (6,4) is the Box–Ljung statistic distributed as χ^2.
The *LR* test represents a likelihood ratio test and is used to determine the deterministic time trend. The nature of the trend is a local level model with drift. Prediction error variance (p.e.v.), prediction error mean deviation (p.e.v./m.d.^{2}), and the coefficients of determination (R^2, R^2d) are all measures of the quality of fit.

logarithm of per capita oil consumption, and Y^2 is the square of log [GDP] per capita. μ_t represents the underlying demand trend as defined above, and ε_t is a random error term.

4. Empirical results

Eq. (5) estimates CO_2 for the total oil consumption and oil consumption in the transport sector. Two lags are selected on the basis of the Akaike information criterion (AIC) after deleting the insignificant variables from the model. The final estimates are presented in Table 2, and the diagnostic test results are presented in Table 3. The preferred model passes all of the diagnostic tests for residuals and auxiliary residuals and the prediction tests for 2002–2010. The irregular and level interventions identified in this study provide valuable information regarding certain events and periods during which oil exportation from Saudi Arabia was affected. The estimated equation identified two irregular interventions, for 1984 and 1991, and three level interventions, for 1986, 1990 and 2009, all of which can be correlated to political events in the Middle East.

4.1. Total oil consumption model

The LR test for the total oil consumption model, as displayed in Table 3, does not reject the stochastic specification of the UEDT in the data. The UEDT has a stochastic level and slope. Thus, the form of the UEDT is a local level trend model. The estimated UEDT in Fig. 5 is continuously increasing throughout the period studies but increasing at a decreasing rate. The persistently increasing slope of the UEDT for total oil consumption model suggests that either energy efficient appliances have not been used to protect environmental quality or that any energy efficiency improvement due to

Table 3
Auxiliary residuals.

	Total oil consumption	Transport oil consumption
Irregular		
Normality	0.23 [0.893]	0.79 [0.673]
Kurtosis	0.188 [0.664]	0.37 [0.538]
Skewness	0.04 [0.847]	0.41 [0.521]
Level		
Normality	0.12 [0.922]	N/A
Kurtosis	0.004 [0.947]	N/A
Skewness	0.11 [0.735]	N/A
Slope		
Normality	1.37 [0.503]	0.08 [0.960]
Kurtosis	1.04 [0.305]	0.076 [0.782]
Skewness	0.32 [0.569]	0.004[0.948]
Predictive test	3.33[0.852]	9.51 [0.301]
Cusum *t*	0.711 [0.499]	−1.56 [1.842]
LR test	134.52	107.04

Normality (corrected for Bowman–Shenton), kurtosis and skewness are error normality statistics.
Normality is distributed as $\chi^2(2)$, and kurtosis and skewness are distributed as $\chi^2(1)$.
The *LR* test represents a likelihood ratio test and is used to determine the deterministic time trend. The nature of the trend is a local level model with drift. Prediction error variance (p.e.v.), prediction error mean deviation (p.e.v./m.d.^{2}), and the coefficients of determination (R^2, Rd^2) are all measures of the quality of fit.
N/A denotes for not applicable.

