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Price and Income Elasticities of Demand for Crude Oil. A study of thirteen OECD and Non-OECD Countries

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This study examines the determinants of crude oil demand in a panel of thirteen OECD and non-OECD countries constituting about 62% of global crude oil consumption in 2015. Panel unit root and panel cointegration techniques are employed for the estimation of price and income elasticities of crude oil demand. Estimated coefficients in the panel have a statistically significant impact on oil consumption both in the short-run and in the long-run. The empirical panel findings reveal that in the short-run, crude oil demand is price and income inelastic while in the long-run, crude oil demand is income elastic and price inelastic. On the other hand, the estimated coefficients on the price and income variables vary across countries and they are in most of the cases statistically significant.

INTRODUCTION

Energy is considered to be an indispensable input during the production process and economies are heavily reliant upon energy resources (Bithas and Kalimeris, 2016). In recent years, energy-growth nexus has extensively been examined among scientific community (Kalimeris *et.al*, 2013; Stern and Enflo, 2013; Mentis and Tsirimokos, 2016). More specifically, assessment of energy demand has attracted attention, especially in the current context of global economic crisis. During the past two centuries an unprecedented economic growth accompanied by a rapid growth in the extraction and consumption of fossil fuels (coal, oil, and natural gas) has been observed. Fossil fuels nowadays supply almost 82% of energy needs

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with the share of oil accounted for 31.4% (IEA, 2014). More than any other fossil type, oil can be deemed as the primary cause for the great economic boom of the past decades, fueling almost every sector of the industrialized economy. Oil consumption has been recognized as the main driver behind the progress of industrialization and urbanization both in developed and developing countries (Halkos and Tzeremes, 2011) and it is considered as the "life blood of the industrial civilization" (Matutinovic *et al*, 2009), inducing economic development and affecting every aspect of daily life. Transportation, industry, agriculture, public and commercial services require a substantial amount of oil. Additionally, oil components are used to manufacture the majority of chemical products such as plastics, soaps, detergents, polyester clothing, fertilizers etc.

Since the mid-1970s two major oil price shocks, several studies have examined the relationship between oil consumption and economic growth (Hamilton, 1983, MacKillop, 1989; Zou and Chau, 2006; Behmiri and Manso, 2014), as well as the supply and demand factors affecting oil prices (Ferderer, 1996; Hamilton, 2009; Kilian, 2014; Krugman, 2014). Moreover, oil price forecasts have gained significant importance over the last decade since they are essential for oil-intensive industries and policy makers, such as central banks, to measuring financial and economic stability (Degiannakiks and Filis, 2016). Especially, due to high volatility and sharp increases of oil prices observed in recent years (Fig. 1) modeling the factors affecting crude oil market has been an important issue.

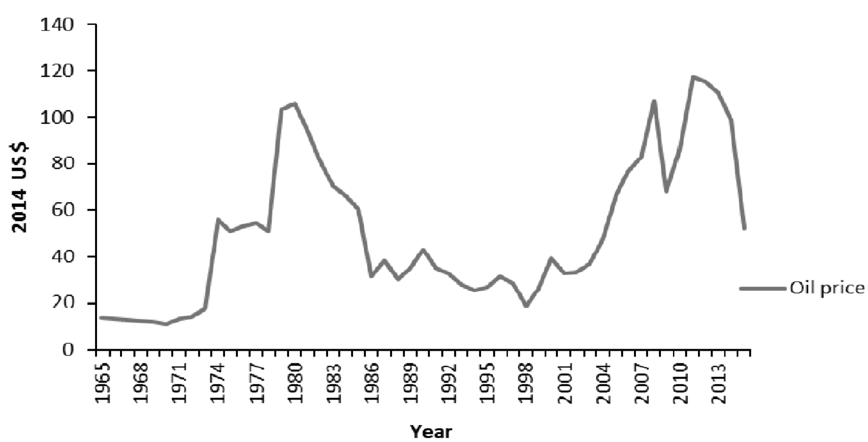

Figure 1: Crude oil prices at constant 2005 US $ per barrel (1965-2015)

Source: BP (2016)

Concerning the supply side of the oil market, the peak oil effect is of paramount importance (Hirsch, 2005; Zhao et *al.*, 2009; Kerschner *et al.*, 2013) while on the demand side the main issue is the growth in oil consumption in developing countries (Kutasovic, 2012).

