Gasoline Demand Elasticities at the Backdrop of Lower Oil Prices: Fuel-Subsidizing Country Case

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Abstract: This study investigates the income and price elasticities of gasoline demand for a fuel subsidizing country case, applying three different time-varying coefficient approaches to the data spanning the period from January 2002 to June 2018. The empirical estimations concluded a cointegration relationship between gasoline demand, income, and gasoline price. The income elasticity found ranges from 0.10 to 0.29, while the price elasticity remains constant over time, being −0.15. Income elasticity increases over time, slightly decreasing close to the end of the period, which is specific for a developing country. In the short run, gasoline demand does not respond to the changes in income and price. The policy implications are discussed based on the findings of the study. Research results show that since the income elasticity of demand is not constant, the use of constant elasticities obtained in previous studies might be misleading for policymaking purposes. An increase in income elasticity might be the cause of the inefficiency of the existing vehicles. The small price elasticity allows to say that if policy makers plan to reduce gasoline consumption then increasing its price would not substantially reduce the consumption. The current situation can be utilized to increase energy efficiency and implement eco-friendly technologies. For this purpose, the quality of existing transport modes can be improved. Meanwhile, to meet households' needs, policies such as providing soft auto loans need to be formed to balance the recent drop in car sales.

Keywords: gasoline demand modeling; time-varying income and price elasticities; oil-prices; Azerbaijan; MIS; STSM

1. Introduction

Estimation of energy demand has received growing attention in a global context. In particular, the impacts of disposable income of households and gasoline price are widely scrutinized. The elasticities of gasoline demand are used to measure the responsiveness of gasoline consumption to changes in income and gasoline prices. For example, an elasticity value of −0.5 means that for every 1 percent increase in the price of gasoline, gasoline consumption falls by 0.5 percent. In terms of income, an elasticity value of 0.5 means that for every 1 percent increase in income, gasoline consumption increases by 0.5 percent. Income and price elasticities of demand for petroleum products are of great importance for policymakers to manage and forecast demand and evaluate policies

aimed at environmental protection. Nonetheless, the estimation of energy demand in oil-exporting countries has received little attention in the literature. Within the framework of limited-resource settings, the estimation of the elasticities is particularly indispensable for policymakers of oil-rich and fuel-producing countries to forecast energy demand and plan required refining capacity to meet future consumption.

In their development paths, oil-rich countries have experienced growing standards of living and a high degree of urbanization, which has resulted in an increase in gasoline consumption. However, the income is endangered if the country's economic growth is mainly driven by oil exports and is vulnerable to oil price shocks, which cause the fluctuations of income-determining macroeconomic variables such as GDP, unemployment, inflation, exchange rate, and credit by the government for households and transportation.

Meanwhile, gasoline prices also tend to be volatile due to several factors such as demand for refinery for crude oil, demand/supply shifts, government taxes, and fuel specifications. Theoretically, change in gasoline prices is proportional to changes in the refinery's production costs resulting from oil price fluctuations. Oil-producing countries (particularly, gasoline producers) have historically preserved fuel subsidies because they treated natural resources like crude oil as a national property [1] (For more information on fossil-fuel consumption subsidies by country see: [2]). Therefore, the price elasticity of gasoline demand in oil-rich and fuel-subsidizing countries may be more inelastic than that in other countries due to a relatively lower price of domestically produced fuel [1]. From these debatable points of view, estimation of price and income elasticities of demand for gasoline in oil-rich countries becomes of great importance for policymakers.

Azerbaijan is an oil-rich country, and oil export constitutes 86% of its total exports [3]. Azerbaijan experienced surging oil prices until 2008–2011 (with a drop in 2009, attributed to the 2007–2008 global financial crisis) and its oil revenue reached pick level in 2006. Meanwhile, Azerbaijan produces and exports AI-92 gasoline (previously known as AI-93), and imports AI-95 and AI-98 brand gasoline (since 2005). During the period of increasing high oil prices, until 2008, the price of AI-92 gasoline showed an upward tendency, increased from 0.31 AZN (0.35 $) per liter in 2000 to 0.36 AZN (0.40 $) in 2006 and 0.55 AZN (0.64 $) in 2007 [3]. Azerbaijan's oil revenue as a percentage of GDP reached an all-time high of 39% in 2006, and the highest share of oil export in total exports reached an all-time high of 96% in 2008 (when the price of Azerbaijani light oil reached $149 per barrel). However, the share of oil rents in GDP showed a diminishing tendency due to the gradually declining growth rate of crude oil prices and Azerbaijan's oil reserves, and the government's policy to gradually lower oil production, starting in 2011, in order to decrease the dependency of the economy on the oil industry and minimize risks associated with sharp output decline.

As to the government's fossil fuel subsidies, they grew on average 2.8 percent per year during 2011–2013, which decreased by 7.22 percent in 2014 due to the sharp decline in oil prices affecting natural resource revenue and GDP of Azerbaijan negatively. During the recovery period of 2015–2018, government subsidy grew by 4.8 percent per year [4] (Average subsidization rate in Azerbaijan is 43%, subsidy per person is 190 $, and total subsidy as share of GDP is 4% (Source: [3])).

Nevertheless, the price of gasoline remained fixed at around 0.55 AZN during the period of 2007–2013 [3]. In spite of the increasing price of gasoline, the level of consumption amplified steadily in 1999–2014 and seemed to have an inelastic price elasticity, and to be less responsive to positive and negative oil price shocks between 2000–2008, gasoline consumption grew at an average annual rate of 16.6% and the number of motor vehicles grew at an average annual rate of 8.86% (private passenger cars at 9.78%), reflecting the growth of the economy and limited responsiveness of demand to price changes [3]. In the subsequent period, the growth rate of consumption slowed to an average annual rate of 6.4% in 2009–2014, and the average annual growth rate of motor vehicles declined to 7.02% (private passenger cars at 7.8%) due to the reduction in oil revenue and the growth rate of GDP per capita (although the AI-93 gasoline price was fixed at 0.55 AZN in this period). It is also worthwhile to stress that the AI-93 gasoline price reached 0.80 AZN (0.42 $) in 2018 and then 0.90 AZN

(0.47 $) in 2020. The average price of gasoline in the world is 1.02 $. There is substantial difference in these prices among countries depending on their economic development levels (rich countries have higher prices and poor countries and oil producing and exporting countries have lower prices). Under normal circumstances, in addition to the above-mentioned determinants of gasoline price (economic development, demand/supply shifts, government taxes and subsidies) geopolitics also would exert price pressure on fuel prices. In Azerbaijan, prices are determined by Tariff (price) Council of the Republic of Azerbaijan. The price of gasoline in Azerbaijan is far below those in the majority of neighboring countries (for example: 0.70 $ in Georgia, 0.61 $ in Russia, 0.69 $ in Belarus, 0.91 $ in Turkey, 0.63 $ Iraq, and 0.86 $ in Ukraine) [5].

