

Liberalizing Energy Price and Abatement Cost of Emissions: Evidence from Iranian Agro-Environment

S. H. Mosavi¹, A. Alipour¹, and N. Shahvari¹

ABSTRACT

Iran is one of the most energy-rich countries subsidizing energy carriers, especially in the agricultural sector, to the extent that the resulting growth is at the expense of the environment. This study tries to investigate the potential impacts of energy price reform on the agro-environment, based on the Marginal Abatement Costs (MACs) of emissions. Firstly, the energy demand function of the agricultural sector and the probable reaction of inputs and outputs to the reform were estimated. Then, using an Input Distance Function (IDF), the country and provincial-wide MAC were simulated through counterfactual reform scenarios. The results indicated that energy price reform would increase the MAC of emissions and socio-environmental benefits. However, the reform adversely affected the income of farmers. Also, the results provided detailed information both at a nationwide and provincial scale. Finally, it was recommended to implement complementary policies alongside reforms to compensate for the reduction in farmers' income.

Keywords: Energy demand function, Input distance function, Marginal abatement cost, Shadow price.

INTRODUCTION

Nowadays, the world is faced by numerous environmental problems which have led to many crucial crises. Greenhouse Gas emissions (GHG) and some other air pollutants generated by human activities (e.g. CO_2 , N_2O , CH_4 , SPM , CO , SO_3 , SO_2 , NOX) are considered as dangerous pollutants threatening human life (Shahidipour, 2011; Alipour *et al.*, 2014). This issue is more significant among energy-rich countries like Iran, where considerable amounts of subsidy are paid to tradable energy carriers, such as diesel, gasoline, and electricity. Energy carriers are the government's main foreign source of revenue. The price of energy abroad is usually much higher than in the home country. So, the government subsidizes domestic energy consumers (Hessari, 2005). These subsidies lead to excessive consumption of energy in different

sectors of the economy and consequently cause numerous environmental difficulties like higher rate of air pollution (Guillaume and Roman, 2010; Lechtenbohmer *et al.*, 2011). Among all, the agricultural sector is one of the main energy consumers in Iran (Nasrnia and Esmaeili, 2009; Alipour *et al.*, 2014). Farmers use subsidized electricity for extracting ground water and also fuel subsidy for machinery operations and transportation to and from the market. The amount of subsidy received by farmers is based on their consumption and is quite different among provincial sectors. Energy consumption (including oil and non-oil products) has increased in proportion to the growth in agricultural products. Therefore, the greater the energy consumption, the more are the air pollutants. These pollutants are considered as detrimental byproducts generated by burning fossil fuels (Alipour *et al.*, 2014; Najafi Alamdarlo, 2016). Preserving the environmental qualities by

¹ Department of Agricultural Economics, Faculty of Agriculture, Tarbiat Modares University, Tehran, Islamic Republic of Iran.

* Corresponding author; e-mail: shamosavi@modares.ac.ir



prudently managing the available resources through the sustainable use of energy is necessary for the future socio-economic development of the country (Bijani, 2015). Energy price reform was considered as the core of Iran's economic reform plan, according to a bill passed by the parliament. Based on this plan, the Iranian government was entailed to liberalize energy prices from 2010 in several phases to finally reach up to at least 90% of its export prices in the Persian Gulf. In 2010, subsequent to the first stage of liberalization of energy prices in Iran, energy prices significantly increased. For example, the price of each liter of gas oil increased from 0.01 \$ per liter to 0.33 \$ while the price of each liter of gasoline increased from 0.09 \$ per liter to 0.37 \$. The energy prices on FOB Persian Gulf was 0.58 \$ for every liter of gas oil and 0.55 \$ for every liter of gasoline in that year. Then, based on the Act by Islamic Consultative Assembly, it was prescribed that the amount added to energy price should be lower than annual inflation rate per year till the energy price eventually increases to 90% of Persian Gulf energy prices (Iran's energy export price) while this trend should be preserved up to 2025 towards the perspective considered by the Islamic Republic of Iran (Iran FOB price of energy).