Global oil consumption grew by 1.26% per year on average in 1980 – 2015, from 62 thousand barrels per day to just over 95 thousand barrels per day — an increase of 54.7% (Fig. 2). Non-OECD countries are fully responsible for this increase. It is noteworthy that in 1980 only a 21.4% of the world oil demand was stemming from non-OECD countries while the corresponding share was 51.9% in 2015. In other words, over the period 1980 -2015 oil consumption in non-OECD countries has been increased sharply by 142.3% while oil consumption in OECD countries has been decreased by 11.2%. Thereafter, it is clear that the world oil consumption map is recording a significant change. However, as countries' energy needs grow and there are not adequate substitutes for oil, global consumption of crude oil will continue to rise in the future, reaching 112 thousand barrels per day by 2040 (OPEC, 2014). Most of the future oil demand growth will be originated from developing economies such as China and India, in which automobile use and factories are growing vigorously (OPEC, 2014).

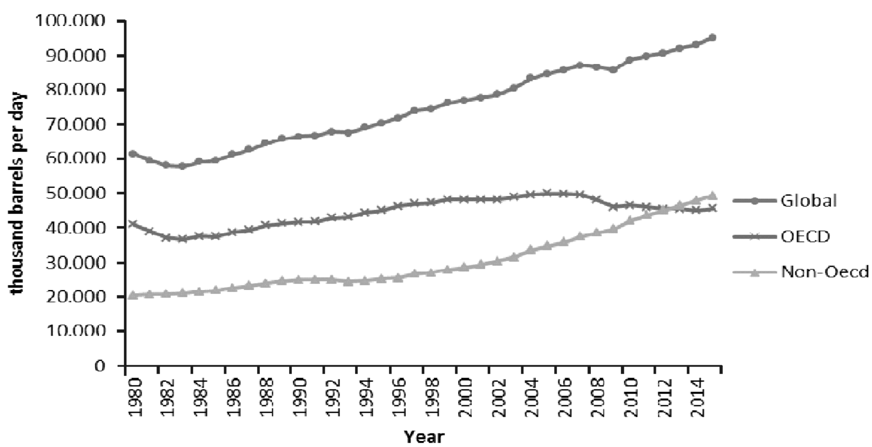

Figure 2: Oil Consumption (1980-2015)

Source: BP (2016)

In this context, estimation of price and income elasticities has turned out to be a necessary tool for governments providing useful information to policy makers for the designing of energy policies. Within the literature of energy economics, several different econometric methodologies have been applied to examine crude oil demand. However, to our knowledge there are only a few studies estimating oil demand in a panel data set context. Based on the above-mentioned explanations, this paper extends the existing literature by deriving price and income elasticities of crude oil demand in thirteen OECD and non-OECD countries over the period 1980 – 2015, by adopting panel unit root and cointegration tests.

The structure of the paper is as follows. Next section presents a literature review on crude oil demand. In section 3, the methodology employed in this study is illustrated along with the utilized data. Section 4 presents the empirical findings of the paper while the last section includes the conclusions of the study.

