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Towards agricultural demand for the main energy carriers in Iran: Application of linear approximate almost ideal demand system (LA-AIDS) analysis

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ABSTRACT

Due to the necessity of cognizance of demand for the various forms of energy in the agricultural sector in Iran's economy and considering the effects of price liberalization policies on forms of energy, analysis of the main energy carriers' demand is very important. This study used the LA-AIDS approach and ISUR technique to estimate the demand and elasticities for various energy carriers. Also, the welfare effects of increasing energy prices under the 20, 40, 60, 80 and 100% scenarios are evaluated using the compensating variation (CV). The uncompensated and compensated own-price demand elasticities for oil products, electricity and, natural gas carriers were −1.21, −0.85 and −0.55, and −0.98, −0.32 and −0.30, respectively, confirming the demand theory. The cross-price elasticities showed that electricity has substitutability and complementarity relationship with oil products and natural gas, respectively, while the relationship between natural gas and oil products is a substitutability relationship. The income elasticities of energy usages estimated to be 0.64, 1.2 and 1.05. Agricultural producers' welfare would experience a further decrease in oil products and electricity price liberalization, though the welfare impacts of natural gas are trivial. As price elasticity is different in the agricultural sector, price policies, then price liberalization and omitting energy subsidy should be applied based on the elastic or inelastic of energy carriers. The price policies effectiveness on oil products is more than electricity and natural gas. Given the prevalence of consumption and high price elasticities of oil products and pollutants, rising oil prices can reduce their consumption and environmental pollution.

1. Introduction

The agriculture sector plays a great role in the Iranian economy due to its contributions through employment creation, food security, fostering the non-oil exports and currency importing, investment promotion, and poverty diminution in rural areas (Agheli, 2015). Based on the recent data, this sector accounted for about 9.8% and 11.3% of gross domestic product (GDP) with petroleum and non-petroleum, respectively (CBI, 2018). Also, about 17.4% of the employed person over 10 years of age engaged in the agriculture sector (SCI, 2018). Moreover, the energy intensity (EID), energy productivity (EPI) and energy coefficient (EF) indexes in the agriculture sector in 2016 were 0.30 BOE[1]/10^6 Rial, 3277.45 10^3 Rial/BOE and 0.52, respectively.

Energy as a driving force of development plays an important role in the country's economic growth and its subsectors such as industry, service and, agriculture (Hall et al., 2003). Today, energy doesn't only consider to be a leading input in the agricultural sector, also within the past 30 years caused industrial and commercial farming replaced the subsistence (Tabar et al., 2010). Energy requirements in the agriculture sector are divided into three groups: oil products, electricity and, natural gas. Although energy carriers are the most valuable and scarce natural endowments, they are used as a final consumption product and also an energy input (Bildirici and Bakirtas, 2014).

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[1] Barrel of Oil Equivalent.

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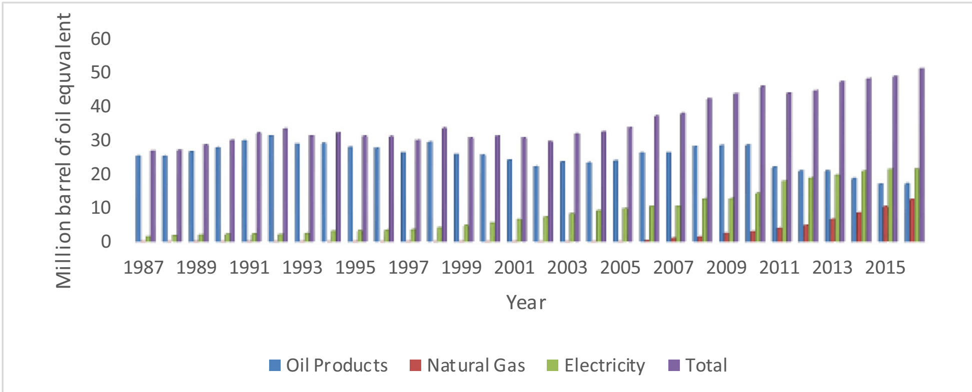

Fig. 1. Trend of energy carriers usage in Iran agriculture sector.

