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TIME-VARYING LONG-RUN ELASTICITIES OF OIL DEMAND: EVIDENCE FROM AN EMERGING MARKET

Abstract. *This study estimates the elasticities of the time-varying oil demand function in Turkey. To this end, a time-varying cointegration (TVC) method is utilized that allows for smooth changes in parameters. The TVC findings indicate the variation in long-run parameters over time by rejecting the null hypothesis of time-invariant cointegration. Oil can be considered a necessary good based on inelastic income evidence because time-varying income parameters are statistically significant but inelastic for the majority of the estimation period. However, oil demand in Turkey appears to be unaffected by price fluctuations and is more responsive to changes in real economic activity. As a result, our findings suggest that regulating the price of oil products through the imposition of a consumption tax is not a viable way to reduce oil demand. Our findings emphasize the importance of developing policies that promote indigenous production and increase energy production from renewable sources.*

Keywords: *Oil demand, Income elasticity, Price elasticity, Time-varying cointegration, Turkey.*

JEL Classification: C22, C32, C50, Q41

1. Introduction

In the last three decades, the oil demand has been the subject of many theoretical and empirical analyzes. This is due to the leading role of oil as a fundamental and strategic commodity, as economic activity has become largely dependent on the oil demand. Hence, the impact of oil on economic activity has been a source of great concern to scholars, economists, and policymakers. Moreover, in conjunction with the development of modern economic life and industrialization, the population growth and the trend towards urbanization also played a role in increased oil demand.

Because of the importance of oil demand in Turkey's economic growth, this research focuses primarily on estimating the elasticities of oil demand across

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time. Given the Turkish economy's relatively rapid economic expansion over the last decade, oil consumption has a substantial potential for future growth with the support of expanding economic activity (Ozturk and Arisoy, 2016). Following the 2001 financial crisis, the Turkish economy has witnessed greater growth rates. Between 2001 and 2010, the average annual real economic growth rates in the globe and advanced countries were 3.9 percent and 1.7 percent, respectively, whereas Turkey's growth rate was 4 percent. Turkey's average real GDP growth rate was 6.1 percent from 2021 to 2018, outpacing the global average by 3.6 percent, advanced economies by 1.9 percent, and BRICS countries by 3.7 percent (World Economic Outlook, 2019).

Figure 1 depicting the domestic oil demand of Turkey demonstrates that oil demand has an increasing trend from 1990: Q1 to 2018: Q4. Furthermore, fast economic and population expansion has boosted energy consumption, resulting in a growing reliance on oil and gas imports due to a lack of domestic energy supplies. As a result, Turkey's reliance on oil imports has climbed from 70.8 percent in 1970 to 93.3 percent in 2018 (EIA, 2021). Turkey's excessive energy reliance jeopardizes its energy supply security. As a result, one could argue that projecting oil demand requires an accurate estimate of the long-run price and income elasticities of oil demand in Turkey.

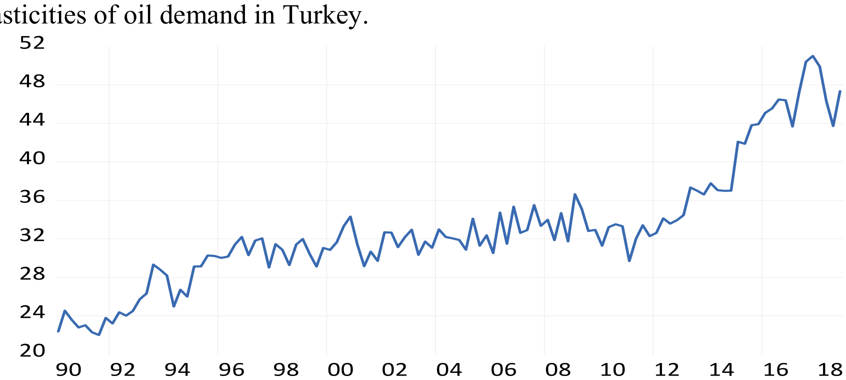

Figure 1. Domestic oil demand of Turkey (mtoe)

Because of the importance mentioned above, numerous studies covering different single countries or groups of countries and time periods have been conducted to estimate oil demand elasticities in the literature. These studies produced mixed results due to the specific economic factors and the reasons driven by the application of various methodologies. The majority of the adopted methodologies are mainly based on the presumption that oil demand elasticities are constant over the analysis period therefore, they are time-invariant. Many studies have estimated elasticities using the ordinary least squares method (OLS), for example, Dahl (1994) for 50 developing countries. Other studies estimated elasticities for a group of countries by using panel data, e. g. Pesaran et al., (1998) for 10 Asian countries, Narayan and Smyth (2007) for 12 countries in the Middle East. Additionally, some researchers have used cointegration, error correction models, VAR, and VECM (e.g., Ziramba, 2010). Several studies have estimated long- and short-run elasticities using the autoregressive distributed lag method (ARDL), including Bentzen and Engsted (2001) for Denmark, Altinay (2007) for Turkey, and Sa'ad (2009) for Indonesia. In comparison, only a few research has analyzed the time-varying characteristics of the demand for oil or another energy product, such as Park and Zhao (2010), Neto (2012), Ozturk and Arisoy (2016), and Abu Eleyan et al. (2021).