Considering all the above-mentioned facts, the purpose of the current study is to develop a model for gasoline demand in the case of Azerbaijan, studying the varying nature of the responses of demand to its main drivers. The paper dedicates attention to evaluating the extent to which the crisis has influenced the income and price elasticities in Azerbaijan due to the reduction of disposable income and an increase in gasoline prices.

This study is the first attempt to estimate the income and price responsiveness of demand for gasoline in Azerbaijan. The reviewed literature indicates that no research has been conducted in this direction in the case of Azerbaijan, utilizing country-specific time series data. If the country-specific parameters are not evaluated, then the estimated elasticities represent the average responses, which might not be an appropriate representative for a country-specific characteristic. Therefore, utilizing time-varying coefficient cointegration approach (TVCC hereafter) proposed by Park and Hahn [6], the aim of this paper is to fill in this gap by investigating the main determinants of gasoline demand in the case of Azerbaijan, being one of the oil-rich developing countries endowed also with abundant renewable energy resources that make it a distinct case for this research.

The results of the paper are crucial for economic policymakers to develop proper policies in favor of sustainable energy demand. It will also be a needed condition for an accurate assessment of the effect of energy, environmental and fiscal policies on gasoline prices [7,8]. It will elucidate the impacts of other widespread economic crises on gasoline demand. In this regard, we deem necessary to highlight the recent COVID-19 crisis, which seems to reform energy markets worldwide. The progressing economic stoppage is intensified by the unstable behavior of oil prices and the destruction of global energy demand. Likewise, the COVID "crisis" has already harmed overall energy supply chains. To soften harmful effects of pandemic, almost all states have already taken appropriate procedures to lower energy use or make consumption of energy rational. Another issue the recent pandemic triggered is an access to renewable energy resources. Therefore, the current crisis signifies finding ways for secure energy sources. This requires launching appropriate procedures to attain energy transition combined with high-tech innovations [9].

The rest of the paper is structured as follows: The literature review is discussed in Section 2. Theoretical Framework and Functional Specification are provided in Section 3. Section 4 defines the methodology. Section 5 depicts the data used. Section 6 presents estimations results. Section 7 discusses the findings, while Section 8 concludes and suggests policy implications.

2. Literature Review

The current section reviews the studies dedicated to the illustration of how gasoline demand is related to price, income, and other variables. Additionally, we review research papers based on time series and panel data analysis conducted for both developed and developing countries (including Azerbaijan). Table 1 summarizes the findings of the reviewed studies. As can be seen from the table, a great variation in the results of these studies is observed due to the time span of the data, specification of demand (functional form and variables included), and econometric approach.

Table 1. Summary of the relatively recent studies.

Study	Country/Country Group	Period	Data Type	Methodology	Price Elasticity		Income Elasticity	
					SR	LR	SR	LR
Totto and Johnson [10]	OPEC	1970–1979	T/A	MOLS	n/a	−0.09	n/a	1.02 to 1.26
Al-Sahlawi [11]	KSA	1970–1985	T/A	OLS/PAM	−0.08	−0.67	0.11	0.92
Al-Faris [12]	KSA	1970–1990	T/A	OLS/PAM	−0.08	−0.30	0.02	0.07
Eltony [13]	GCC	1975–1989	T/A	CFE /PAM	−0.09 to −0.11	−0.11 to −0.13	0.21 to 0.41	0.23 to 0.48
Eltony [14]	GCC	1975–1993	T/A	CFE /PAM	−0.11	−0.17	0.31	0.48
Al-Faris [15]	KSA	1970–1991	T/A	OLS/PAM	−0.09	−0.32	0.03	0.11
Al-Sahlawi [16]	KSA	1971–1995	T/A	OLS/PAM	−0.16	−0.80	0.30	1.50
Alves et al. [17]	Brazil	1974–1999	T/A	OLS/ECM	−0.09	−0.46	0.122	0.12
Cheung and Thomson [18]	China	1949–1999	T/A	VECM	−0.19	−0.56	1.64	0.97
De Vita et al. [19]	Namibia	1980–2002	T/Q	ARDL		−0.79		0.96
Polemis [20]	Greece	1978–2003	T/A	VECM	−0.10	−0.38	0.36	0.79
Akinboade et al. [21]	South Africa	1978–2005	T/A	ARDL		- 0.47		0.36
Chakravorty et al. [22]	KSA	1972–1992	T/A	OLS/PAM	−0.08	−0.52	0.10	0.66
Crotte et al. [23]	Mexico	1980–2006, 1993–2004	T/A and P	GMM, OLS, FMOLS	−0.06 (OLS), −0.10 (FMOLS), −0.15 (GMM)	−0.06 (OLS), −0.29 (FMOLS), −0.39 (GMM)	0.78 (OLS), 0.43(FMOLS), 047 (GMM)	0.76 (OLS), 0.53(FMOLS), 1.19 (GMM)
Park and Zhao [24]	U.S.	1976 −2008	T/A	TVCC		−0.42 (M1), −0.66 for (M2).		0.48 for (M1), 0.57 for (M2).
Liddle [25]	14 OECD Countries	1978–2005	P/A	Panel DOLS and FMOLS, Panel Granger-causality	−0.16	−0.43	0.28	0.34
Neto [26]	Switzerland	1973: Q1 to 2010: Q4	T/Q	FMOLS/TVC	−0.17		0.69	
Dahl [27]	Panel of 120 countries, AZE included	Different time intervals	T/A and P	Review of previous studies (In some cases, the author employed different techniques to find the missed elasticities.)	n/a	−0.22 (AZE)	n/a	1.27 (AZE)
Coyle et al. [28]	U.S.	1990–2009	T/Q	OLS, 3SLS	−0.08	−0.06 [a], −0.08 [b]	0.41	0.36 [a], 0.46 [b]
Ben Sita et al. [29]	Lebanon	2000:M1–2010:M12	T/M	Structural breaks	−0.62	−0.30	0.31	1.14
Sene [30]	Senegal	1970 to 2008			−0.12		0.46	
Al Yousef [31]	THE KSA	1980–2010	P/A	Panel FMOLS & DOLS	n/a	−0.28 to −0.36	n/a	0.55 to 0.56
Burke and Nishitaten [32]	132 countries	1995–2008	P/A	PPOLS	n/a	−0.5 to −0.2	n/a	0.95 to 1.10
Baranzini and Weber [33]	Switzerland	1970–2008	T/Q	ECM	−0.09	−0.34	0.03	0.67
Lin and Prince [34]	USA	1990−2012	T/M	OLS	−0.07 to −0.03	−0.29 to −0.24	0.03 to 0.27	0.23 to 0.27
Ackah and Adu [35]	Ghana	1971–2010	T/A	STSM	−0.01	−0.07	0.713	5.13
Scott [36]	29 countries	1990–2011	P/A	FE 2SLS, PMGE	−0.05 to −0.20	−0.74 to −0.19	0.25 to 0.28	0.82 to 1.09
Arzaghi and Squalli [1]	32 fuel-subsidizing Countries, AZE included	1998–2010	P/A	CFE, RE, FE /PAM	−0.05	−0.25	0.16	0.81