A BRIEF LITERATURE REVIEW ON CRUDE OIL DEMAND

Although there is a plethora of academic studies that examine the demand of aggregate energy demand (Bentzen and Engsted, 2001; De vita *et al.*, 2006; Sa'ad, 2011; Lee and Chiu, 2013; Huang, 2014), little attention has been paid on the estimation demand of a particular type of energy sources. Every type of energy has its own impact on the economy and has to be analyzed separately (Stambuli, 2013). In this context, there are studies estimating gasoline (Alves and Bueno, 2003; Sene, 2012; Baranzini & Weber, 2013), electricity (Dergiades and Tsoulfidis, 2008; Dergiades and Tsoulfidis, 2011; Jamil & Ahmad, 2012; Lim *et al.,* 2014) or natural gas demand (Erdoglu, 2010; Dilaver *et al*, 2014; Yu *et al*., 2014). In regard to the empirical studies modeling the demand for crude oil, several studies apply either time series data (Gately and Huntington, 2001; Ghouri, 2001; Altinay, 2007; Dees et al., 2007; Xiong and Wu, 2008; Ghosh, 2009; Tsirimokos, 2009; Ziramba, 2010; Lakuma, 2013; Stambuli, 2013; Marbuah, 2014; Yapraki and Kaplan, 2015) or panel data (Narayan and Smyth, 2007; Narayan and Wong, 2009; Behmiri and Manso, 2012; Fawcett and Price, 2012; Ozcan, 2015). While most of the studies estimate crude oil demand in individual countries (Altinay, 2007; Ghosh, 2009; Ziramba, 2010; Moore, 2011; Lakuma, 2013; Marbuah, 2014) there are only a few papers modeling oil demand in a group of countries (Ibrahim and Hurst, 1989; Gately and Huntington, 2001; Askari and Krichene; 2010).

The studies which utilize time series data for the estimation of price and income elasticities of crude oil demand, employ either autoregressive lagged models (Gately and Huntington, 2001; Ghouri, 2001, Stambuli, 2013) or/and time series cointegration tests (Altinay, 2007; Dees *et al*., 2007; Xiong and Wu, 2008; Ghosh, 2009). Gately and Huntington (2001) analyzed the determinants of crude oil demand in 96 OECD and non-OECD countries by employing Koyck lagged model. They found that long-run price and income elasticities of crude oil demand ranged between -0.60 to -0.12 and 0.55 to 0.95 respectively. Ghouri (2001) modeled crude oil demand in USA, Canada and Mexico for the time period 1980 – 1999 by using Almon polynomial distributed lag model and found that long-run income elasticity in USA, Canada and Mexico is 0.98, 1.08 and 0.84 respectively. Stambuli (2013) adopted Nerlove's partial adjustment model (PAM) to investigate how oil demand in Tanzania responds to change in international oil prices and national income. He concluded that in the short-run, demand for oil was both price (-0.005) and income (0.747) inelastic while in the long-run, demand for oil was income elastic (1.750) and price inelastic (-0.012). Altinay (2007) estimated elasticities of crude oil demand in Turkey for the time span 1980-2005 by using an autoregressive distributed lag (ARDL) bounds testing approach to cointegration. He found out that crude oil demand is price inelastic (-0.10 in the short-run and -0.18 in the long-run) and income inelastic (0.64 in the short-run and 0.61 in the long-run). Dees et al (2007) analyzed the world oil market over the period 1984 – 2002 by using an error correction model (ECM) for the estimation of price and income elasticities. They conclude that the long-run income elasticities range from 0.17 to 0.98 while in the short - run income elasticities range from 0.0001 to 0.82. Short – run price elasticities found to be inelastic, approaching zero values. Xiong and Wu (2008) examined and forecasted the crude oil demand in China during the time period 1979 - 2004 by using an ECM for the estimation of price and income elasticities of crude oil demand. Results indicated an income elasticity of 0.0647 and a price elasticity of -0.365. Ghosh (2009) examined the crude oil demand in India for the time period 1970 – 2006 by using an ARDL bounds testing approach of cointegration. He found that long run price and income elasticity accounted for -0.63 and 1.97 respectively.