In light of this, the purpose of this research is to add to the empirical literature on Turkish oil demand in a variety of ways. First, we argue that methodologies presuming the linearity and constancy of parameters of the oil demand function may lead to inaccurate estimation of the parameters due to the volatile characteristics of the oil market. Therefore, we consider cointegration tests that include structural breaks in the time series of oil demand function variables to account for the nonlinearity and possible endogenous regime shifts. Second, the time-invariant hypothesis of elasticities is tested, and then if this hypothesis is rejected, the long-run elasticities are estimated based on the time-varying parameters methodology. Third, in this study, we employ the time-varying cointegration (TVC) approach developed by Bierens and Martins (2010), based on the Chebyshev time polynomials to estimate time-varying long-run elasticities. To our knowledge, there are no studies that have explored this issue for Turkey using this approach. Finally, compared to previous articles utilizing the data with the annual frequency we employ quarterly data covering the period 1990: Q1 to 2018: Q4. Hence, the use of more number of observations enables us to gauge the determinants of oil demand over time more precisely.

The following is the structure of the remainder of the article. The next section gives an overview of the literature on oil demand. Section three introduces the data used in the estimation of the oil demand function. Section four discusses the nonlinear cointegration methods used to examine the existence of a long-run connection among the oil demand variables. Section five interprets empirical findings from cointegration tests. Finally, the paper ends with concluding remarks.

2. Literature review

Elasticities of oil demand are critical indicators for determining the impact of economic growth and price volatility on social welfare. As a result, numerous empirical studies have been conducted using a variety of methodologies to estimate the elasticities of oil demand for a country or group of countries. These studies produced disparate findings due to methodological differences, periods, frequency of series, and selected countries. Despite the abundance of empirical research on the elasticities of energy markets, the vast majority of them have used linear approaches that only allow for the estimation of time-invariant parameters.

According to the methodology used in the studies, the literature on estimating the price and income elasticities of energy demand falls into two categories. The first category estimates a single elasticity of price and income for a sample of group countries. For example, Prosser (1985) reported that the OECD countries' income and price elasticities for energy demand were 1.02 and -0.37 after 1971, respectively. Dahl (1994) concluded that energy demand was moderately elastic in terms of income but inelastic in terms of price. Dahl reported that the long-run price elasticity was -0.33 and the mean long-run income elasticity was 1.27 for aggregated energy consumption in 50 developing countries, while the short-run income elasticity was 0.53 and the price elasticity was -0.33. Pesaran et al. (1998) investigated the long-run income and price elasticities of oil demand in ten Asian countries. The authors discovered that the income elasticity varied between 0.22 and 2.21 in Sri Lanka and Malaysia and that the average long-run income elasticity was 1.23, while the average long-run price elasticity was -0.26. Oil demand elasticities in India were -0.07 and 1.56, respectively, over the long run. Narayan and Smyth (2007) estimated the short-run and long-run price and income elasticities for twelve Middle Eastern countries to be -0.0008 and 0.715, respectively, and -0.015 and 1.014, respectively.

The second category of studies employs time series methodologies, in which market characteristics are used to estimate price and income elasticities. For example, Bentzen and Engsted (2001) estimated income and price elasticities in Denmark using ARDL. They estimated that the short-run elasticities of income and price were 0.444 and -0.354, respectively. However, the income and price elasticities were 1.294 and -1.032 in the long run, respectively. Altinay (2007) found that the long-run income price elasticities for oil demand in Turkey were 0.61 and -0.18 using the same methodology. In the short run, the price and income elasticities were -0.02 and 0.39, respectively. Sa'ad (2009) reported long-run price and income elasticities of 0.16 and 0.88, respectively, in a study of petroleum demand in Indonesia. Kim and Baek (2013) examined the dynamics of South Korea's demand for imported crude oil. Price and income elasticities, in the long run, were -0.43 and 1.31, respectively. Price and income elasticities in the short run were obtained as -0.36 and 0.11, respectively. Jebran et al. (2017) estimated Pakistan's long- and short-run income and price elasticities for energy demand. Marbuah (2017) estimated that demand for crude oil in Ghana was both short- and long-run income elastic, while the price was inelastic in the short run but elastic in the long run. Utilization of the Nonlinear ARDL methodology Shin et al. (2018) discovered that the long-run income elasticity of imported crude oil in Korea is positive and significant. Additionally, the authors demonstrate the asymmetric effect of oil prices on long-run demand for imported crude oil. Ziramba (2010) estimated the long-run price and income elasticities for South Africa's crude oil import demand to be 0.147 and 0.429, respectively, indicating that both income and price are inelastic. Gorus et al. (2019) estimated the long-run price and income elasticities of crude oil import demand in Turkey to be 0.11 and 1.04, respectively, using the DOLS approach. Kavaz (2020) estimated the price and income elasticities of oil demand in Turkey to be 0.66 and -0.11, respectively, using Structural Time Series Modeling.