Table 1. *Cont.*

Study	Country/Country Group	Period	Data Type	Methodology	Price Elasticity		Income Elasticity	
					SR	**LR**	**SR**	**LR**
Hössinger et al. [37]	Austria	2002M10–2011M12	T/M	OLS		−0.14		0.18
Atalla et al. [38]	KSA	1981–2015	T/A	STSM	−0.09 to −0.10	−0.15 [c], −0.09 [d]	insignificant	0.15, 0.62
Mikayilov et al. [39]	KSA	1980–2017	T/A	TVCC	−0.13	−0.31 to −0.05	insignificant	0 to 0.15
Mousavi and Ghavidel [40]	Iran	1980–2016	T/A	STSM	n/a	−0.24 to −0.17	n/a	0.38 to 0.48
Mikayilov et al. [41]	Russia	2002Q1–2018Q1	T/Q	DOLS, FMOLS, CCR, STSM, TVCC	n/a	−0.17	n/a	0.78

Notes: OPEC = Organization of the Petroleum Exporting Countries; T/A = annual times series; T/Q = quarterly time series; T/M = monthly time series; OLS = Ordinary Least Squares Method; MOLS = Modified OLS; FMOLS = Fully Modified OLS; DOLS = Dynamic OLS; PAM = Partial Adjustment Model; P = panel; CFE = Country Fixed Effects; P = panel; TVC = time varying coefficient approach TVCC = time varying coefficient cointegration approach; VECM = vector error correction method; ARDL = autoregressive distributed lagged model; GMM = generalized method of moments; 3SLS = 3 stage least squares method; FE 2SLS = fixed effect 2 stage least squares method PPOLS = Pooled panel OLS; PMGE= pooled-mean-group estimator; ECM = error correction model. [a] with no economic controls; [b] with macroeconomic controls; [c] with GDP; [d] with non-oil GDP; KSA = Kingdom of Saudi Arabia.

Relatively recent studies, after 2010, concluded that the long-run price elasticity of gasoline demand ranges from −0.66 to −0.2. However, Crotte et al. [23], Coyle et al. [26], Dahl [27], Hössinger et al. [37], and Atalla et al. [38] concluded that the price elasticity varies around −0.1. Based on the same studies, the long-run income elasticity ranges from 0 to 5.13.

The literature survey can be summed up as follows: (a) Park and Zhao [24], Neto [26], Mikayilov et al. [39], Mousavi and Ghavidel [40], and Mikayilov et al. [41] investigated the time-varying features of elasticities; (b) the surveyed papers showed that, the long-run income elasticity of demand for gasoline changes between 0.00 and 1.50 (except Ackah and Adu [35] for the Ghana case, being unexpectedly high, 5.13); (c) while the interval for long-run price elasticity is from −0.80 to −0.05; (d) Gasoline demand has not been studied for Azerbaijan case, using country-specific time series data to see idiosyncratic features of the relationship.

3. Theoretical Framework and Functional Specification

Following widely used conventional specification, we treat per capita gasoline demand as a function of gasoline price and income in per capita terms. To be precise we use the following specification:

$$g_t = \alpha_0 + \alpha_1 i_t + \alpha_2 p_t + \varepsilon_t \tag{1}$$

where g_t, i_t and p_t are gasoline demand and income, both in per capita terms, and real gasoline price, respectively. The used variables are expressed in a logarithmic scale. α_1 and α_2 are coefficients to be estimated econometrically, and ε_t is error term. From the time when the explanatory variables in (1) change/evolve over time, one can expect that the elasticities of gasoline demand to the variations in the drivers will differ over time. The sources of the changes might be newly initiated policies, structural changes etc. In comparison with model (1), the model with parameters evolving over time can consider the variability of elasticity. The use of this approach gains special importance when the parameters are time-varying, otherwise one can encounter with misleading regression results coming from misspecification error. Therefore, to avoid the abovementioned trap, this study utilizes a time-varying parameter approach. Considering the time-varying feature of the coefficients, Equation (1) can be re-written as below:

$$g_t = \alpha_0 + \alpha_{1t} i_t + \alpha_{2t} p_t + \varepsilon_t. \tag{2}$$

In our empirical estimations, Equation (2) will be utilized as a functional specification.

4. Econometric Methodology

This research paper utilizes the Time-Varying Coefficient Cointegration approach (TVCC hereafter) suggested by Park and Hahn [6] as a main tool. For robustness check the Structural Time Series Modeling-STSM [42] and Multiplicative Indicator Saturation-MIS [43–45] approaches have been employed. These approaches nest the fixed/constant coefficient case as a special case. Furthermore, these approaches enable us to test the coefficients for time-variation. The TVCC approach uses Fourier Flexible Forms (FFF) to "catch" the behavior of the varying coefficient, STSM does it using random walk parameters/coefficients, return to normality model and spline function approaches [42], while the MIS approach utilizes multiplicative step dummies methodology. Since the TVCC and STSM techniques are used in a number of papers and described in detail we will not explain them here. Harvey [6], Koopman et al. [46], Commandeur and Koopman [47], and Mikayilov et al. [48] for STSM, Park and Hahn [6], Chang et al. [49], Mikayilov et al. [39] for TVCC can be referred to for details. While the MIS approach is used only in a few studies. Hence it is briefly described below. For further details on the MIS Ericsson [43], Castle et al. [44], and Castle and Hendry [45] are valuable sources to be referred.