There are also studies, which estimate price and income elasticities of crude oil within a panel data framework. Narayan and Smyth (2007) examined the crude oil demand in 12 Middle Eastern countries for the time span 1971–2002. They conclude that the long-run income elasticities range from 0.204 to 1.81 while the long - run price elasticities range from -0.071 to -0.002. Narayan and Wong (2009) estimated price and income elasticities of crude oil demand for six Australian states and one territory during the period 1985–2006. They found that long-run income and price elasticity were 0.17 and 0.02 respectively. Behmiri and Manso (2012) examined the Granger causality among crude oil consumption, crude oil price, dollar exchange rate and economic growth in twenty seven OECD countries over the period 1976 - 2009 within a panel multivariate framework. He concluded that long-run price and income elasticities of crude oil demand ranged between -0.23 to -0.09 and -0.41 to 2.5 respectively. Fawcett and Price (2012) modeling crude oil demand in a panel dataset including 53 countries during the period 1984 – 2009, found that in the long – run price and income elasticities ranged from -0.154 to -0.068 respectively. In the short – run, price elasticities ranged from -0.047 to 0.008 while income elasticities ranged from 0.610 to 0.905. Ozcan (2015) analyzed demand for oil in 20 selected OECD countries over the period 1980 to 2011, within the framework of panel data model. He found that long-run price and income elasticities ranged from -1.16 to 0.74 and –0.38 to 3.49 respectively.

Table 1 illustrates a summary of various selected studies and surveys on elasticities of crude oil demand. The majority of the studies conclude that crude oil demand is price inelastic both in the short and in the long-term, the demand for oil is relatively inelastic with respect to income in the short-term and finally that oil demand is income elastic in the long-term.

Table 1
Summary of elasticities on crude oil demand from main selected studies

Study	*Country*	*Period*	*Method*	*SR Elasticities*		*LR Elasticities*	
				Price	*Income*	*Price*	*Income*
Altinay (2007)	Turkey	1980 – 2005	ARDL	-0.64	0.10	-0.61	0.18
Cooper (2003)	23 OECD	1979 – 2000	Nerlove's PAM			-0.568 to 0.005	0.001 to 0.109
Dees *et al.* (2007)	Global	1984 – 2002	DOLS and ECM	-0.07 to -0.03	0.01 to 0.82		0.17 to 0.98
Ghosh (2009)	India	1970 – 2006	ARDL			-0.63	1.97
Xiong & Wu (2008)	China	1979 – 2004	Cointegration and VECM			-0.365	0.647
Marbuah (2014)	Ghana	1980 – 2012	ARDL	0.232 to 0.791	-1.48 to 0.99	-0.45 to -0.16	1.63 to 2.63

contd. table 1

Study	*Country*	*Period*	*Method*	*SR Elasticities*		*LR Elasticities*	
				Price	*Income*	*Price*	*Income*
Barbados (2011)		1998 - 2009	ARDL			-0.55	0.91
Narayan and Smyth (2007)	12 Middle East countries	1971 – 2002	Panel Cointeg-ration and DOLS	0.1715	-0.0008	-0.015	1.014
Ozcan (2015)	20 OECD	1980 – 2011	Panel Cointeg-ration and FMOLS			-1.16 to 0.74	-0.38 to 3.49
Sillah & Al-Sheikh (2012)	6 GCC	1980 – 2010	Cointeg-ration and VECM			-0.30 to 2.51	-2.20 to 0.28
Stambuli (2013)	Tanzania	1972 – 2010	Nerlove's PAM	-0.012	1.750	-0.005	0.747
Ziramba (2010)	South Africa	1980 – 2006	Cointegration and VECM	0.046	0.206	-0.147	0.429

Notes: SR and LR denote short-run and long-run respectively.

ESTIMATION METHODOLOGIES

Regression model and data

Several factors can affect crude oil demand such as oil price, prices of substitute goods (e.g. natural gas price), income, consumer preferences, lifestyle decisions and technological improvements (Howarth *et.al.,* 1993). However, the fact that those factors are difficult to be quantified and measured, crude oil demand is considered within the literature as a function of real crude oil prices and real income (real GDP per capita) (Dahl, 1994; Narayan and Smith, 2007). In this context, crude oil demand can be written as follows:

$$OC_t = f(P_t, Y_t) \tag{1}$$

where oil consumption in year t (OC_t) is treated as a negative function of real crude oil prices (P_t) and a positive function of real per capita income (Y_t). Therefore, based on the classical demand theory, a higher oil price is expected to reduce oil consumption while a higher per capita income would lead to increased oil consumption.