However, there is a scarcity of research on the time-varying elasticities of oil demand. We came across only two studies analyzing the demand for oil using time-varying methodologies. Ozturk and Arisoy (2016) used a time-varying parameter regression based on a Kalman filter to investigate Turkey's short-run crude oil import demand. They employed data from 1966 to 2012 with an annual frequency. According to the findings, income elasticity is significant, whereas the price elasticity of oil consumption is inelastic. The estimated short-run income elasticity of 1.182 indicates that income changes over the study period have a significant influence on crude oil imports. Abu Eleyan et al. (2021) estimated the time-varying oil demand elasticities of the BRICS countries using the time-varying cointegration (TVC) technique. The findings indicate that long-run elasticities are not constant over time in all countries. Additionally, the average time-varying elasticities of income and price are less than one for all countries, suggesting that oil demand is inelastic with respect to income and price. Furthermore, despite the evidence for oil as a necessary commodity, the evidence suggests that BRICS oil consumption is more impacted by real income than by prices.

Apart from the studies mentioned above, we found several studies examining the time-varying elasticities of gasoline demand. Park and Zhao (2010) examined the elasticities of US gasoline consumption from 1976 to 2008 using a time-varying cointegration method. The estimates based on quarterly data indicate that price elasticity varies over time, which may be explained by changes in the percentage of income spent on gasoline and fluctuations in the degree of necessity. Neto (2012) analyzed the long-run elasticities of gasoline demand in Switzerland from 1973:Q1 to 2010:Q4. The findings indicate that the time-invariant long-run cointegrating relationship hypothesis for the Swiss gasoline market has been rejected. Income elasticity is estimated to be positive and to follow a steady path around its average value of 0.69, whereas price elasticities have remained largely negative, averaging -0.17.

Given the empirical literature discussed previously, the number of studies testing the time-invariant hypothesis of long-run oil demand elasticities is extremely limited, particularly for Turkey, which has not been previously analyzed to our knowledge. As a result, this study fills a void in the literature by investigating time-varying cointegration and then estimating the time-varying elasticities of oil prices and income in Turkey using Bierens and Martins (2010) TVC methodology.

3. Model and data

In accordance with prior research, this article defines the following oil demand function by taking the natural logarithm of both sides, allowing parameter estimations to be interpreted in terms of elasticities:

$$lnOilQ_t = \beta_0 + \beta_1 lnGDP_t + \beta_2 lnOilP_t + \varepsilon_t \quad (1)$$

Where $lnOilQ_t$ is the natural log of oil demanded in mtoe (see Figure 1). As a measure of income in Turkey we utilize real Gross Domestic Product (GDP_t) with 2009 prices. $lnOilP_t$ is the natural log of the real oil price, it is calculated by multiplying the average crude oil prices in the three major spot markets, i.e. the Dated Brent, the West Texas Intermediate, and the Dubai Fateh, with Turkish lira /

USD exchange rate and then dividing by the implicit GDP deflator. ε_t is the error term. The parameters of the oil demand function denoted by β_1 and β_2, are the income and price elasticities of demand, and if oil is a normal good, their signs are anticipated to be positive and negative, respectively. As previously mentioned, as one of the paper's unique contributions, this study employs data with quarterly frequency acquired from the Thomson Reuters DataStream database, spanning from 1990:Q1 to 2018:Q4.[1]

The variables in the oil demand function are displayed in Figure 2. During the analysis period, there is an increasing trend in both oil demand ($lnOilQ_t$) and real income ($lnGDP_t$). It is also worth noting that the quantity of oil needed has increased dramatically, particularly in the past decade. This implies that the Turkish economy is becoming more dependent on oil as the price of imported oil rises. However, the real oil price ($lnOilP_t$) lacks a distinct trend and instead follows a fluctuating pattern. Finally, a visual analysis of time series indicates that structural changes in variables may be attributed to local or worldwide economic events.

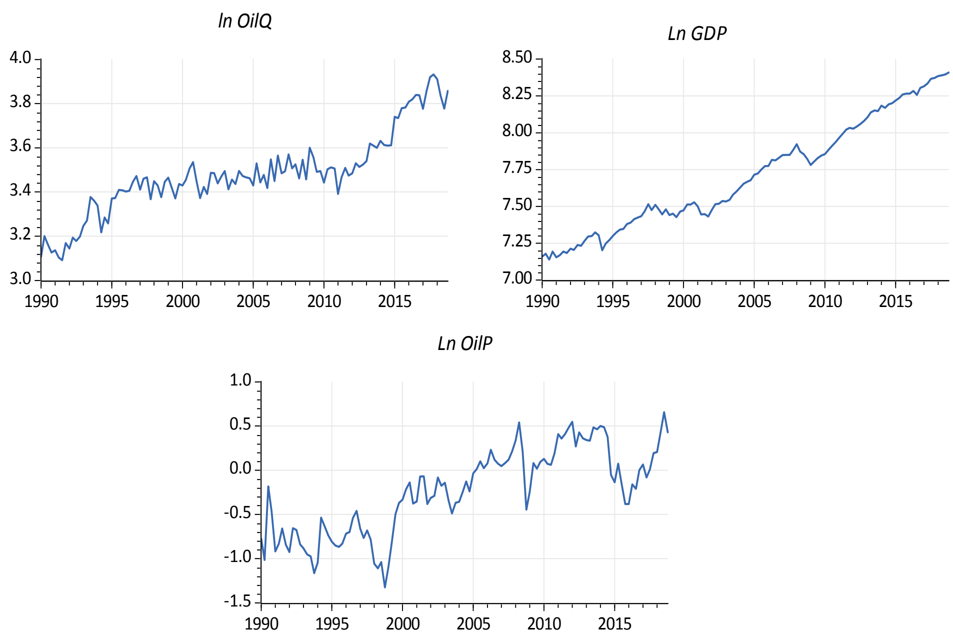

Figure 2. The variables in the oil demand equation: 1990. I – 2018: IV

As a conventional step of the cointegration analysis, we carry out linear unit root tests, namely Augmented Dickey and Fuller (ADF) and Phillips and

[1] The variables are seasonally adjusted though the Census X-13 method before the estimation of oil demand function.