The TVCC estimations have been performed using programming features of *Eviews 11* software.

The STSM estimations are done utilizing the 8.40 version of STAMP by Koopman, Lit, and Harvey [50].

Multiplicative Indicator Saturation (MIS) Approach

In the multiplicative-indicator saturation approach, each variable in a candidate set is multiplied by step indicators assigned to each observation [43] to see whether there is a change in the corresponding variable's coefficient. As an example, with four regressor variables and a sample size of 50, there will be 200 candidates to select from. Kitov and Tabor [51] examined the properties of the MIS using simulations and observed that the technique can reveal shifts in regression parameters regardless of the huge number of candidate variables. Castle et al. [44] applied this approach to detect potential shifts followed by a policy intervention. A multi-path block search model selection algorithm, *Autometrics* [52,53], allows us to search relevant variables/terms even when the number of variables is substantially bigger than the number of regressors.

The functional specification with one regressor can be expressed as below:

$$y_t = \alpha_0 + \sum_{t=1}^{n} \alpha_t * I : t + \sum_{t=1}^{n} \beta_t * S1 : t + \gamma_1 * x_t + \sum_{t=1}^{n-1} \delta_t * S1 : t * x_t + \varepsilon_t \tag{3}$$

where y_t and x_t are variables, $\alpha_i, \beta_i, \gamma_i, \delta_i$'s are coefficients to be estimated. $I : t$ is impulse dummy taking 1 for time point t and 0 otherwise, $S1 : t$ is step dummy being 1 up to time period t and 0 after that time point. Second and third terms at the right-hand side of Equation (3) are added to capture whether there are some one-time (impulse) changes and location shifts (step) in the constant term of the model. The search of impulse and step dummies is also performed using *Autometrics*.

The MIS estimations have been performed using OxMetrics 8.10 software.

5. Data

This study uses monthly (seasonally adjusted) time series data. Gasoline demand data is taken from the Joint Organizations Data Initiative Oil-Jodi [54]. GDP and price data are taken from booklets of the Central Bank of Azerbaijan Republic- CBAR [55], and the State Statistical Committee of the Republic of Azerbaijan [3], respectively. Data span is from 2002M01 to 2018M06. Gasoline demand and income data have been converted to per capita terms, and CPI data is used to express price in real terms. Population and CPI data have been obtained from the State Statistical Committee of the Republic of Azerbaijan [56] and CBAR [55], respectively.

Figure 1 presents the plots of the variables used in logarithmic form, while the differenced variables are sketched in Figure 2.
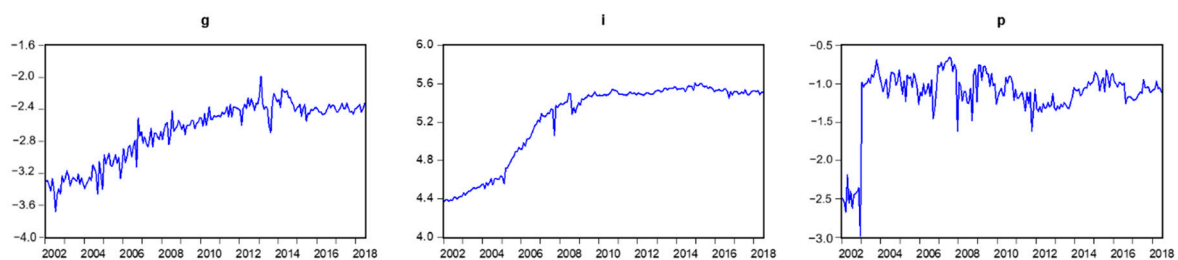
Figure 1. Plots of the variables (in logarithmic scale). notes: g, i, and p are gasoline demand and income, both in per capita terms, and real gasoline price, respectively.
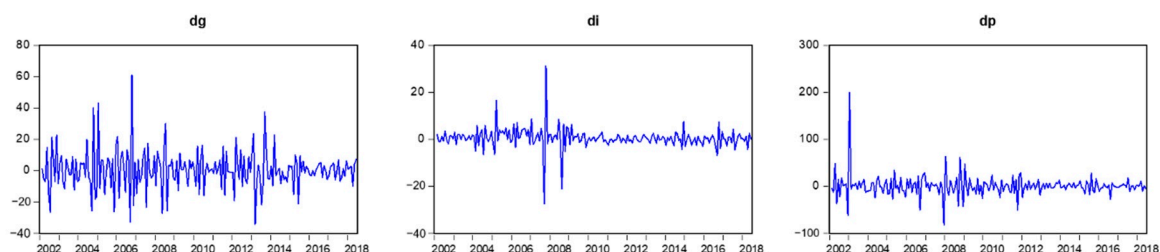
Figure 2. Plots of the differenced variables. notes: dg, di and dp are differenced gasoline demand and income, both in per capita terms, and real gasoline price, respectively. d is difference operator.

6. Empirical Estimation Results

6.1. Unit Root Test Results

In line with the conventional procedure, we first test the variables for unit root properties. For this purpose, the Elliott-Rothenberg-Stock DF-GLS (ERS) [57] and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) [58] tests are employed. The null hypothesis for ERS test is that the series are non-stationary, while the null of KPSS states the opposite. The tests' results are presented in Table 2, and as can be seen, one can conclude that all the variables are integrated of the first order. Since based on the plot the price variable might seem to be stationary, we tested it using a unit root test with a structural break [59]. The test concluded that it is stationary with a break around 2002M12 in level form. These results are contradicting to ERS and KPSS tests' results. However, since there is a potential cointegration relationship between gasoline demand and income variable, the inclusion of stationary variable into the cointegrated relationship (the linear relationship of two non-stationary variables, which is stationary) does not alter the findings. In addition, the TVCC "technique is robust to included stationary variables" [49]. Since at least two of the variables of interest are integrated of the same order they can be tested for the common long-run trend–cointegration.

Table 2. Unit root tests' results.