In natural logarithmic form the regression model in equation (1) can be defined as follows:

$$lnOC_{it} = \beta_{oi} + b_{1i}\, lnP_{it} + \beta_{2i}\ lnY_{it} + u_{it} \tag{2}$$

The coefficients β_1 and β_2 measure the price and income elasticity of crude oil consumption respectively. In other words, the coefficients β_1 and β_2 gauge the responsiveness or the sensitivity of crude oil demand to changes in oil prices and income respectively. The subscript i depicts each of the countries within the sample while u_t is the error term which is considered to be independently and normally distributed.

Data on crude oil consumption and prices are drawn from BP Statistical Review of World Energy Workbook (2015). Oil consumption is expressed in thousand barrels per day while crude oil prices are expressed in US dollars and are based on constant prices of 2014. Data on the GDP and population are drawn from The Conference Board Total Economy Database (2015). The GDP is measured in million 1990 International Geary-Khamis dollars while population is expressed in thousands of persons per year.

Data used in the study are in the form of annual time series that covers the period of 1980–2015. The 13 examined OECD and Non-OECD countries included in our panel setting are: Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Korea, Mexico UK, USA as representative developed and developing countries, since accounted for over 62% of the global crude oil consumption in 2015. In the same year, the 5 largest–consuming countries (USA, China, India, Japan and Brazil) accounted for 42% of global oil demand.

Panel unit root test

A prerequisite for employing a panel cointegration test is to examine whether the variables contain a panel unit root (e.g. variables are not stationary). Recent studies suggest that panel unit root tests have higher power than unit root tests based on individual time series (Chen and Lee, 2007; Lee and Chang, 2008; Maslyuk and Smyth, 2009). Although several unit root tests have been developed (Harris and Tzavalis, 1999; Maddala and Wu, 1999; Hadri, 2000; Choi, 2001; Levin *et al.*, 2002; Im *et. al.*, 2003), we employ the panel unit root test proposed by Breitung (2000). Hlouskova and Wagner (2006) conducted a large scale simulation study presenting results on the size and power of first generation panel unit root tests. They conclude that Breitung (2000) panel stationarity test has among the entire examined panel unit root test the best power behaviour and the smallest size distortions. Breitung (2000) test consider the following specification:

$$y_{it} = \mu_i + \beta_{i\tau} + \chi_{it}, \tag{3}$$

where χ_{it} is generated by the following autoregressive process:

$$\chi_{it} = \Sigma_{k=1}^{\rho+1} \alpha_{ik} x_{it-k} + \varepsilon_{it}, \tag{4}$$

The null and alternative hypotheses for the test may be written as:

$$H_0: \ \Sigma_{k=1}^{\rho+1} \alpha_{ik} - 1 = 0.$$

$$H_1: \ \Sigma_{k=1}^{\rho+1} \alpha_{ik} - 1 < 0.$$

Under the null hypothesis each time series contains a unit root while under the alternative one, each time series contains no unit root implying that the panel series is stationary. For the examination of the null hypothesis Breitung (2000), suggests a t-test statistic which is asymptotically distributed as a standard normal.[1]

Panel cointegration test

If all the variables contain a panel unit root and need to be first differenced to render them stationary (e.g. each variable is integrated of order one) then long-run cointegrating relationship among the variables is tested. Pedroni (2004) cointegration test is employed to investigate whether per capita oil consumption, real crude oil prices and real per capita income have a long-run equilibrium relationship. The Pedroni (2004) test is based on the Engle-Granger (1987) two-step (residual-based) cointegration test. Consider the following panel cointegration regression:

$$lnOC_{it} = \beta_i + b_i \ lnP_{it} + \varphi_i \ lnY_{it} + u_{it}, \tag{5}$$

for $t = 1, \ldots\ldots, T$ and $i = 1, \ldots\ldots, N$. T and N refer to the number of observations over the time and the number of each country in the panel. The general approach is to obtain residuals from the panel regression of equation (5) and testing if the residuals are I(1) by running the auxiliary regression:

$$u_{it} = \rho_i \, u_{it-1} + \varepsilon_{it} \tag{6}$$

Under the null hypothesis of no cointegration (ρ_i is unity) in the panel, the residuals u_{it} will be integrated of order one $I(1)$.