Perron (PP) to examine the stationarity properties of the variables. Furthermore, as linear unit root tests have been criticized for having low power in the presence of potential structural breaks, we use the Kapetanios (2005) unit root test, which allows for a maximum of five endogenous structural breaks (*m=5*) in the variables.

Table 1. ADF and PP unit root tests

Variable	Specification	ADF		PP	
		Level	First diff.	Level	First diff.
$lnOilQ_t$	Intercept	-0.87	-16.37**	-1.17	-20.27**
	Trend and intercept	-2.40	-16.29**	-3.48*	-20.57**
$lnGDP_t$	Intercept	0.56	-11.74**	0.76	11.71**-
	Trend and intercept	-2.25	-11.81**	-2.31	-11.81**
$lnOilP_t$	Intercept	-2.08	-11.38**	-1.87	-11.09**
	Trend and intercept	-3.81*	-11.37**	-3.80*	-11.03**

Notes: The null hypothesis for ADF and PP are: the series has a unit root I (1).
** denote significance at 1%; * significance at 5%.

The linear unit root tests findings in Table 1 reveal that all variables are stationary in the first difference at one percent level of significance. Table 2 reports the Kapetanios (2005) test results allowing for breaks in trend and intercept. The test findings show that important domestic and worldwide events have a substantial impact on the Turkish economy though breaking dates differ across the variables. For example, the breaking dates in the real oil price mostly seems to be coincided with the global oil price rise in 1996, the Russian financial crisis at the end of the 1990s, the US-led invasion of Iraq in 2003, the global financial crisis in 2008, and the oil price shock of 2014. Meanwhile, first break in the real GDP is occurred in the first quarter of 1994 attributable to the local financial crisis experienced on that time. The remaining real GDP breaking dates appear to be linked to other economic crises, such as the Russian crisis in 1998, the Turkish financial crisis in 2001, and the 2008 Global financial crisis.

Table 2. Kapetanios unit root test with structural breaks

Variable	Level		First diff.	
	t- statistic	Breakpoints	t-statistic	Breakpoints
$lnOilQ_t$	-5.901	1997:Q3, 2009:Q2, 2014:Q4	-5.758***	2014:Q3
$lnGDP_t$	-7.958	1994:Q1, 1998:Q1, 2001:Q4, 2008:Q1, 2011:Q4	-6.731***	2001:Q3
$lnOilP_t$	-7.963	1996:Q2, 1999:Q1, 2003:Q1, 2008:Q2, 2014:Q3	-6.831***	2014:Q1

Note: ***, ** and * indicate significant at 1%, 5% and 10% respectively.

Overall, the results of conventional and unit root with breaks tests imply that all variables are non-stationary in the level and stationary in the first difference, i.e. I(1). As a result, first difference stationarity of the variables has important implications. First, it allows us to test the presence of a long-run relationship among the variables in the oil demand function. Second, the evidence on the significant structural breaks in the variables might also implies the presence of possible instabilities in the long-run parameters obtained through linear estimation methodologies, this encourages the use of non-linear cointegration techniques to obtain accurate estimation of the elasticities.

4. Methodology

4.1. Cointegration tests with structural breaks

Before relaxing the assumption on the time-invariance of the elasticities, we utilized Hatemi-J (2008), and Gregory-Hansen (1996) tests to account for the existence of possible of structural breaks on long-run parameters of the oil demand function. To test the null hypothesis, no cointegration versus cointegration in the vectors in level or regime shifts Gregory and Hansen (1996) used ADF, Z_t, and Z_α. statistics depending on the following specifications:

Model (C):

Level shift: $y_t = \mu_1 + \mu_2\varphi_{t\tau} + \alpha x_t + \varepsilon_t$ (2)

Model (C/T):

Level shift with trend $y_t = \mu_1 + \mu_2\varphi_{t\tau} + \beta t + \alpha x_t + \varepsilon_t$ (3)

Model (C/S):

Regime shift: $y_t = \mu_1 + \mu_2\varphi_{t\tau} + \alpha_1 x_t + \alpha_2 x_t\varphi_{t\tau} + \varepsilon_t$ (4)

Model (C/S/T):