	Elliott-Rothenberg-Stock DF-GLS Test (ERS)				Kwiatkowski-Phillips-Schmidt-Shin Test	
	Variables	**Level**	**k**	**First Difference**	**k**	**Level**	**First Difference**
Intercept	g_t	0.021	2	−17.413 ***	1	1.530 ***	0.181
	i_t	1.048	1	−2.448 **	6	1.392 ***	0.572 *
	p_t	−0.486	2	−19.878 ***	0	0.253 ***	0.202
Intercept and trend	g_t	−2.117	2			0.439 ***	
	i_t	0.048	2			0.415 ***	
	p_t	−1.388	2			0.156 *	

Notes: For ERS test optimal lag order (k) is selected based on Bayesian info criteria, setting the maximum lag to eight; rejection of the null hypotheses at the 1%, 5% and 10% significance levels expressed by ***, ** and *, respectively; The MacKinnon [60] critical values have been used. Kwiatkowski–Phillips–Schmidt–Shin [58] critical values are from their paper.

6.2. Long and Short-Run Estimation Results

6.2.1. TVCC Estimation Results

Before conducting the cointegration exercises, following the methodology we should choose the relevant model based on the Schwarz information criterion (SIC), that is, the optimal number for polynomials (p) and trigonometric pairs (q) should be chosen for both coefficients. Using the maximum number for both, p and q, to be 2, and based on the SIC criteria for income coefficient the optimal number of p and q are $p = 2$ and $q = 0$. The price elasticity is found to be constant, that is its variation was insignificant. After modifying the data employing Canonical Cointegration

Regression (CCR) transformations considering the time-varying coefficient feature, we estimated the relationship using transformed data. Then we can test variables for the cointegration relationship calculating the Variable Addition Test-VAT [61] statistics. The cointegration test results are given in Panel A of Table 3. As the table demonstrates, the test statistics result is smaller than any critical value, which means there is enough evidence to conclude the cointegration relationship among the variables at any significance level.

Table 3. Cointegration and TVC Significance tests results.

	Panel A				Panel B	
	Variable Addition Test				TVC Significance Test	
	Test Statistics				Test Statistics	
	3.50				149.33	
	Critical Values					
1%	5%	10%	1%	5%	10%	
13.18	9.49	7.78	9.21	5.99	4.61	

Notes: Since we used four trend variables for VAT test the degree of freedom is 4; For TVC significance test p = 2, q = 0, df = p + 2q = 2; p is number of polynomials, and q is number of trigonometric pairs in TVCC specification, df is degree of freedom.

As a next step, the estimated elasticities need to be tested to see whether they are time varying. That is, the joint significance of the coefficients of polynomials and trigonometric functions should be tested. The results of the TVC's significance tests are presented in Panel B of Table 3. As can be seen from the table, the test statistics is greater than the critical values for any significance level. Hence, we conclude that the coefficient of income is time varying. The long-run estimations results are given in Table 4, and the time-varying income elasticity is depicted, with 99% confidence interval bands, in Figure 3. The estimated long-run income elasticity ranges from 0.10 to 0.29, while the long-run price elasticity is −0.15.

Table 4. Long-run estimation results.

		FC	Polynomials ($p = 2$)				FC	
	Chosen terms	1	$\frac{t}{T}$	$\left(\frac{t}{T}\right)^2$			1	
		Corresponding coefficients of the chosen terms						
		(intercept)	θ_0	θ_1	θ_2			
İncome	coefficients	−4.695	0.252	0.263	−0.177	Price	−0.15	
	p-values	(0.000)	(0.017)	(0.016)	(0.096)			

Notes: FC is fixed coefficient, which is coefficient of variable without TVC part; *p*-values are in parenthesis.
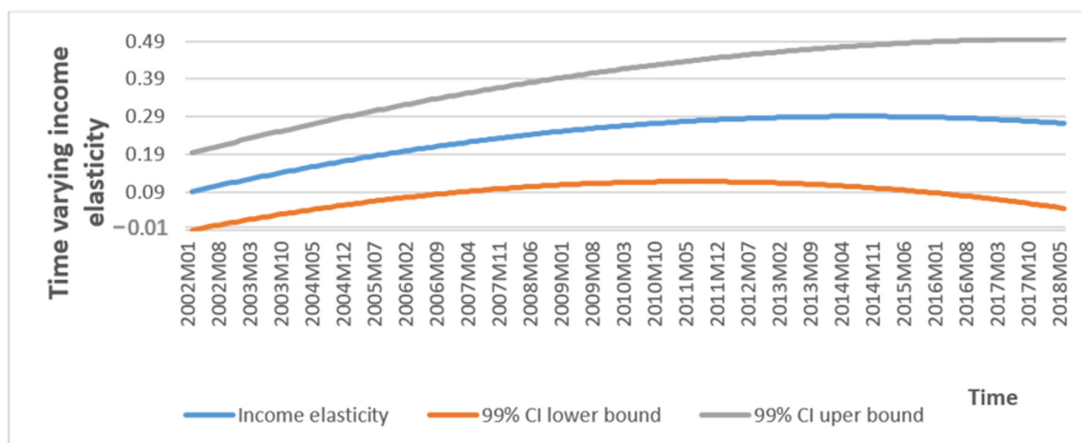
Figure 3. Time varying income elasticity: TVCC result.

Table 5 presents short-run estimations results where the error correction (ect) term comes from TVCC long-run equation. In this estimation, the *Autometrics* option of OxMetrics software is used following the *Gets* procedure. Assigning different type dummies, *Autometrics* allows to detect changes and location shifts in the short-run mean. As Table 5 presents, all diagnostic tests' results are in favor of the found final specification. The estimation results show that neither income nor price has a statistically significant impact on gasoline demand in the short run.

Table 5. TVCC short-run estimation results.

	ect(−1)	dp(−1)	Constant Term	R_Square	Sigma
	−0.726 [0.0000]	−0.090 [0.0000]	−0.7070 to 0.438	0.739	0.069
		Diagnostic tests' results			
AR test	ARCH test	Normality test	Hetero test	Hetero X test	RESET test
1.3743 [0.2192]	0.43057 [0.8822]	2.1657 [0.3386]	0.76945 [0.6301]	0.68131 [0.7252]	0.080982 [0.9222]

Notes: ect(−1) = lagged value of error correction term; dp(−1) = lagged value of differenced price; constant term = constant term of regression equation; sigma = regression standard error; AR test = Ljung and Box [62] test for autocorrelation; ARCH = autoregressive conditional heteroscedasticity test [63]; Normality test = Doornik and Hansen [64] test; Hetero test = White [65] heteroscedasticity test; Hetero X test = White [65] heteroscedasticity test using squares and cross-products; RESET = Ramsey [66] Regression Specification Test.