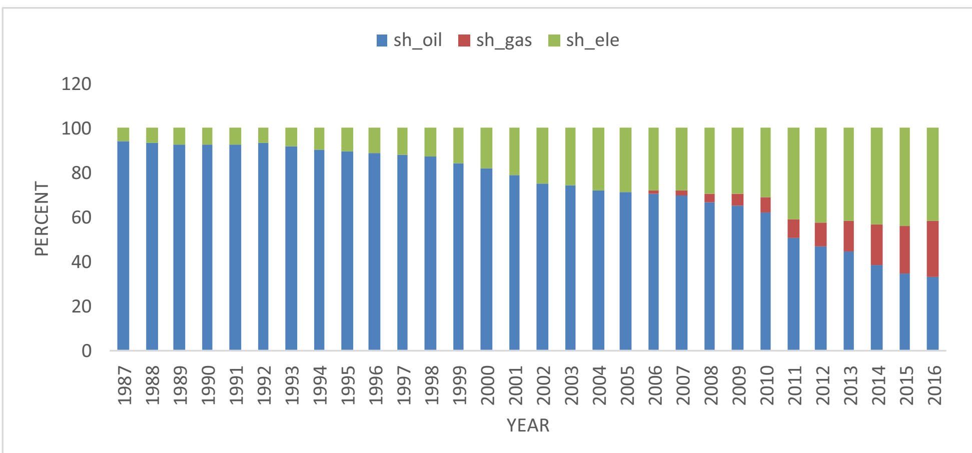

Fig. 2. The contribution of energy carriers to the agriculture over the period of 1987–2016.

As can be seen from Figs. 1 and 2, the pattern of energy carriers' usage has changed with time in Iran's agriculture sector. This pattern over the period 1987 to 2016 indicated that the main energy carrier used in the agricultural sector was oil products. However, its share was gradually decreased and replaced with electricity and natural gas. According to statistics provided by the Deputy of Electricity and Energy Affairs of the ministry of energy in 2016, 33, 24 and 42% of energy usage are, respectively, attributed to oil products, natural gas and electricity. However, energy usage in 1986 for oil products, natural gas and, electricity was 95, 0 and 5%, respectively (Iran Energy Balance Sheet, 2018). Also, the amount of oil products, electricity and, natural gas consumption in this sector was 17, 21.3 and 12.4 million barrel of oil equivalent in 2016 (BBOE), whiles the usage of these energy components in 1987 was 25.1, 1.5 and 0 BBOE, respectively. The increase in accessibility of electricity and gas, the policy of switching fuel to irrigation pump sets from oil products to electricity, as well as reduction of fuel carrying cost have led to a downward trend in oil products consumption in this sector (Asgari and Noor Mohammadi, 2016; Saha and Bhattacharya, 2018).

Some studies have been conducted to analyze the energy carriers' demand in Iran and world (Asgari and Noor Mohammadi, 2016; Bakhshahyesh and Yazdani, 2015; Campbell, 2018; Chambwera and Folmer, 2007; Farid Ghader et al., 2006; Guta, 2012; Morovat et al., 2018; Ngui et al., 2011; Salehi et al., 2017; Thompson, 2013). Therefore, this study aimed to evaluate the demand for energy carriers, in particular, oil, electricity and, natural gas in the agricultural sector of Iran, through the almost ideal demand system approach. Also, we attempted to attain some subordinate objectives including calculation of uncompensated own and cross-price, compensated own and cross-price, and income or expenditure elasticities to investigate the effect of relative changes in prices and expenditure on the relative change in the demanded amount.

2. Materials and methods

In recent years, system demand functions have been replaced by single-equations. System demand functions can be arranged into four categories, the Linear Expenditure System (LES), the Indirect Translog Utility Function, the Rotterdam System, and the Almost Ideal Demand System (AIDS). In this study, we applied a model of demand for energy carriers based on the Linear Approximate Almost Ideal Demand System (LA-AIDS) according to total expenditure on energy carriers. Energy sources in the Iran agriculture sector including oil products, electricity and, natural gas were selected.