Regime and trend shift: $y_t = \mu_1 + \mu_2\varphi_{t\tau} + \beta_1 t + \beta_2 t\varphi_{t\tau} + \alpha_1 x_t + \alpha_2 x_t\varphi_{t\tau} + \varepsilon_t$ (5)

where y_t represents the quantity demanded of oil ($lnOilQ_t$), i.e., the dependent variable. x_t refers to the m-dimension vector of explanatory variables, $(lnGDP_t\ lnOilP_t)'$. ε_t is the error term, $t = 1, 2, \dots, n$, while $\varphi_{t\tau}$ refers to the dummy variable, which is $\varphi_{t\tau} = 0$ if $t \leq [n\tau]$ and $\varphi_{t\tau} = 1$ if $t > [n\tau]$. Besides, $\tau \in (0, 1)$ indicates the relative timing of structural dates, $\mu_1$and μ_2 are intercept coefficients before and at the shift, α and β denote the coefficients of the cointegrating vector and trend. Finally, α_1 and β_1 are the coefficients before the shift for cointegration and the trend, while the corresponding changes after the breakpoint are α_2 and β_2. Hatemi-J (2008) extends the Gregory and Hansen (1996) test to investigate the existence of cointegration with two structural shifts using the following specification:

$$y_t = \alpha_0 + \alpha_1 D_{1t} + \alpha_2 D_{2t} + \beta_0' x_t + \beta_1' D_{1t} x_t + \beta_2' D_{2t} x_t + u_t \quad (6)$$

in this case, α_0, α_1 and α_2 are the coefficients for the intercept, while β_0', β_1' and β_2' are the slope coefficients for the vectors in the model. Furthermore, D_{1t} and D_{2t} represent dummy variables described by:

$$D_{1t} = \begin{cases} 1 & \text{if } t > [n\tau_1] \\ 0 & \text{if } t \leq [n\tau_1] \end{cases} \text{ and } D_{2t} = \begin{cases} 1 & \text{if } t > [n\tau_2] \\ 0 & \text{if } t \leq [n\tau_2] \end{cases}$$

τ_1 and τ_2 indicate the location of the unknown breaks, where $\tau_1, \tau_2 \in (0, 1)$. The following statistics are suggested to test the significance of breaks:

$ADF^* = inf_{(\tau_1,\tau_2)\in T}\ ADF(\tau_1, \tau_2)$,

$Z_t^* = inf_{(\tau_1,\tau_2)\in T}\ Z_t(\tau_1, \tau_2)$,

$Z_\alpha^* = inf_{(\tau_1,\tau_2)\in T}\ Z_\alpha(\tau_1, \tau_2)$,

where $\tau_1 \in T_1 = (0.15, 0.70)$ and $\tau_2 \in T_2 = (0.15 + \tau_1, 0.85)$.

4.2. Time-varying cointegration test

In light of the inadequacies of the constant-coefficient methodologies discussed in the review of literature, this study employs a TVC methodology by Bierens and Martins (2010), allowing for variation in the cointegrating vector varying over time. To estimate the long-run time-varying income and price elasticities, we begin with the conventional time-invariant cointegration methodology of Johansen-Johansen and Juselius (1990). Based on this, the linear form of the vector error correction model (VECM) is specified as follows:

$$\Delta Z_t = \mu + \Pi' Z_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \, \Delta Z_{t-i} + \varepsilon_t, \tag{7}$$

where $\Pi = \sum_{i=1}^{p} A_i - I \; and \; \Gamma_i = -\sum_{j=i+1}^{p} A_j$,

where Z_t represents the $k \times 1$ vector of the time series of the variables in the oil demand model, namely $(lnOilQ_t \; lnGDP_t \; lnOilP_t)'$, and $\varepsilon_t \sim N_k(0, \Omega)$ which is a $k \times 1$ vector of the error term. The rank of the matrix Π gives the dimension of the cointegrating vector; and if its rank is reduced so that $r < k$, then there exists $k \times r$ matrices α and β each with rank r, where $\Pi = \alpha\beta'$ and $\beta' y_t$ is stationary. In this case, β and α are defined as vectors for both the cointegration and adjustment coefficients. To find the number of cointegration vectors, Johansen's approach suggests two different tests as follows:

$$\lambda_{trace}(r) = -N \sum_{i=r+1}^{g} \ln(1 - \hat{\lambda}_i) \tag{8}$$

and

$$\lambda_{max}(r, r+1) = -N \ln(1 - \hat{\lambda}_{r+1}) \tag{9}$$

where *N* and *r* are the number of observations and the cointegration vectors, while $\hat{\lambda}_i$ is the value of the characteristic roots.

To investigate the possibility of time-variation in the cointegration relationship, the linear VECM is converted into a time-varying form as proposed by Bierens and Martins (2010):

$$\Delta Z_t = \mu + \Pi_t' Z_{t-1} + \sum_{j=1}^{p-1} \Gamma_j \; \Delta Z_{t-j} + \varepsilon_t \tag{10}$$

where Π_t' is a matrix containing the time-varying parameters. The equation (10) defined above allows us to test existence of time-invariant (TI) cointegration (H_0: $\Pi_t' = \Pi' = \alpha\beta'$, where α and β represent TI $k \times r$ matrices with rank r) versus time-varying cointegration (TV) (H_1: $\Pi_t' = \alpha\beta_t'$, where α as before is invariant but here β_t represents $k \times r$ TV matrices with rank also r) among the oil demand variables. Ω and Γ_j denote constant matrices $k \times k$ and $1 \leq r \leq k$ in both cases. In Bierens and Martins (2010) β_t represents the matrix including the long-run cointegrating parameters and is modeled through Chebyshev time polynomials. The long-run time-varying parameters β_t can be approximated under the assumption of standard smoothness and orthonormality conditions as follows,