6.2.2. STSM Estimation Results

Before applying the STSM approach, the variables were tested for long-run co-movement using the Nyblom and Harvey [67,68] cointegration test. As can be seen from the left upper side of Table 6, only one eigenvalue is statistically different from zero, indicating one cointegration relationship among the variables. Like the TVCC method, the STSM also concluded constant price and time-varying income response. Testing different options, the income elasticity is modeled as random walk. The estimated long-run price elasticity is −0.12, while income elasticity ranges from 0.35 to 0.40.

The time-varying income elasticity found is plotted in Figure 4, with 95% confidence interval bands. Using different structures of time-series data, the so-called constant term is found to be time-varying, ranging from −0.75 to −4.46. Short-run estimation results from the STSM are given in Table 7.
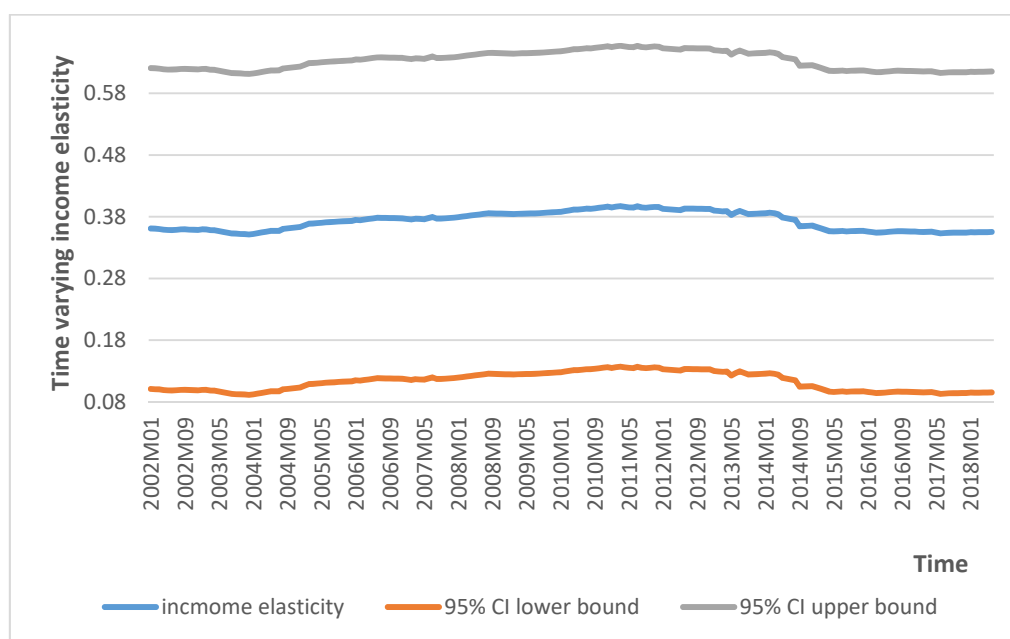
Figure 4. Time varying income elasticity: STSM result.

Table 6. STSM long-run estimation results.

	Eigenvalues		Price	Income	Constant Term	R_Square	Prediction Error Variance:
0.002466	2.71×10^{-19}	-8.470×10^{-22}	-0.117 [0.018]	0.350 to 0.397	-4.745 to -4.455	0.731	0.005
			Diagnostic tests' results				
	Normality 2.8288 [0.2431]	H(56) 0.40921 [0.9995]	Q(24) 22.617 [0.0000]	r(1) -0.128	r(24) -0.024	DW 2.211	

Notes: eigenvalues are for cointegration test (Nyblom and Harvey [67,68]; numbers in parenthesis are *p*-values; Normality stands for Jarque–Bera [69] test tor checking if residuals are normally distributed; H(k) denotes the unequal variance test for residuals; Q(q,q-p) shows autocorrelation test due to Ljung–Box Q test [62]; r(10) shows the Lagrange multiplier test to see if residuals are serially correlated [70]; aa = confidence interval for Lagrange multiplier test is (−0.143, 0.143), according to the used sample size [71].

Table 7. STSM short-run estimation results.

	ect(−1)	Dincome(−1)	Constant Term	R_Square	PREDICTION Error Variance:
	-0.784 [0.000]	0.397 [0.005]	-0.370 to 0.569	0.888	0.006
		Diagnostic tests' results			
Normality 1.6745 [0.4329]	H(56) 36.178 [0.0000]	Q(24) 36.178 [0.0527]	r(1) -0.053	r(24) 0.004	DW 2.099

Notes: ect(−1) = lagged value of equilibrium correction term; numbers in parenthesis are *p*-values; the Jarque–Bera [69] goodness-of-fit test is used for checking the normality; H(k) denotes the unequal variance test for residuals; Q(q,q-p) shows autocorrelation test due to Ljung–Box Q test [62] r; r(10) shows the Lagrange multiplier test for serial correlation [70]; aa = confidence interval for Lagrange multiplier test is (−0.143, 0.143), according to the used sample size [71].

In the short-run estimations, the ect term from the long-run STSM is used. The short-run estimations were also performed using the STSM approach. Like the TVCC, the results show that gasoline demand does not respond to price and income changes in the short run.
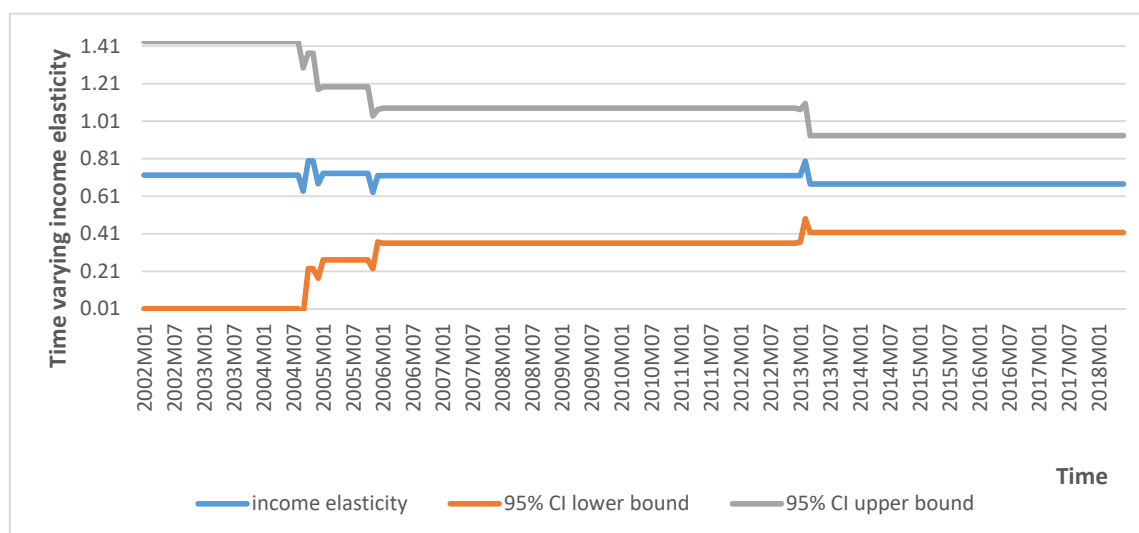
6.2.3. MIS Estimation Results