This study was conducted to investigate the agro-environmental impacts of the reform in terms of abatement costs of air pollutant emissions. The findings of this work will prove significant for future decisions regarding the energy sector and the environment. The objectives in this study are divided into three steps: the first step will determine the reaction of the agricultural sector to the energy price liberalization. The second step measures the new emission levels of pollutants in the agricultural sector after energy price reform. Finally, the last step looks at the potential impacts of energy price reform keeping in mind the above objectives.

To our knowledge, there is no prominent study of environmental issues specifically relevant to this study. Works on Iran's agro-

environment include Darijani *et al.* (2006), Esmaeili and Mohsenpour (2010), Alipour (2013) Alipour *et al.* (2014) and Najafi Alamdarlo *et al.* (2016). However, there are other studies that have been conducted throughout the world (Recka, 2011; Lee and Zhang, 2012; Rodseth, 2013; Gooday *et al.*, 2014; Lee and Zhou, 2015; Schmitt, 2016). These studies used the Input Distance Function (IDF), which is the practical relationship between desirable and undesirable outputs, for evaluating the shadow price of emissions. IDF is a technique for the representation and estimation of multiple-output and multiple-input production technologies. For this reason, non-marketed outputs, such as pollutants can be easily incorporated into an analysis of the environment with the help of IDF. In fact, the trade-off between pollutants and good outputs implied by the estimated IDF can be used to generate shadow prices or Marginal Abatement Cost estimates for pollutants (MAC). This will be useful for environmental policymaking (Hailu, 2003). The shadow price of pollutants provides the marginal opportunity cost of producers who are reducing the pollutants (Fare *et al.*, 1998). Also, the shadow price refers to the MAC of pollutants. Therefore, an efficient degradation of the environment can be estimated by creating a market for emissions (Faber and Proops, 1991, Fare *et al.*, 1993).

To achieve the objectives of the current study, the MAC of pollutions was acquired using IDF in the Iranian agro-environment. Afterwards, considering the elastic nature of demand of energy, the changes in the MAC were simulated for different liberalization scenarios. It is noteworthy that the energy demand function is derived from cost functions and includes several important criteria. These include compatibility with theories, flexibility, usability, computability, and verification of facts. So, among the functional forms, the Transcendental Logarithmic (Translog) cost function has these capabilities compared to others such as, Constant Elasticity of Substitution (CES) and Cobb–Douglas. These cost functions are

superior as they include the non-fixed substitution and price elasticity of inputs. This is very important in the calculation of energy demand elasticity (Kamel, 2015). Therefore, in this study to achieve the own-price elasticity of demand and partial elasticity of substitution or cross price elasticity of demand, the Translog cost function was used. Own-price elasticity of demand is a measure of responsiveness of the quantity of an input to changes in its price and partial elasticity of substitution, or it could be said that cross price elasticity of demand is a measure of responsiveness of the quantity of an input to changes in other input's price. The other input can be a substitute or a supplement for that input. So, if the two inputs can be substitutes, by increasing one's price, the other one's demand would be increased. If the two inputs are supplements, then one's demand would decrease with an increase in the other one's price. The input factors including energy are essentially derived demands i.e. the input demand function can be derived from its output. The firm tends to choose a package of inputs, minimizing the total cost of production subject to a determined level of output. Therefore, the derived demand for inputs depends on the level of outputs, the substitution possibilities among inputs permitted by the production technologies, and the relative prices of inputs.

This study contributes to the literature in various ways. Firstly, both agricultural macro dimensions and subdivisions (including agronomy, horticulture, livestock, fisheries and forestry) were considered. Secondly, the shadow prices of the fuel-source emissions were determined separately for all emissions and provinces. Moreover, implementing the distance function to probe the relation between energy price reform and the MAC of emissions is the other distinct superiority compared to other ways.

This study is outlined as follows. In the next section, the mathematical formulation of the model is explained. Afterwards, the description of data and their sources are

presented. Then, the results are listed and explained and finally, the paper is concluded by remarking on the key results.

METHODOLOGY

Inputs Price Elasticity of Demand

The energy demand function and IDF have been implemented to analyze the changes in MAC of the pollutants. Firstly, different procedures for estimating the energy demand function have been explained. After that, the method used to estimate the parameters of IDF has been discussed.