$$\beta_t = \beta_m\left(\frac{t}{T}\right) = \sum_{i=0}^{m} \xi_{i,T} \, P_{i,T}(t) \tag{11}$$

for some fixed: $m < T - 1$, $t = 1, 2, \ldots, T$, and $i = 1, 2, \ldots, m$. Moreover, $\xi_{i,T} = \frac{1}{T} \sum_{t=1}^{T} \beta_t \, P_{i,T}(t)$ for $i = 0, \ldots, T - 1$, as $k \times r$ unknown matrices. Also, Chebyshev time polynomials $P_{i,T}(t)$ are defined as follows: $P_{0,T}(t) = 1$, $P_{i,T}(t) = \sqrt{2}cos(i\pi(t-0.5)/T)$, where $t = 1, 2, \ldots, T$ and $i = 1, 2, 3, \ldots$.

To model the TVC via Chebyshev Time Polynomials, equation (11) is substituted into equation (10) as follows:

$$\Delta Z_t = \mu + \alpha(\sum_{i=0}^{m} \xi_{i,T} P_{i,T}(t))' Z_{t-1} + \sum_{j=1}^{p-1} \Gamma_j \ \Delta Z_{t-j} + \varepsilon_t \quad (12)$$

where $\Pi_t' = \alpha\beta_t' = \alpha(\sum_{i=0}^{m} \xi_{i,T} P_{i,T}(t))'$. Considering low-order Chebyshev Time Polynomials are smooth functions of t allowing β_t to shift gradually over time. Besides, $\xi_i' = (\xi_0', \xi_1', \ldots, \xi_m')$ is an $r \times (m+1)$ matrix of rank r and $Z_t^m = (Z_{t-1}' P_{1,T}(t), Z_{t-1}' P_{2,T}(t), \ldots, Z_{t-1}' P_{m,T}(t))'$.

Finally, to investigate TVC, we test the following hypotheses: For TI, H_0: $\xi_{i,T} = O_{k\times r}$ for $i = 1, \ldots, m$ and $\xi_i = O_{k\times r}$ for $i > m$. For TV, H_1: $\lim_{T\to\infty} \xi_{i,T} \neq O_{k\times r}$ for some $i = 1, \ldots, m$ and $\xi_i = O_{k\times r}$ for $i > m$. The likelihood ratio statistics are employed to test these hypotheses, $LR_T^{tvc} = -2\left[\hat{l}_T(r,0) - \hat{l}_T(r,m)\right]$, where the restricted model takes $\xi' = \left(\beta', O_{r,k.m}\right)$ and is asymptotically distributed as a chi-squared, χ^2_{rmk}.

5. Empirical results

5.1. Linear cointegration test results

We begin by using the Johansen cointegration test to determine whether there is a long-run linear relationship in Turkey's oil demand function. The test findings in Table 3 confirm the presence of cointegration between the variables of the oil demand function and that there are at most two cointegrating vectors according to λ_{trace} and λ_{max} at five percent level of significance.

Table 3. Johansen Cointegration test Results

H_0	H_1	Eigenvalue	Trace or Max-Eigen Statistic
Trace Test			
r = 0	r ≥ 1	0.168	43.745*
r ≤ 1	r ≥ 2	0.137	22.651*
r ≤ 2	r ≥ 3	0.049	5.815
Maximum Eigenvalue Test			
r = 0	r = 1	0.168	21.093**
r ≤ 1	r = 2	0.137	16.835*
r ≤ 2	r = 3	0.049	5.815

Note: * & ** Denotes rejection of the hypothesis at the 0.05 or 0.10 level, respectively.

After the confirmation of linear cointegration, we normalize the long-run income and price elasticities obtained from the Johansen technique. Based on this transformation the long-run income and price elasticities are obtained as 0.490 and 0.083, respectively. Turkish oil demand is inelastic with respect to both income and price, as the estimated parameters are less than unity in absolute value. The real income elasticity has an expected sign and is statistically significant at the 1% level, whereas the real price elasticity has an unexpected sign but is statistically insignificant. The inelasticity of oil demand parameters may be explained by Turkey's dependence on imports to meet domestic demand due to the lack of domestic oil supply. Additionally, the evidence on the significance of income has a significant and higher elasticity than price implies that Turkish oil demand is predominantly driven by income changes.

5.2. Cointegration with structural breaks test results

After the implementation of linear cointegration, Gregory and Hansen (1996), and Hatemi-J (2008) tests are employed to investigate long-run relationship among the variables in the oil demand function under the presence of structural breaks. Table 4 reports the results of cointegration test with structural breaks. According to Z_t^* and Z_a^* statistics of Gregory and Hansen (1996) where only one structural break is allowed, the null hypothesis of no cointegration is rejected in all specifications. Furthermore, the results of the Hatemi-J test reveal that the null hypothesis of no cointegration is rejected according to the three statistics ADF^*, Z_t^*, and Z_a^*.