The MIS approach uses multi search algorithm utilizing *Autometrics*, assigning different types of dummies to each observation. To model the varying nature of coefficient, step dummies assigned for each observation are multiplied to the corresponding independent variable. Like the previous two approaches, the MIS also concluded constant price and varying income elasticities. The long-run estimation results obtained from using the MIS are given in Table 8. As can be seen from the upper left side of the table, the Banerjee et al. [72] cointegration test concludes the existence of the cointegration relationship among the variables.

Table 8. MIS long-run estimation results.

Cointegration Test	p	Income	Constant Term	R_Square	Sigma
−44.717 [0.0000]	−0.190 [0.001]	0.635 to 0.802	−7.448 to −5.760	0.962	0.119
Diagnostic tests' results					
AR test 1.5508 [0.1535]	ARCH test 0.59958 [0.7558]	Normality test 1.4682 [0.4799]	Hetero test 0.69356 [0.8144]	Hetero X test 0.69693 [0.8645]	RESET test 1.8727 [0.1568]

Notes: cointegration test is = Banerjee et al. [72] cointegration test; constant term = constant term of regression equation; sigma = regression standard error; AR test=Ljung and Box [62] test for autocorrelation; ARCH = autoregressive conditional heteroscedasticity test [63]; Normality test = Doornik and Hansen [64] test; Hetero test = White [65] heteroscedasticity test; Hetero X test = White [65] heteroscedasticity test using squares and cross-products; RESET = Ramsey [66] Regression Specification Test.

The income elasticity is depicted in Figure 5, with 95% confidence interval bands. The general behavior of all three elasticities found is similar, increasing at the beginning of the sample (up to around 2013–2014 in all three cases) and slightly declining close to the end.

Figure 5. Time varying income elasticity: MIS result.

6.2.4. MIS Short-Run Results

Short-run results from the MIS are given in Table 9. It also performed in OxMetrics like the long-run case. In short-run estimations the ect from the long-run MIS is used. The MIS also uncovered

that price and income do not have an impact on gasoline demand in the short run. The constant term of the model is found to be slightly varying, as in the STSM case. All diagnostic tests' results are in line with the requirements.

Table 9. MIS short-run estimation results.

	ect(−1)	Dincome(−1)	Constant Term	R_Square	Sigma
	−0.741 [0.0000]	0.332 [0.0114]	−0.885 to 0.590	0.672	0.077
Diagnostic tests' results					
AR test	ARCH test	Normality test	Hetero test	Hetero X test	RESET test
1.5150	1.5592	2.8067	1.2929	1.1727	0.13447
[0.1652]	[0.1502]	[0.2458]	[0.2500]	[0.3153]	[0.8743]

Notes: ect(−1) = lagged value of error correction term; dincome(−1) = lagged value of differenced income; constant term = constant term of regression equation; sigma=regression standard error; AR test = Ljung and Box [62] test for autocorrelation; ARCH = autoregressive conditional heteroscedasticity test [63]; Normality test = Doornik and Hansen [64] test; Hetero test = White [65] heteroscedasticity test; Hetero X test = White [65] heteroscedasticity test using squares and cross-products; RESET=Ramsey [66] Regression Specification Test.

The TVCC and STSM approaches produce quite close results for income elasticity, varying from 0.10 to 0.29 with TVCC and from 0.35 to 0.40 with STSM. The MIS approach gives relatively higher values, from 0.64 to 0.80.

To the best of our knowledge, there is no clear theoretical/statistical comparison for the three employed econometric techniques in terms of better capturing varying parameters. The estimated long-run price elasticities shown by the three methods are quite close to each other, being −0.15 (with TVCC), −0.12 (with STSM), and −0.19 (with MIS). In the short-run estimations, the differing feature is that the error correction terms come from the long-run relationship with time-varying coefficient [49]. In estimating the short-run relationships, the general-to-specific (*Gets*, [73] inter alia) as well as STSM approaches are used. The results are reported in Tables 5, 7 and 9. The results showed that neither income nor price has a significant impact on gasoline demand in the short run.

7. Discussion of Empirical Results

The results of the empirical estimations concluded time-varying income and constant price elasticity. In terms of time-varying income elasticities of gasoline, this finding is similar to those of Park and Zhao [24] and Mikayilov et al. [39]. Overall, the elasticities found are within the range of previous studies' findings. The income elasticity ranges from 0.10 to 0.29 which is higher than the results for another oil-exporting country, Saudi Arabia, studied by Mikayilov et al. [39], the latter being within the (0, 0.15) interval.

The difference for these country cases might be due to the following factors. First, in terms of the per capita income level in two countries, Saudi Arabia shares 18th place in the world ranking, while Azerbaijan is 84th [74], three times smaller for the latter, magnitude-wise. In other words, in the case with a higher income level, the portion of income spent for gasoline consumption is smaller than in the lower-income case. Therefore, in the case with a lower-income level, the change in income level will cause a substantial change in the expenditure for gasoline consumption. Furthermore, in a country with a higher income level, many households are covering their driving needs, resulting in a relatively smaller portion joining the "new drivers" list, while in a country with a lower income level, owning a car is still one of the necessary needs to be satisfied, increasing the share of people willing to join that list.