2.1. The empirical LA-AIDS model

The almost ideal demand system was first introduced by Deaton and Muellbauer (1980), and applied for demand analysis of energy carriers. This system is derived by the cost function introduced by Deaton and Muellbauer. This function indicates the minimum cost necessary to achieve a certain level of utility U at price vector P as follows:

$$\ln C(U,P) = a_0 + \sum_1^n a_i lnp_i + \frac{1}{2}\sum_i^n\sum_j^n \gamma_{ij} lnp_i lnp_j + u\beta_0 \prod_i p_i^{\beta_i} \quad n=3 \quad i=1,2,3 \tag{1}$$

where $\ln C(U,P)$ is the cost function, α_0, α_i, β_0, β_i and γ_{ij} are constant coefficients, and i and j are the indexes representing different energy carriers. By applying the Shephard's lemma, the first derivative of cost function ($Q_i = \frac{\partial c(u,p_i)}{\partial p_i}$) yields compensatory demand function, ultimately we derive the modified version of an AIDS model, in which expenditure share of the ith group of energy carriers is a function of prices and the related energy expenditures:

$$w_i = a_i + \sum_j \gamma_{ij} lnp_j + \beta_i \ln\left(\frac{m}{p}\right) \tag{2}$$

where w_i and p_j are the expenditure share and price associated with energy carriers, respectively, m is total expenditure on energy carriers given by $m = \sum_j p_j q_j$, where q_j is the quantity demanded for j^{th} group of energy carrier, and α_0, α_i, β_i and γ_{ij} are parameters to be estimated, p is price index of energy carriers calculated using two different methods which yields nonlinear AIDS and LA-AIDS models. Firstly for nonlinear AIDS, Deaton and Muellbauer (1980) and Berck et al. (1997) defined p in Eq. (2) as fellow:

$$lnp = a_0 + \sum_1^n a_i lnp_i + \frac{1}{2}\sum_i^n \sum_j^n \gamma_{ij} lnp_i lnp_j \tag{3}$$

This price index used for the estimation of Eq. (2) needs nonlinear methods. Deaton and Muellbauer (1980) suggested the Stone price index p, that converts the nonlinear AIDS model to LA-AIDS model (Ngui et al., 2011):

$$\ln p = \sum w_i \ln p_i \tag{4}$$

In most empirical studies, the LA-AIDS model is more frequently estimated than the nonlinear AIDS model (Berck et al., 1997; Edgerton et al., 1996; Elsner, 2001).

2.2. Demand function restrictions

To make LA-AIDS Eq. (2) accordance with consumer theory, economic theory imposes the adding-up, homogeneity and symmetry conditions on the parameters of the aforementioned equation:

$$\sum_i a_i = 1 \quad \sum_i \gamma_{ij} = 0 \quad \sum_i \beta_i = 0 \quad \forall j \quad \text{"adding-up"}\ condition \tag{5}$$

$$\sum_j \gamma_{ij} = 0 \quad \forall i \quad \text{"homogenity"}\ codition \tag{6}$$

$$\gamma_{ij} = \gamma_{ji} \quad \forall i, \quad and\ i \neq j \quad \text{"symetry"}\ condition \tag{7}$$

Eq. (5) ensures the expenditure shares always sum up to entity $\sum_{i=1}^n w_i = 1$, Eq. (6) guarantees that if all prices and expenditure change at the same rate, the quantities purchased do not change, while Eq. (7) shows the stability of consumer choices.

2.3. Expenditure and price elasticities

After estimation of system coefficients, expenditure elasticity η_i^E, Marshallian (uncompensated) and Hicksian (compensated) own price and cross price elasticities can be derived from (2) and (4) as follows (Green and Alston, 1990):

$$\eta_i^E = \frac{\beta_i}{w_i} + 1 \quad \text{(Expenditure elasticity)} \tag{8}$$

$$\varepsilon_{ij} = -\delta_{ij} + \frac{\gamma_{ij}}{w_i} - \beta_i \frac{w_j}{w_i} \quad \text{(Marshallian)}$$

where δ_{ij} is Kronecker delta $\delta_{ij} = 1\ for\ i = j$; $\delta_{ij} = 0\ for\ i \neq j$ (9)

$$\varepsilon_{ij}^* = -\delta_{ij} + \frac{\gamma_{ij}}{w_i} + w_j \quad \text{(Hicksian)} \tag{10}$$