Pedroni (2004) employs four panel statistics as well as three group statistics. Regarding with the four panel statistics (or within-dimension test), the first-order autoregressive term is assumed to be the same across all the cross sections allowing for heterogeneity across countries. On the other hand, in the case of group panel statistics (or between-dimension) the parameter is allowed to vary over the cross sections assuming heterogeneity of parameters across countries. Pedroni (2004) shows that the standardized statistic is asymptotically normally distributed. If the test statistic value is greater than the Pedroni's (2004) critical values we reject the null hypothesis of no cointegration. As a result, all variables have a long-run cointegrating relationship.[2]

Panel and long-run elasticities

Having established that there is a linear long-run combination among the variables then long-run price and income elasticities of crude oil demand through the panel based Ordinary Least Square (OLS) and Dynamic Ordinary Least Square (DOLS) are obtained. Kao *et al.* (2000), proposed an extensions of the Stock and Watson (1993) DOLS estimator to panel data settings, including specific lags and leads of the independent variables in order to eliminate the asymptotic endogenity and serial correlation and they found that DOLS was superior to OLS (Narayam and Smyth, 2007).

EMPIRICAL RESULTS

In table 2 the panel Breitung unit root test is presented along with its probability value. Results indicate that the null hypothesis of a panel unit root test cannot be rejected when we consider the levels of the series indicating that all the variables contain the panel unit root (series are non-stationary.) However, when we conduct the test for the first difference of the series we are able to reject the joint unit root null hypothesis at the 1% level. Therefore, all the three variables in their levels are I(1).

Table 2
Panel unit root test results

Variables	*Breitung t-test*	*Probability Value*
lnOC	0.392	0.652
ΔlnOC	-11.921	0.000***
lnP	-1.607	0.154
Δlnp	-8.899	0.002***
lnY	0.100	0.540
ΔlnY	-12.914	0.000***

Notes: lnOC, lnP and lnY denotes natural logarithmic of oil consumption per capita, oil price and GDP per capita respectively. ΔlnOC, ΔlnP and ΔlnY are the first differences of lnOC, lnP and lnY. *** denotes statistical significance at the 1 percent level.

Having found that all panel series are non-stationary, we conduct the Pedroni (2004) cointegration test to observe whether there is long-run relationship between crude oil consumption, real crude oil price and real per capita income. The results are illustrated in table 3. Three out of the four panel based test statistics indicate that the variables are cointegrated at the 5% level or better. In other words, there is evidence of long-run cointegration relationship between the three variables. As far as the group test statistic is concerned, two out of the three tests suggest the existence of a panel cointegration among the variables. Therefore, we conclude that there is strong statistical evidence that oil consumption per capita, real oil prices and per capita income are cointegrated in the long-run.

Table 3
Panel cointegration test results

	Statistics	*Probability Value*
Panel í-statistics	3.521	0.0002***
Panel Phillips-Perron ñ-statistic	-0.593	0.2763
Panel Phllips-Perron t-statistic	-2.442	0.0073***
Panel ADF t-statistic	-1.735	0.0413**
Group Phillips-Perron ñ-statistic	0.446	0.6722
Group Phillips-Perron t-statistic	0.921	0.0017***
Group ADF t-statistic	-3.608	0.0002***

Notes: **, *** denote statistical significance at the 5 and at the 1 percent level respectively.

The long-run and the short-run price and income elasticities of crude oil demand for the panel of thirteen OECD and non-OECD countries is presented in table 4. Long-run elasticities were estimated by OLS and DOLS estimators.