To clarify the model, suppose the Iranian agricultural sector produces $M \times 1$ vector of output Ψ using a $N \times 1$ vector of input X . The vector of inputs comprises land area (A), labour force (L), and fossil fuels as energy inputs (E). The transformation of inputs into outputs is given by the production possibility set f in such a way that:

$$(\Psi, X) \in f \tag{1}$$

According to the theory of duality between cost and production functions, finding the optimum levels of inputs, can be seen as both a question of choosing the lowest isocost line tangent to the production isoquant (minimizing cost), and also as the question of choosing the highest production isoquant tangent to a given isocost line (maximizing production). So, it suggests the following cost function under assumption of a competitive market (Rasmussen, 2012):

$$C(\Psi, H) = \min (HX : (\Psi, X) \in f) \tag{2}$$

Where H denotes the exogenous vector of market which refers to the prices of energy, land and labor that have already been set at input markets and are not calculated by solving the model. The second-order Taylor expansion of $C(\Psi, H)$ interpreted as Translog model can be presented in the logarithmic form as follows (Christensen *et al.*, 1973):

$$\begin{aligned} \text{Ln}C = & \mu_0 + \mu_1 \text{Ln}H + \mu_2 \text{Ln}\Psi + \\ & 0.5\mu_3 \text{Ln}H \text{Ln}H + \mu_4 \text{Ln}H \text{Ln}\Psi + \\ & 0.5\mu_3 \text{Ln}\Psi \text{Ln}\Psi \end{aligned} \tag{3}$$



According to Taylor's theorem, for an infinitely differentiable function at intervals, it is possible to specify it as an infinite exponential function (Christensen *et al.*, 1973). Owing to the flexibility of the Translog cost function, it has been widely used in the energy or electricity demand modeling (Ma *et al.*, 2008; Boluk and Ali Koc, 2010; Mosavi, 2014; Zha and Ding, 2015; Lin and Ahmad, 2016) The input demand equations can be obtained as input cost share from Equation (3) by employing Shepherd's Lemma (See Griliches and Mairesse, 1993):

$$S = \mu_1 + \mu_3 \text{Ln}H + \mu_4 \text{Ln}\Psi \quad (4)$$

In Equation (4) $S = \partial \text{Ln}C / \partial \text{Ln}H$ refers to a vector of input cost share in total production cost. Finally, by inserting Shepherd's Lemma in the equation of partial elasticity of substitution, this equation will be equal to $\varepsilon = (\mu_3 + S\delta)S^{-1}$.

Input Distance Function (IDF)

IDF was adopted to meet the objectives. The privileged feature of this approach is that, there is no need for external estimates of pollution damage values in assessing the shadow prices (Hailu and Veeman, 2000). By partitioning the vector of outputs to desirable output Ψ_i , and undesirable output (air pollutant emissions) Ψ_j , Shephard's (1970) IDF can be written as follows:

$$\omega(\Psi, X, t) = \sup_{\theta} \{ \theta : (\Psi, X/\theta) \in f(t), \theta \in R_+ \} \quad (5)$$

Where t is the time trend vector, $f(t)$ is the production possibility set at time t . The elements of vector θ measure the possible proportion of inputs which can be reduced to produce the quantity of the outputs not less than Ψ . The IDFs are monotonically: (i) Non-decreasing and concave in X ; (ii) Non-increasing and quasi-concave in Ψ and, (iii) Homogenous of degree one in X (Fare and Grosskopf, 1990; Hailu and Veeman, 2000; Shephard, 1970). Solving cost-minimization problem subject to $\omega(\Psi, X, t)$ yields:

$$C(\Psi, v, t) = \text{Min}_x \{ vX : \omega(\Psi, X, t) \geq 1, X \in R_+^3 \} \quad (6)$$

In Equation (6) $C(\Psi, v, t)$ refers to cost function and v refers to input price vector. Differentiating $C(\Psi, v, t)$ with respect to v gives:

$$\begin{aligned} \nabla C(\Psi, v, t) &= \\ -\Lambda(\Psi, v, t) \nabla_{\Psi} \omega(\Psi, X, t) &= \\ -C(\Psi, v, t) \nabla_{\Psi} \omega(\Psi, X, t) & \quad (7) \end{aligned}$$