2.4. LA-AIDS specification

The equations system to be estimated is:

$$\begin{aligned} w_{ot} &= a_o + \gamma_{oo} lnp_{ot} + \gamma_{oe} lnp_{et} + \gamma_{og} lnp_{gt} + \beta_o \ln\left(\frac{m}{p}\right)_t + u_{ot} \\ w_{et} &= a_e + \gamma_{eo} lnp_{ot} + \gamma_{ee} lnp_{et} + \gamma_{eg} lnp_{gt} + \beta_e \ln\left(\frac{m}{p}\right)_t + u_{et} \\ w_{gt} &= a_g + \gamma_{go} lnp_{ot} + \gamma_{ge} lnp_{et} + \gamma_{gg} lnp_{gt} + \beta_g \ln\left(\frac{m}{p}\right)_t + u_{gt} \end{aligned} \tag{11}$$

where o, e and, g are oil products, electricity and, natural gas as energy carriers employed in the agriculture sector, respectively. After applying the constraints into the model, the number of equations in the LA-AIDS model becomes 2 and the other equations can be estimated using an Iterative Seemingly Unrelated Regressions (ISUR) technique. Furthermore, the time series data over 1987–2017 and econometric software Eviews 10 were used.

2.5. Welfare indicators in AIDS system

By changing the energy carriers' price, consumer utility rates may increase or decrease. The Compensating Variation (CV) is often used to determine the impacts of price changes on consumers. The aforementioned index shows the amount of money that is necessary to compensate a consumer as a result of price change so that it achieves the first utility. The CV represented based on the Compensated Demand Curve, in other words, the Hicksian demand curve (Fig. 3) (Davoodi, 2010). Supposed that the price of energy carriers changes, that way $p^0 \neq p^1$. The change of CV can be written in the form of a difference between two values of the expenditure function after and before the price change (Araghi and Barkhordari, 2012; Hicks, 1946):

$$CV = E(P1^d, U_0) - E(P_0{}^d, U0) \tag{12}$$

where E and U refer to expenditure and indirect utility functions, respectively. As well as the subscripts of (0) and (1) show the before and after the price change. To measure the welfare effects of rising prices, the compensating variation function for the almost ideal demand system is extracted as follows (Nourelahi et al., 2017):

$$\begin{aligned} CV &= exp\left[A_1 + \prod_{i=1}^n (p_i^1/p_i^0)^{\beta_i}.(logc(u^0,p^0) - A_0)\right] - c(u^0,p^0) \\ A_0 &= a_0 + \sum_{i=1}^n a_i logp_i^0 + 1/2 \sum_{i=1}^n \sum_{j=1}^n \gamma_{ij} logp_i^0 logp_j^0 \\ A_1 &= a_0 + \sum_{i=1}^n a_i logp_i^1 + 1/2 \sum_{i=1}^n \sum_{j=1}^n \gamma_{ij} logp_i^1 logp_j^1 \end{aligned} \tag{13}$$

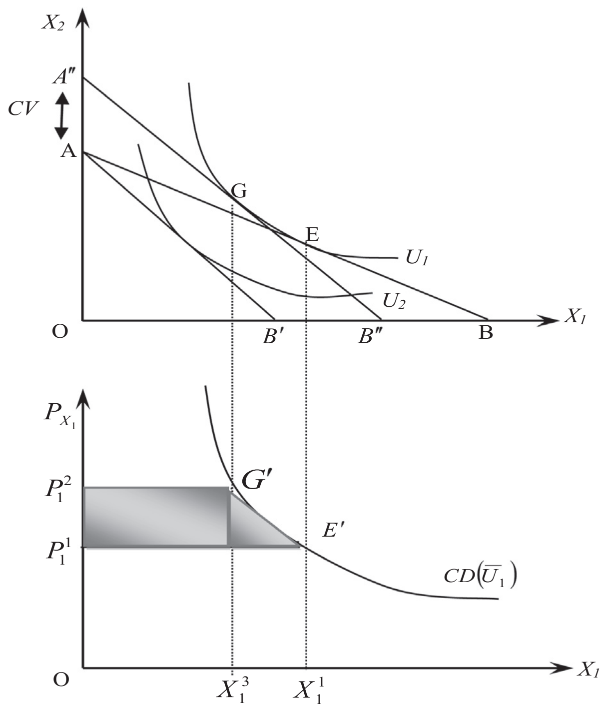

Fig. 3. The compensating variation.