Our panel results show that both real oil prices and real per capita income have statistically significant effect on per capita oil consumption. As it was expected, the coefficient on the real crude oil prices variable is negative while the coefficient variable of the real income per capita is positive. Oil demand is found to be highly price inelastic indicating that countries are insensitive to oil price changes. Therefore, it could be asserted that crude oil is an essential energy source type for both OECD and non-OECD countries (Ozcan, 2015). More accurately, results indicate that a 1% increase in real oil prices leads to decrease in per capita oil consumption by 0.06% (using OLS estimator) or 0.09% (using DOLS estimator) for the whole panel set. On the other hand, crude oil demand is estimated to be income elastic in the long-run.

Moreover, long-run crude oil demand is more elastic for the full panel compared to the short-run panel elasticities of oil demand pointing out that countries are most responsive to income and price changes in the long run. As a result, a 1% increase in per capita income leads to an increase in per capita oil consumption by 1.22% (using OLS estimator) or 1.01% (using DOLS estimator).

Short-run elasticities have been estimated to capture the speed of adjustment of crude oil demand to its “desired” long-run level. All estimated short-run elasticity coefficients have theoretically correct signs going in line with economic theory and they are statistically significant at the 1% level. ECM_{t-1} is the error correction term which measures the speed of adjustment to long-run equilibrium following a shock to the system. The coefficient value of the one period lagged error correction term is found to be negative and statistically significant at the 1% level. The speed of adjustment of per capita oil consumption towards its desired level in the long run is extremely low. More precisely, after a shock to the system, the per capita oil consumption is adjusted towards its long run desired level by 0.84% in each year.

Table 4
Panel long-run and short-run elasticities

	Long-run elasticities	
	OLS	DOLS
lnP	-0.0612*** (-2.4916)	-0.0925*** (-7.5296)
LnY	1.2246*** (87.0798)	1.0121*** (9.4677)
	Short-run elasticities	
Δlnp	-0.0217*** (-2.7722)	
ΔlnY	0.4059*** (5.8152)	
ECT_{t-1}	-0.0084*** (-4.1942)	

Notes: t-statistics values are in parenthesis, *** denotes statistical significance at the 1 percent level.

The results of the DOLS long-run elasticities for each of the thirteen countries are presented in table 5. With the exception of USA, which has a positive but insignificant price elasticity coefficient, all coefficients of price and income elasticities have the expected and corrected sign. The long-run price elasticity is ranged from–0.0085 to -0.1457 implying that a 1% increase in real oil prices decreases per capita oil consumption in the range of -0.008% — -0.145%. Long-run income elasticity is found to be ranged from 0.1440 and 2.6865, indicating that a 1% increase in the real per capita income increases per capita oil consumption in by 0.14%–2.68%.

In only 7 out of the 13 countries (Brazil, Germany, India, Indonesia, Japan, Mexico and UK) the coefficient on price is statistically significant at 10% level or better, suggesting that an increase in oil price leads to a decrease of per capita oil consumption. With the exception of Brazil and India, the crude oil demand is price inelastic indicating that countries are insensitive to changes in oil prices. Insignificant price elasticity coefficients were obtained for Canada, China, France, Italy, S. Korea and USA indicating that changes in oil price do not to have an impact on crude oil consumption.

For 11 out of the 13 examined countries the income elasticity coefficient is found to be significant. Indonesia and Mexico are the only countries where the obtained coefficient of income elasticity value is statistically insignificant. Oil demand is found to be income inelastic in Canada, China, Germany, India, Indonesia, Japan, Mexico and UK. In those countries long-run income elasticity ranges from 0.2995 to 0.8603 implying that a 1% increases in countries' per capita income levels results in a less than 1% increase in their per capita oil consumption levels. This is the case of the decoupling effect[3]. Decoupling effect stated that when the growth rate of natural resources consumption such as energy is lower than the growth rate of output (GDP), then a relative decoupling of natural resources from economic growth is occurred (Fisher-Kowalski et al., 2011). On the other hand, in Brazil, France, Italy, S. Korea and USA oil demand is income elastic. For instance, in USA a 1% increase in per capita income leads to a more than 1% increase in country's per capita oil consumption.