Where ∇ is the gradient operator and Λ is a vector of the Lagrangian multiplier for the cost-minimization problem. The first component in Equation (7) follows directly from the first order conditions for the solutions to Equation (6) and the second part is obtained because Λ is equal to the value of the optimized cost function (Jacobsen, 1972; Shephard, 1970). Increasing the production costs of an additional unit of the output can be interpreted as shadow price. As the IDF does not decrease in pollutant outputs, the shadow prices for these kinds of output will be non-positive. It is important to note that the input prices, especially emissions abating input prices are not usually available; therefore, it is impossible to estimate the optimal cost of production. As a result, an alternative formula derived from Equation (7) can be used to calculate the ratio of the shadow price of desirable output (ζ_i) to undesirable output (ζ_j):

$$\begin{aligned} \zeta_i / \zeta_j &= \\ [\partial \omega(\Psi, X, t) / \partial \Psi_i] [\partial \omega(\Psi, X, t) / \partial \Psi_j]^{-1} & \quad (8) \end{aligned}$$

where Ψ_i and Ψ_j are desirable production and desirable outputs in the agricultural sector (Agricultural products and Air pollutants produced in the agricultural sector, respectively). The above-mentioned shadow price measures the number of units of Ψ_i that are forgone to abate an additional unit of Ψ_j and is equivalent to the marginal abatement opportunity cost of emission. Therefore, the shadow price of emissions can be calculated as follows:

$$\zeta_i = \zeta_j [\partial \omega(\Psi, X, t) / \partial \Psi_i] [\partial \omega(\Psi, X, t) / \partial \Psi_j]^{-1} \quad (9)$$

Computation of ζ_i in Equation (9) is required to estimate the value of $\omega(\Psi, X, t)$. The mathematical programming technique originally adopted by Aigner and Chu (1968) was used to estimate the parameters of $\omega(\Psi, X, t)$.

$$\begin{aligned} \text{Min } \text{Ln}\omega(\Psi, X, t) &= \alpha_0 + \alpha_1 \text{Ln}X + \beta_1 \text{Ln}\Psi_i + \gamma_1 t + \alpha_2 t \text{Ln}X + \beta_2 t \text{Ln}\Psi_i \\ &+ \frac{1}{2} \left[\delta_1 \text{Ln}X \text{Ln}X + \delta_2 \text{Ln}X \text{Ln}\Psi_i \right. \\ &\left. + \delta_3 \text{Ln}\Psi_i \text{Ln}\Psi_j + \delta_4 t t \right] \quad (10) \end{aligned}$$

s. t.

$$\begin{aligned} \text{Ln}\omega(\Psi, X, t) &\geq 0 \\ \partial \text{Ln}\omega(\Psi, X, t) / \partial X &\geq 0 \\ \partial \text{Ln}\omega(\Psi, X, t) / \partial \Psi_i &\leq 0 \\ \partial \text{Ln}\omega(\Psi, X, t) / \partial \Psi_j &\geq 0 \\ \alpha_1 \alpha_1 &= I, \quad \beta_1 \beta_1 = -I \\ \delta_1 \delta_1, \delta_2 \delta_2, \delta_3 \delta_3 &= 0 \\ \alpha_2 \alpha_2, \beta_2 \beta_2 &= 0 \\ \delta_1 &= \delta_1^T, \delta_3 = \delta_3^T \end{aligned}$$

The objective function narrows the gap between an efficient boundary and individual observations, subject to subsequent constraints. The first constraint corresponds to the range of IDF values. Afterwards, monotonicity conditions for X and Ψ_i, Ψ_j are imposed in the second through fourth constraints, respectively. Other constraints necessitate linear homogeneity in X , parameter symmetry conditions as well as the constant returns to scale on the estimated IDF. Eventually, the IDF was executed using GAMS programming language and was solved by the CONOPT3 solver.

RESULTS AND DISCUSSION

Inputs Demand Elasticity

A panel data set covering the period from 1991 to 2014 for 24 provinces was used in this study. The data set includes energy consumption (aggregated liter of gasoline),

labour (person per year), land (hectare), agricultural production (ton), and input prices (Rial). Also, the amount of air pollutant emissions, including CO_2 , SPM , CO , SO_2 , and NOX are in tons. All the data was obtained from the national statistical yearbooks. It should be noted that since the time series data of GHG emissions for some provinces was not available, it was not possible to investigate all GHG emissions.