Consequently, the decline in the income level will not substantially affect the driving habits in a rich country, while its impact will be higher a country with a lower income level, due to reasons such as postponing the car ownership plan to the future, or lack of income to afford to buy a car. Moreover, in the case with a lower income level, increase (decrease) in income levels will likely result in an increase (decrease) in car sales, and, consequently, an increase (decrease) in gasoline demand.

While in higher-income countries the increase in income level might not result in higher numbers of car sales since most households are car owners already. This can be evidenced by the fact that the number of cars in Azerbaijan per 100 persons is 14, while this is 21 for the KSA (data for 2015 from CEIC [75]). Moreover, based on the CEIC data [75] motor vehicle sales decreased by 52% annually from 2014 to 2017 in Azerbaijan, while this number is 12% for the KSA.

These facts evidence that in the case of a country with a lower income level the increase in income goes to meet the necessary need, car purchase, and consequently the decrease will result in changing the opinion for better spending, instead of buying a car. Second, in the relatively low-income countries, newly-purchased cars are not efficient; hence, the increase in car numbers increases gasoline demand, while in the rich countries due to the efficient car sales the increased number of cars does not result in the same increase in gasoline demand, due to the efficiency. For example, in Azerbaijan 77% of cars are vehicles that have more than 10 years of operation [76]. According to the State Statistical Committee of the Republic of Azerbaijan [3], 47% of cars are the product of Russia, mainly with lower fuel efficiency. Moreover, based on Jodi data [54] compared with 2017, gasoline demand increased in 2018 in Azerbaijan, most likely due to less fuel-efficient cars, while it decreased in the KSA. This fact also justifies our point in terms of the car efficiency perspective.

All techniques conclude that income elasticity starts to decline after around 2013–2014. Due to the peak in oil revenues for the period around 2004 (in 2006 Azerbaijani light oil price was $146 per barrel), up to the 2008 financial crisis, the economic conditions of households were substantially increasing, which resulted in increases in car purchases as discussed in the Introduction section. However, after the 2014 oil price drop, households were not able to retain the same potential to "afford" the same response of gasoline consumption to income. Hence, after around 2014, all methods conclude that there was a decline in the response. The estimated elasticity with the TVCC and STSM for 2018 are quite close, being 0.28 with the TVCC and 0.35 with STSM. Combining the discussed point, we conclude that the 2014 oil price drop resulted in the change of the demand response to income.

Our income elasticity, ranging from 0.10 to 0.29, is in line with the conclusion of Havranek and Kokes [77], who concluded the average long-run income elasticity to be 0.23, based on reviewed studies.

Long-run price elasticity is −0.15 (TVCC result), which is quite similar to the finding of Mikayilov et al. [39] for the KSA case. By comparing our results with Mikayilov et al. [39], two points can be directly observed. First, even though in both cases the average elasticity is the same, the value for price elasticity is smaller and constant in the Azerbaijani case, varying over time and being −0.26 for the last year (2018) in the KSA case. One explanation for this difference can be the availability of room to lessen driving habits in the KSA case during higher price periods, while there will not be substantial room to do so in the Azerbaijani case. This point is also supported by the finding of unresponsiveness of gasoline demand to a price change in the short run.

Basically, consumers could not respond in the short run since there is no room to cut consumption, while in the long run the demand response, though smaller, gets shaped due to the unaffordability of the previous driving habits during the higher price regime. Second, the price elasticity is constant over time in the Azerbaijan case, while it changes in the KSA case. This difference can be explained by the fact that although in both countries the gasoline prices are centrally administered (before 2015), the KSA has a policy to transfer oil revenues to the private sector, adjusted accordingly during high price regimes, which in its turn historically dampened the responses to price changes. Our finding is in line with the result by Havranek et al. [78], who concluded that the average long run-price elasticity is −0.31, the same for the high- or low-income countries. In the short-run gasoline demand, as with price changes, does not respond to changes in income. Potential explanation for this finding might be that for the period of estimation the amount of annual change with the available income level does not allow consumers to change their driving habits, i.e., becoming drivers or replacing the current cars with more efficient ones.

8. Conclusions and Policy Insights

For oil-dependent countries, proper use of oil products, in addition to following a sustainable economic development path and using eco-friendly technologies, is important in order to maximize the benefit for the current generation, and convey it with increased "value" to the future generations. In this regard, the oil price drop in recent years can be seen as an alternative advantage for these countries to re-shape their development targets in order to minimize oil dependence and diversify economy. The ongoing reforms and set future targets in oil-exporting countries are indeed aiming to imply proper policies and achieve their development targets more prudently. In this regard, the efficient use of energy/energy types is one of the main points to be focused on. Henceforth, it is worthwhile to investigate the behavioral change, if any, in the consumption of different fuel types after the recent oil price drop. Therefore, this study investigates the income and price impacts of gasoline demand in the case of Azerbaijan, one of the oil-rich developing countries. For this purpose, the study uses a time-varying coefficient approach to consider the varying nature of demand responses to the changes in income and price levels. The estimated income and price elasticities have the expected signs and are statistically significant. The long-run income elasticity varies from 0.10 to 0.29. The range of varying elasticity is in line with the previous studies' findings see, for example [77]. The results show that the demand response to income changed after the 2014 oil price drop. The long-run price elasticity is around −0.15, again similar to that in the previous studies, such as Havranek and Kokes [77], and Mikayilov et al. [39]. In terms of the trajectory, being relatively steep, the elasticities found are expected for the developing country case, Azerbaijan see, [79]. That is, for similar country cases, there is still room for needs to be satisfied and hence the responses are relatively higher. In the short run, gasoline demand does not respond to income and price changes.

Based on the findings of the current study, the following conclusions and policy suggestions can be made:

(a) Income elasticity of gasoline demand is not constant. Hence, the use of the constant elasticities concluded by previous studies for policymaking purposes might be misleading. (b) Over time, an increase in income elasticities can be caused by the inefficiency of the existing cars or the unavailability of enough vehicles. (c) The current situation can be utilized as an advantage for increasing energy efficiency and implementing eco-friendly technologies. (d) Policies such as providing soft auto loans need to be followed to balance the recent significant drop in car sales to cover households' needs. (e) The small price elasticity allows to say that if policy makers plan to reduce gasoline consumption then increasing its price would not substantially reduce the consumption. To achieve this goal the quality of existing transportation modes can be increased. In this regard, the historically employed electrified public transport services can be modernized. In addition, the metro lines coverage in capital city should be widened to achieve more areas.

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