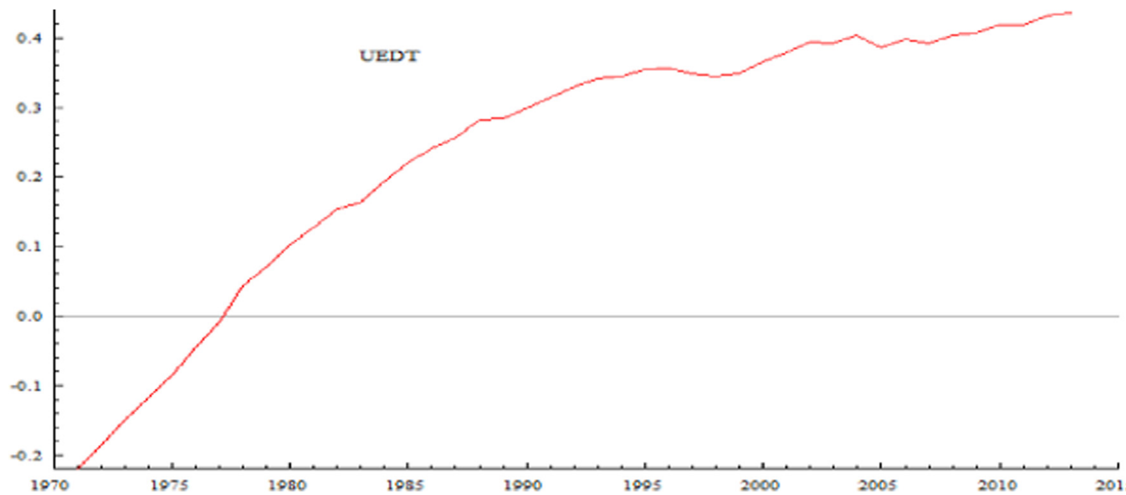

Fig. 5. Estimated UEDT CO_2 emissions from total oil consumption.

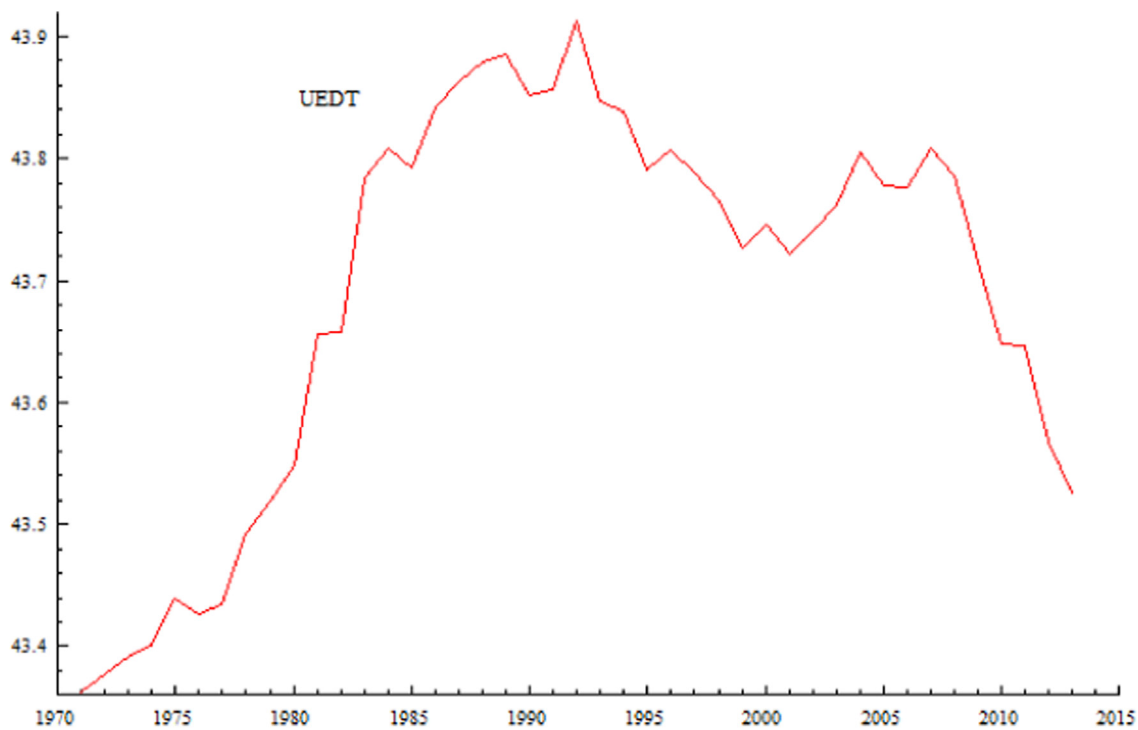

Fig. 6. Estimated UEDT CO_2 emissions from transport oil consumption.

technical progress is offset by other exogenous factors, such as bulk oil use in all sectors in Saudi Arabia.

Estimated long-run elasticities are reported in Table 2. The long-run elasticity estimates of carbon emissions with respect to total oil consumption are significant and positive. The estimated long-run elasticity of carbon emissions with respect to total oil consumption is 0.87, which indicates that a 1% increase in total oil consumption in Saudi Arabia will lead to an 87% increase in carbon emissions in the long run. The long-run elasticity estimate of CO_2 emissions with respect to real income is positive and significant. We also find a positive and significant relationship between carbon emissions and the square of real income in the long run. The positive significant relationship between CO_2 and the square of real income indicates that income leads to greater CO_2 emissions in Saudi Arabia. Saudi Arabia is an oil- based economy, and domestic oil prices are highly subsidized, which leads to high oil consumption. Oil intensive industries and energy intensive life styles in the building, transportation and, most importantly, oil exploration sectors result in a monotonically increasing relationship between income and environmental quality in Saudi Arabia. The results are supported by the findings of Alkhathlan and Javid (2013). Our findings demand strict environmental regulation and even limits on economic growth to ensure a sustainable scale of economic activity within an environmental friendly atmosphere.