As stated before, the price of energy carriers should be raised to their opportunity cost of about 90% of the Persian Gulf FOB levels. Also, after the implementation of the first phase of liberalization of energy prices in 2010, the Iranian parliament passed a law that the energy price reform should occur in one of the three situations including 40, 70 or 100% increase per annum (Iranian Budget Act of 2013). In fact, according to the legislation, the government should investigate the aspects of each one of these three situations and analyze them. So, based on the parliament legislations, three scenarios S_1 , S_2 , and S_3 were designed to address each situation respectively in this study. The percentage deviation of the emissions and their abatement costs after implementing these three policy scenarios were reported separately.

So, at the first step, input demand equations were estimated. It was found that the Variance-Covariance Matrix of the error terms in the input demand equations [Equation (4)] is non-diagonal using Breuch-Pagan (1979) and Housman (1978) tests. Therefore, the efficient parameters of the input demand equations were estimated using the Iterative Seemingly Unrelated Regressions (ISUR) approach (Zellner, 1962). The provincial price elasticity of energy demand is shown in Table 1. It is apparent that energy demand is sensitive to price changes in all provinces. However, these sensitivities vary in different regions. The central provinces of Iran (Esfahan, Fars, Hamadan, Markazi, Tehran and Yazd) tend to consume less energy, according to Table 1.

**Table 1.** Price elasticity of energy demand.

Geographical position	Provinces	Elasticity		
		ϵ_{EE}	ϵ_{EA}	ϵ_{EL}
North	Ardebil	-0.38	0.38	0.08
	Gilan	-0.42	0.44	0.06
	Mazandaran	-0.62	0.58	0.09
	Semnan	-0.61	0.64	0.02
East	Kerman	-0.10	0.16	0.05
	Khorasan	-0.06	0.15	0.04
	Sistan and Baluchestan	-0.60	0.54	0.02
Central	Esfahan	-0.75	0.75	0.03
	Fars	-0.67	0.65	0.06
	Hamadan	-0.67	0.63	0.08
	Markazi	-0.67	0.60	0.05
	Tehran	-0.73	0.76	0.01
	Yazd	-0.80	0.78	0.04
West	Chaharmahal and Bakhtiyari	-0.05	0.12	0.05
	East Azarbayejan	-0.09	0.18	0.04
	Ilam	-0.49	0.41	0.13
	Kermanshah	-0.45	0.35	0.15
	Kohgiluyeh and Boyerahmad	-0.18	0.22	0.07
	Kordestan	-0.17	0.60	0.20
	Lorestan	-0.52	0.47	0.11
	West Azarbayejan	-0.06	0.15	0.04
Zanjan	-0.62	0.53	0.14	
South	Bushehr	-0.28	0.36	0.02
	Hormozgan	-0.58	0.60	0.03
	Countrywide elasticity	-0.11	0.51	0.02

Source: Findings of the study.

Nevertheless, the south or mountainous or border provinces (Chaharmahal and Bakhtiyari, Khorasan, Kohgiluyeh and Boyerahmad, East Azarbayejan, Kerman, Kordestan and West Azarbayejan) are less sensitive to energy price liberalization. The major reason for these differences is the geographic and strategic location of provinces. It means that provinces near the central regions of the country have access to cheaper modes of transportation, such as railroad transportation. Also, they are more industrial in nature, operating in the field of new and more efficient agricultural equipment in the center of the country. It is thus easier for them to discard the old

alternative energy equipment like electrical systems or agricultural machinery. On the other hand, in the other provinces, such as mountainous and border provinces, accessing the new alternative energy equipment is more difficult due to lack of cheap transportation and inadequate supply of the new and modern energy intensive machineries and systems. In other words, the accessibility to energy substitutes is easier for the mentioned provinces than others due to more communication facilities in the central parts of the country. A cheaper possibility of replacing new alternative energy equipment in the agricultural sector for the central provinces has been

emphasized in the study by Alipour *et al.* (2014) entitled “*Energy Price Liberalization in Iran, a Threat or an Opportunity for the Agricultural Sector?*”. Hence, the various provincial pollution changes will be undoubtedly as a result of different reactions to energy prices. These points out the importance of the own-price elasticity of demand, which has a direct correlation between reduction of energy consumption and emissions. It should be noted that because of constant energy conversion factors, changes in energy consumption is equivalent to pollutants emitted by that. Therefore, various provincial pollution changes after energy price liberalization is dependent on the rate of their energy price elasticity of demand.