3. Results and discussion

The results in Table 1 illustrate that all variables are non-stationary time series by using the test types of the Kwiatkowski-Phillips-Schmidt-Shin (KPSS), Phillips-Perron and Augmented Dickey Fuller. To avoid spurious results we, therefore, needed to check the existence of cointegration relationships between the variables. Tables 2–4 show the outputs of Johanson unrestricted cointegration rank test (Trace test) indicating that there were at least two cointegration relationships in three equations of system (Johansen, 1988).

To determine the single equation or system estimation strategy, Breusch-Pagan diagonally test for the variance-covariance matrix of error terms was applied (Breusch and Pagan, 1980). Based on the test, the diagonality of the aforementioned matrix was rejected. Thus, our equations were estimated as a system, and the ISUR technique was applied.

$$\lambda = N\left(\sum_{i=2}^{G}\sum_{j=1}^{i-1} r_{ij}^2\right) = 84.003 \geq 16.226 \quad (12)$$

The homogeneity and symmetry conditions were the constraints considered by the Wald test ($H_0: \ \gamma_{i1} + \gamma_{i2} + \gamma_{i3} = 0 \ \forall i$) and ($H_0: \ \gamma_{ij} = \gamma_{ji} \ \forall i, j$ and $i \neq j$), respectively, to explain and understand the consumer's behavior. The homogeneity test results

Table 2
The results of unrestricted cointegration rank test for electricity share equation (Trace test).

Null hypothesis	Trace statistic	Critical value 5%	Prob.**
r = 0	130.1295	95.75366	0.0000
$r \leq 1^*$	84.33613	69.81889	0.0023
$r \leq 2^*$	53.15567	47.85613	0.0146
$r \leq 3$	26.15709	29.79707	0.1241
$r \leq 4$	5.765902	15.49471	0.7230
$r \leq 5$	0.537174	3.841466	0.4636

Table 3
The results of unrestricted cointegration rank test for oil products share equation (Trace test).

Null hypothesis	Trace statistic	Critical value 5%	Prob.**
r = 0	125.5143	95.75366	0.0001
$r \leq 1^*$	79.49161	69.81889	0.0069
$r \leq 12^*$	49.51590	47.85613	0.0346
$r \leq 13$	24.50037	29.79707	0.1801
$r \leq 14$	4.482794	15.49471	0.8610
$r \leq 15$	0.004735	3.841466	0.9442

Table 4
The results of unrestricted cointegration rank test for natural gas share equation (Trace test).

Null hypothesis	Trace statistic	0.05 Critical value 5%	Prob.**
r = 0	149.1428	95.75366	0.0000
$r \leq 11^*$	95.77965	69.81889	0.0001
$r \leq 12^*$	52.67660	47.85613	0.0165
$r \leq 13$	26.70367	29.79707	0.1091
$r \leq 14$	12.02197	15.49471	0.1559
$r \leq 15$	2.053412	3.841466	0.1519

demonstrate (Table 5) that null-hypothesis was rejected. Hence, the consumers had a monetary illusion in all energy carriers to purchase these three kinds of energy, instead of paying attention to real incomes and prices. Further, the Wald test rejected the symmetry nature of coefficients in the system implying that the price coefficient of the j^{th} commodity in the equation relating to the share of the i^{th} commodity was not equal to the i^{th} commodity price factor in the equation relating to the share of j^{th} commodity.