4.2. *Oil consumption in the transport sector*

The LR test for oil consumption in the transport sector, as displayed in the last row of Table 3, does not reject the stochastic specification of the UEDT in the data. The UEDT has a stochastic slope and a fixed level; therefore, the form of the UEDT is a smooth trend. The UEDT for oil consumption in the transport sector shows an upward trend from 1971 to the mid-1990s. After the mid-1990s, the UEDT begins to decline (Fig. 6). The upward shape of the UEDT probably indicates that the introduction of appliances that are more energy efficient has no role in curbing CO_2 emissions in Saudi Arabia's transport sector.

These results suggest that the changes in energy use due to the introduction of more energy efficient appliances are outweighed by other exogenous factors for the period from 1971 to 1995, but after 1995 the downward slope of the UEDT indicates that energy efficient appliances result in less pollution in Saudi Arabia. The downward slope of the UEDT in the transport oil consumption model suggests that technological innovations reduced the impact of oil consumption and exploration on the environment in Saudi Arabia after 1995. The most important exogenous factor that likely contributes to the upward UEDT slope is the large increase in the number of vehicles in Saudi Arabia between 1971 and 1995.

The results for the transport oil consumption model reported in Table 3 indicate that there is positive significant impact of real income and transport oil consumption on environmental degradation in Saudi Arabia. The estimated elasticity of carbon emissions with respect to transport oil consumption is not only positive and significant but is more elastic, which implies that a one-unit increase in transport oil consumption causes more than one unit of increase in carbon emissions from the transport sector. The coefficients of real income and the square of real income have significantly positive effects on CO_2 emissions in Saudi Arabia, which indicate that there is a monotonically increasing relationship between transport oil consumption and real income. The empirical findings of this study demonstrated that growing real income forces CO_2 emissions to grow, whereas the reverse is not true for both models.

5. Conclusions and recommendations

The objective of this study is to analyze the impact of total oil consumption and oil consumption in the transport sector in Saudi Arabia on environmental quality over the period from 1971 to 2013. A structural time series technique was employed in this study. In addition to finding the estimates and significance levels of the effect of oil consumption and income on carbon emissions, this methodology also helps to uncover the UEDT for the total oil consumption and oil consumption in the transport sector. The results suggest that the nature of the trend is non-linear and stochastic in shape. The UEDT for the total oil consumption model showed an upward slope for the entire estimated period. The downward slope of UEDT in the transport oil consumption model suggests that technological innovations have reduced the impact of oil consumption and exploration on the environment in Saudi Arabia.

The UEDT for the total oil consumption model showed an upward slope for the entire period. This upward slope suggests that any energy efficiency improvement due to technological progress that reduces CO_2 emissions is outweighed by other exogenous factors. For example, because oil is cheap and abundant, the government of Saudi Arabia would not be able to develop a public transportation system as a whole and particularly in urban regions, as a system for the growing population. The public relies mostly on private cars; there is no public transportation to move residents to work places, schools, colleges, universities or shopping malls. To reduce domestic oil consumption, particularly in the oil sector, and to protect the environment, the government of Saudi Arabia needs to develop an efficient, fast and state of the art urban public transportation system. There is also a need to set strict fuel efficiency standards for vehicles, to reduce oil consumption. Government regulation and legislation have significantly affected the domestic consumption of oil through taxation and price regulation. It is also suggested that government of Saudi Arabia should introduce the solar powered railway system for transportation in the country, particularly for across the city transportation. According to Jaffery et al. [21] railway transport can be considered the most energy efficient and environmentally friendly mode of transport. The proposed solar powered railway system will reduce oil consumption in transport sector of Saudi Arabia, and at the same time, it will help to minimize CO_2 emissions in the country and will improve the quality of life [20].

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