Table 4. Cointegration test results with structural break

(a) Gregory and Hansen (1996)					
Model	ADF^*	Breakpoint	Z_t^*	Z_a^*	Breakpoint
C	-3.60	2004:Q4	-4.75*	-42.74*	1994:Q1
C/T	-3.75	2004:Q4	-5.33**	49.27*	2008:Q4
C/S	-4.13	2004:Q4	-6.63***	-66.52**	2002:Q4
C/S/T	-4.52	2009:Q1	-6.86***	69.49**	2002:Q4

(b) Hatemi-J (2008)			
Test statistic	Test Value	First breakpoint	Second breakpoint
ADF^*	-10.723***	1995:Q1	2006:Q4
Z_t^*	-10.950***	1995:Q1	2006:Q2
Z_a^*	-118.931***	1995:Q1	2006:Q2

Notes: The lag length is determined via AIC. *, ** and *** indicate rejection of the null hypothesis at 10%, 5% and 1% level respectively. Asymptotic critical values are obtained from Gregory and Hansen test (1996) and Hatemi-J (2008).

The timespan covered in this article includes a number of local and foreign economic events that had an impact on Turkish macroeconomic indicators as well as the volatile movements in oil prices. The importance of certain structural breaks derived from cointegration tests has also demonstrated the impact of these developments. For example, Gregory and Hansen's (1996) test finds a structural break in model (C) that correlates to the 1994 Turkish financial crisis and the 2008 global financial crisis in model (C/T). However, according to, Z_t^* and Z_a^* statistics, the structural break occurs in the C/S and C/S/T models in the aftermath of the 2001 financial crisis. Meanwhile, according to the three statistics, the first structural date in the Hatemi-J test (2008) occurred in the first quarter of 1995, possibly as a consequence of the 1994 financial crisis.

Overall, the findings of the two tests show that structural breaks have a significant impact on the oil demand function of Turkey. This conclusion supports the use of approaches that enable long-run coefficients to evolve, such as TVC methodology.

5.3. Time-varying cointegration test results

Before the elasticities are estimated, the time-invariant hypothesis of elasticities is investigated, and then if this hypothesis is rejected, the time-varying elasticities are estimated in the long run.

Table 5. Time-varying cointegration test results

M	r = 1	r = 2	r = 3
1	-8.07	-8.66	-8.86
2	-8.06	-8.61	-8.81
3	-8.11	-8.65	-8.85
4	-8.08	-8.56	-8.69
5	-8.14	-8.64	-8.75
6	-8.15	-8.67	-8.76
7	-8.15	-8.81	-8.91
8	-8.11	-8.70	-8.74
9	-8.33	-8.92	-9.02
10	-8.29	-8.96	-9.05
11	-8.31	-8.91	-8.93
12	-8.25	-8.88	-8.91
Min m	9	10	10

Table 5 displays the TVC results of Bierens and Martins (2010) for alternative number of Chebyshev time polynomials, where *r* represents the number of cointegration relationships while m refers to the number of polynomials. Based on the Hannan-Quinn information criterion, the length of the time polynomials is determined. According to the LR_T^{tvc} test, the null hypothesis of the time-invariant cointegration against TVC is rejected for 1 to 3 cointegration vectors. Besides, there is robust evidence for the long-run time-varying relationship in selecting various numbers of lags determined by other information criteria.[2]

Figure 3 illustrates plots of the long-run time-varying income and price elasticities after finding significant evidence in support of time-varying cointegration. Time-varying elasticities are displayed with their two standard error bands in order to assess their significance throughout the study period. Panel (a) of Figure 3 depicts the time-varying income elasticity (β_1) of the study period. The empirical findings show that income elasticity is statistically significant throughout the study period. Furthermore, the sign of the elasticity is positive for the whole period, which is consistent with theoretical predictions. The average income elasticity is estimated as 0.862, with a standard deviation of 0.102 over the period.

[2] Other information criterion findings are not presented in the article, but they are accessible upon request from the authors.

Consequently, income elasticity (average) is inelastic in the Turkish economy, but it is close to unity.

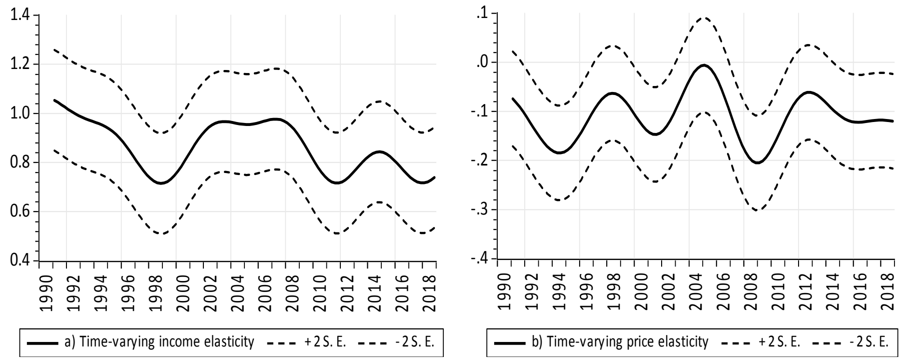

Figure 3. Time-varying income and price elasticities of oil demand

Income elasticities follow a moderately stable pattern and are close to unity at the beginning of the study period, indicating that rising real income leads to a proportionate rise in oil demand. However, income elasticity has declined dramatically from 1.052 percent in 1991 to 0.714 percent in 1998. This might be attributable to the contractionary effects of economic crisis, e.g. 1998 Russian crisis and 2001 Turkish financial crisis, on the economic activity. Income elasticity remains stable around unity between 2002 to 2008 compared to the rest of the period. After that time, it is declined to around 0.75 percent by the end of 2010. It is also noteworthy that 2008 global financial crisis seems to create fluctuations in the income elasticity. Our estimates in general suggest that oil can be considered as a necessary commodity for the consumers in Turkey. It is also worth noting that global and local events that cause economic activity to contract appear to have a significant impact on time-varying income elasticity.