The average expenditure of energy carriers shares, $w_o = 0.345$, $w_e = 0.420$ and $w_g = 0.234$, the Marshallian, Hicksian and expenditure elasticities were computed (Table 6). The outputs are given in Table 7. The uncompensated elasticities are known and interpreted as conditional elasticities (Ngui et al., 2011). This implies that the relative price changes within energy carriers would not affect the real on expenditure energy carriers. All uncompensated own-price elasticities were negative and had the expected signs. These results were consistent with economic theory. The results portray that electricity and natural gas carriers had own-price inelastic demand (−0.85 and −0.55) while oil products had own-price demand elastic (−1.21). This implies that a 10% price increase

Table 1
The results of unit root test.

Variable	KPSS		Phillips-Perron		Augmented dickey fuller	
	Level	First difference	Level	First difference	Level	First difference
$\ln(\frac{M}{P})$	0.40	0.11	−1.52	−3.78**	−1.94	−4.32**
$\ln p_o$	0.54	0.10	−1.53	−4.58**	−1.46	−4.32**
$\ln p_e$	0.19	0.25	−1.96	−5.66***	−2.02	−5.1***
$\ln p_g$	0.47	0.50	−2.17	−12.87***	−2.22	−8.41***
w_o	0.67	0.43	2.72	−3.7**	2.65	−3.66**
w_e	0.68	0.11	−0.05	−4.05**	−0.003	−4.12**
w_g	0.52	0.55	−0.51	−10.48***	−2.65	−10.75***

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Table 5
The results of demand homogeneity hypothesis: Wald test.

Energy carrier	Null hypothesis $H_0: \sum_{j=1}^{3}\gamma_{ij} = 0$	Test statistic	Value	Prob.
Electricity		Chi-Square	27.17	0.0000
Oil		Chi-Square	9.03	0.0027
Natural gas		Chi-Square	33.36	0.0000
All	Null hypothesis $H_0: \gamma_{ij} = \gamma_{ji}$	Chi-Square	14.47	0.0023

Table 6
Results of LA-AIDS system estimation using ISUR method.

Equations	Intercept c	Price of electricity (lnp_e)	Price of oil_p (lnp_o)	Price of natural_g lnp_g	Expenditure/price index $\ln(\frac{M}{P})$	R^2	DW
w_e	−2.7628***	0.1064**	0.1035***	−0.094	0.10756**	0.89	1.57
	(−6.54)	(2.48)	(5.65)	(0.14)	(7.26)		
w_o	3.7315***	0.0065	−0.1152***	−0.0133*	−0.12***	0.87	1.78
	(5.69)	(0.01)	(−4.05)	(−1.67)	(−5.26)		
w_g	0.031	−0.1130	0.0116	−0.1186	0.0134	–	–

Note: t statistics given in parenthesis are for those parameters not obtained from restrictions on parameters.
*** Indicates 1% significance level.
** Indicates 5% significance level.
* Indicates 10% significance level.

Table 7
The results of income, uncompensated and compensated price elasticity of energy carriers.

	Energy carrier	Electricity	Oil products	Natural gas	Income elasticity
Uncompensated own and cross price elasticity	Electricity	**−0.85**	0.15	−0.28	1.25
	Oil products	0.16	**−1.21**	0.04	0.64
	Natural gas	−0.50	0.03	**−0.55**	1.05
Compensated own and cross price elasticity	Electricity	**−0.32**	0.59	0.01	–
	Oil products	0.43	**−0.98**	0.19	–
	Natural gas	−0.06	0.39	**−0.30**	–

of electricity and natural gas will decrease the quantity demanded of the same carriers by less than 10%. On the other hand, as oil products is an elastic carrier, a 10% increase will cause a more than 10% increment in the purchase of oil products. These findings are in line with those Asgari and Noor Mohammadi (2016), Bakhshahyesh and Yazdani (2015), amadeh et al. (2014) and Khalilabadi et al. (2014).

The demand reaction of an energy carrier to a change in the price of another energy source was also determined by cross-price elasticity. The negative and positive sign of cross-price elasticity specified the complementary and substitution relationship between energy carriers, respectively. The results (Table 7) indicated that electricity has substitutability and complementarity relationship with oil products and natural gas, respectively. Moreover, the relationship between natural gas and oil products based on the cross-price elasticity is substitutability. Hence, a 10% percent increment in oil products price reduces electricity usage by 1.5%. The interpretation of compensated own and cross price elasticities are the same for uncompensated, With this difference that in this type of elasticities, the effect of a change in real income is adjusted due to a change in the price, and changes in demand are only due to price changes, while uncompensated elasticities inclusive the both effects of the income and price of price changes.