Table 5
DOLS Long-run elasticities for each country

Countries	*lnP*	*LnY*
Brazil	-0.1257*** (3.1294)	1.2286*** (2.9293)
Canada	-0.0085 (-0.0796)	0.7590*** (3.8214)
China	-0.0474 (1.4474)	0.7330*** (30.2393)
France	-0.0474 (-1.4474)	1.6725*** (4.8956)
Germany	-0.0598*** (-4.4478)	0.5134* (2.0077)
India	-0.1457*** (-5.2719)	0.8603*** (23.2844)
Indonesia	-0.0712* (-2.0322)	0.2995 (1.2248)
Italy	-0.0385 (1.3668)	1.5609*** (6.9609)
Japan	-0.0980** (-2.4311)	0.6127* (1.7492)
Mexico	-0.0865*** (-3.7048)	0.1440 (0.6187)
S. Korea	-0.0854 (-0.5875)	2.6865 *** (3.2157)
UK	-0.0676*** (-2.8403)	0.6274** (1.8584)
USA	0.0053 (0.7549)	1.2235*** (10.9089)

Notes: t-statistics values are in parenthesis, *, **, *** denote statistical significance at the 10, 5 and 1 percent levels respectively

CONCLUDING REMARKS

In this study we examined the price and the income elasticities of crude oil demand for 13 OECD and non-OECD countries, constituting about 62% of global crude oil consumption in 2015, in a panel data framework during the period 1980-2015. It was found that oil consumption, oil price and income are panel cointegrated. Estimated coefficients in the panel have theoretically correct signs going in line with economic theory and they have a statistically significant impact on oil consumption both in the short-run and in the long-run. On the other hand, the estimated coefficients on the price and income variables vary across countries. With the exception of USA, which has a positive but insignificant price elasticity coefficient, all the coefficients of price and income elasticities have the expected and corrected sign and they are in most of the cases statistically significant. With respect to the results for the individual countries, long-run price elasticity is ranged from -0.0085 to -0.1457 while the long-run income elasticity is found to be ranged from 0.1440 to 2.6865.

The estimation of price and income elasticities reveals that short-run elasticities values are lower than the corresponding long-run ones both in terms of the results for the full panel of 13 countries and for the individual countries. The fact that crude oil demand in the short-run is less elastic compared to the long-run elasticities of oil demand implying that countries need a necessary time-lag to response to price and income changes.

Crude oil demand is highly price inelastic both in the short-run and in the long-run. Price inelasticity makes countries to be vulnerable to oil price shocks. This implies that if rising oil prices do not results in significant changes of oil consumption then there are other factors such as economic growth, technology or substitutes for oil, which may determine the demand for crude oil more than oil prices. Although most of the countries are constrained by technology and they have difficulties in finding alternative energy resources there are countries that traditionally used other sources of energy. For instance, France uses primarily nuclear energy for its energy production (IEA, 2015) and Brazil which utilizes hydropower for its electricity production exploiting its domestic oil resources (Gomes, 2014). In addition, other countries such as Germany have shown its political commitment of diversifying their energy resources with the “Energiewende” concept (Agora Energiewende, 2015). Nevertheless, such political initiatives and commitments that aim to reduce oil dependency are relatively new, thus their impact remains to be seen in the future (European Commission, 2014).

Crude oil demand is income inelastic in the short-run while in the long-run income elasticities are mostly close or greater than unity. The fact that crude oil demand grows at a greater rate than income in the long-run reveals that oil is a superior good for these countries. Oil demand increases in line with an increase in real income implying that economic growth is associated by high oil consumption, which may induce a rise on oil prices causing inflationary pressures. In certain this can be partially explained by primarily a number of OECD but also a number of non-OECD countries whose industry sector is heavily dominated by "energy intensive" industries. Products from such industries e.g. cement, steel, chemical and car manufacturing industries integrate in their value a high percentage of energy cost, thus rendering them volatile to price fluctuations.

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Notes

1. Interested readers are referred to Breitung (2000) for further details of the panel unit root test.
2. For further details on the cointegration test methodology are provided in the original Pedroni's paper (2004).
3. Decoupling effect is also called dematerialization.

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