Panel (b) of Figure 3 illustrates the time-varying price elasticities (β_2) obtained through TVC methodology. It is notable that the estimated price elasticity is lower in terms of magnitude and less significant than the income elasticity, implying that oil demand is more responsive to income changes compared to prices. The average value of price elasticity is estimated as -0.111 reaching the maximum with -0.005 in 2005 and the minimum value -0.204 in 2009 with a standard deviation of 0.048 (see Table 6). As shown in panel (b), the price elasticity does not follow a stable path, and it is negative and less than one in terms of absolute value for the whole study period. This implies that the oil demand is not elastic with respect to oil prices in the Turkish economy. Furthermore, the price elasticity is significant only for specific periods, i.e., 1992-1997, 2000-2003, and 2007-2011. Since the elasticity coefficients are less than one, oil can be treated as an ordinary good in Turkey. The empirical results also indicate that change in elasticity is closely associated with the fluctuations in oil prices. For example, price elasticity of oil demand decreased from the maximum value in 2005 to its minimum in 2009. This could be related to the sharp rise in oil prices from 2005 to 2008 as a result of the global economic expansion.[3]

Finally, the evidence on the price inelasticity of oil demand can be explained by the Turkish economy's strong dependence on oil and oil products and the lack of substitute as oil is an indispensable commodity. Furthermore, the time-varying price elasticity is more unstable during the analysis period, and this may imply that the domestic oil market is very sensitive to the fluctuations of the global oil market compared to other events.

Table 6. Descriptive statistics for the estimated time-varying elasticities

Elasticity	Mean	Median	Max.	Min.	Std. Dev.
β_1	0.862	0.850	1.052 (1991:Q1)	0.714 (1998:Q4)	0.102
β_2	-0.111	-0.117	-0.005 (2005:Q1)	-0.204 (2009:Q1)	0.048

6. Conclusion and policy implications

This study presents new evidence for estimating the oil demand elasticities over time for Turkey. That is, determining the effect of changes in real income and the real price on the oil demand. To this end, we employed the TVC methodology proposed by Bierens and Martins (2010) by using quarterly data covering the period 1990: Q1-2018: Q4.

The linear cointegration test results corroborate the presence of the long-run relationship among the variables. However, Gregory and Hansen (1995) and Hatemi-J (2008) tests allowing for endogenous structural breaks indicate that structural breaks caused by local and global events at that time cause significant parameter instabilities in the oil demand. As a result, we argue that methods based on the assumption of cointegration relationship stability may lead to erroneous inferences about the precise estimation of elasticities in the oil demand equation.

The TVC test findings based on Bierens and Martins (2010) corroborate the time-varying pattern in the long-run oil demand function. The results show that income elasticity is significant and estimated as less than one excluding in the early period of 1990. The price elasticity of oil demand is inelastic for the entire analysis period, and it is statistically insignificant for the vast majority of the analysis period. Although both income and price elasticities evolve over time, it is observed that price elasticity follows a more volatile trajectory. The evidence on the inelasticity of oil demand with respect to income supports the identification of oil as a necessary commodity. The findings further indicate that income fluctuations have a more significant impact on oil consumption than price changes. The results regarding inelastic income and price align with those of Abu Eleyan et al. (2021) for the BRICS, Ziramba (2010) for South Africa, Sa'ad (2009) for Indonesia, and

[3] The average global oil price grew from roughly US$ 53.3 in 2005 to about US$ 96.7 in 2008 per barrel, representing an 81.1 percent rise.

Altinay (2007), and Kavaz (2020) for Turkey. The results, on the other hand, vary with prior studies. For instance, Kim and Beak (2013) show that oil demand is income elastic but price inelastic in South Korea. Meanwhile, Jebran et al. (2017) and Marbuah (2017) demonstrate that oil demand in the Pakistani and Ghanaian economies is elastic in terms of both income and price.

The empirical findings have important implications for designing efficient oil market policies. The evidence on the inelasticity of oil demand with respect to income and prices reveals the dependency on oil products, as consumers demand oil regardless of price or income changes. As a result, the only strategy to minimize this reliance appears to cut the oil import demand of Turkey. Given that oil demand is inelastic with respect to prices, controlling the price of oil products by the imposition of a special consumption tax might not be considered as an efficient method of reducing oil demand. As a result, the government should implement policies that encourage indigenous production and increase energy generation from renewable sources. Policies aimed at reducing oil demand should be also centered on transportation, as this sector consumes approximately 70.58 percent of oil as of 2018 (IEA, 2021). To reduce oil consumption in the transportation sector, one could consider promoting fuel-efficient vehicles such as hybrid and electric cars and investing in public transportation to provide affordable alternatives to private vehicles. As the International Energy Agency has underlined, reducing the share of fossil fuels in the energy mix would also contribute to achieving the net-zero emissions target of 2050 necessary to keep global warming under control.

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