Expenditure elasticities of demand for energy carriers used in the agriculture sector are given in Table 7. Note that these estimates are with respect to the expenditure on energy carriers in the agriculture sector. We find that all income elasticities have a positive sign, so energy carriers are normal commodities. This underlines the fact that increased income rises the demand. The values of income elasticities varied for the different energy carriers, demand for electricity and natural gas carriers were income elastic (> 1), while oil products were inelastic (< 1) in terms of income. Therefore, unlike the oil products, electricity and natural demand in Iran agriculture sector can be considered as luxury energy carriers. These results are confirmed by the studies conducted by Bakhshahyesh and Yazdani (2015).

Ultimately, in this section, we surveyed the producers' welfare of the agricultural sector by increasing the energy carriers' prices.

Table 8
Agricultural sector welfare index with energy carriers' price changes (Billion Rials).

	Compensating variation(CV)					Total expenditure (TE)
	20%	40%	60%	80%	100%	
Oil products	1431.16	2468.34	3222.43	3360.53	3215.63	8140.83
Natural gas	428.13	806.43	1134.91	1413.53	1642.32	2265.27
Electricity	1378.72	2501.28	3367.68	3977.94	4332.03	7533.97
Total	3238.01	5776.01	7614.00	8751.99	9189.98	17940.06
CV/TE	0.18	0.32	0.42	0.48	0.51	–

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For this purpose, we increase the energy carriers' price over the five scenarios of 20%, 40%, 60%, 80% and, 100%. The Compensating Variation (CV) to determine the welfare change was applied. The results are presented in Table 8.

The results of the CV index shows that with the increase in energy prices under the 20%, 40%, 60%, 80% and 100% scenarios, the welfare of producers will decrease in this sector. So, in order to reach the initial level of utility, the government compensation payments should be 3238.01, 5776.01, 7614.00, 8751.99 and 9189.98 billion Rials, respectively. As well as, the results show that to offset the effects of price increases, consumers' of electricity need to pay more than oil and gas.

4. Conclusion and policy implications

This study examined the agricultural demand for energy in Iran's economy. The main energy components used in this sector are oil products, electricity and, natural gas. To estimate the energy demand equations and elasticities, the LAIDS model and ISUR technique were employed. The results show that oil products were an elastic (−1.21) energy in this sector, unlike the electricity (−0.85) and natural gas (−0.55) which were inelastic. The electricity (1.25) and natural gas (1.05) were also found to be luxury energy, while oil products (0.64) were necessity energy. Rising prices will create welfare costs in the agriculture sector. According to the results, the following suggestions are provided for policymakers:

1. Income elasticities values indicate that with increasing agricultural sector value added, the consumption of electricity and natural gas will increase more than oil products. The value added of the agricultural sector from 1987 to 2016, has risen by 173%. Therefore, based on the values of income elasticities, the share of electricity and natural gas has increased in the energy demand of the agricultural sector (Fig. 2). Therefore, in analyzing the consequences of price liberalization on the level of energy consumption, it is necessary to consider the effects of price increases along with the programs for increasing the value added of the agricultural sector.
2. Low price elasticity of natural gas and electricity relative to oil products leads to inefficient price policy. Price liberalization and natural gas and electricity subsidy removal are thus crucial measures to increase the price policy effectiveness, as well as reduce the energy usage.
3. Given the propagation usage of oil products, their contamination, and the high price elasticities of these carriers, increasing oil prices can decrease their consumption and environmental pollution.
4. Considering the fact that natural gas and electricity are inexpensive and cleaner energy sources than the oil products, it is recommended that the government encourages farmers, by adopting appropriate supportive policies, to replace oil products with these energy sources. This surely requires infrastructure enhancement in the agricultural sector.
5. Given the negative welfare effects associated with clean energy e.g. electricity and natural gas, it is necessary to mitigate these negative effects in the design of economic policies through compensation payments.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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