Furthermore, results confirm that land and labour demand would increase by adding the energy price. The major energy consumption is dedicated to machinery activities in the Iranian agricultural sector. Hence, agricultural labour as one of the key inputs would increase to make up for the reduction in agricultural machinery consumption. Moreover, the demand for agricultural land is implicit (Kanlaya *et al.*, 2010) and is derived from its revenues and expenses. In other words, an increase in energy prices in Iran, will lead to a rise in operating expenses of agricultural land. With respect to this issue, along with the rising cost of production factors, including energy in the agricultural sector of Iran, it is natural that the price of agricultural production will consequently increase. Hence, it may increase the value of land. Energy price reform in Iran stipulates that the production sectors, including agriculture should receive at least 30% of total savings from the reform. This will help cover their high energy bill and finance buying more energy efficient equipment (Mosavi, 2016). Historical experiences have revealed that operating costs of agricultural land has been rising along with an increase in energy price. However, supporting the agricultural sector with deficiency payments has boosted the

costs. Therefore, rising energy prices will be accompanied by growth in demand for land.

It becomes possible to determine the changes in air pollutant emissions by having both energy demand functions and the relation of emissions and energy consumption. As it has been mentioned formerly, emission level decreases with a fall in energy consumption while energy price increases. In the other words, as the energy price increases, energy consumption decreases followed by a reduction in the emissions based on the own-price elasticity of energy.

Variations in Provincial Pollutant Emissions

The rate of change in the pollutants is reported in Table 2 for different reform scenarios. The pollutants level will progressively decrease with an increase in energy prices. The countrywide results show that total emissions would fall by about 19.1, 33.4, and 47.8% in different scenarios, respectively. It can be observed from the results that the reform would depend on the environmental qualities in different regions as well as the whole country. Enhancing the environmental qualities as a result of energy price reform can be interpreted as an improvement in socio-environmental welfare.

Also, different provinces are faced with dissimilar environmental welfare distribution while energy price increases. It is more appropriate to explain environmental welfare distribution between the provinces using economic measures, such as MAC. As mentioned before, a non-linear mathematical programming procedure was applied to estimate the IDF and MAC of the pollutants. After that, changes in MAC corresponding to the energy price liberalization scenarios were assessed. Increasing energy carrier prices would change the input demand especially energy and consequently, air pollutant emissions as well as agricultural production. Therefore, evaluating the

**Table 2.** Changes in total emissions by the provinces.

Geographical position	Provinces	Baseline (Ton)	Scenarios (Percent)		
			S ₁	S ₂	S ₃
North	Ardebil	252	-15.2	-26.5	-37.9
	Gilan	265	-16.9	-29.5	-42.2
	Mazandaran	1234	-24.9	-43.6	-62.2
	Semnan	175	-24.5	-42.9	-61.2
East	Kerman	533	-3.8	-6.7	-9.6
	Khorasan	243	-2.6	-4.5	-6.4
	Sistan and Baluchestan	397	-26.8	-47	-67.1
Central	Esfahan	682	-29.9	-52.2	-74.6
	Fars	1425	-26.7	-46.8	-66.8
	Hamadan	494	-26.7	-46.7	-66.8
	Markazi	412	-26.8	-46.9	-66.9
	Tehran	1145	-29.3	-51.3	-73.3
	Yazd	421	-31.9	-55.8	-79.7
West	Chaharmahal and Bakhtiyari	72	-1.8	-3.2	-4.6
	East Azarbayejan	509	-3.7	-6.4	-9.2
	Ilam	42	-19.4	-34	-48.5
	Kermanshah	218	-17.8	-31.2	-44.6
	Kohgiluyeh and Boyerahmad	48	-7.2	-12.6	-18.0
	Kordestan	50	-3.4	-7.0	-11.4
	Lorestan	259	-21	-36.7	-52.4
	West Azarbayejan	758	-2.6	-4.5	-6.4
Zanjan	246	-24.9	-43.7	-62.4	
South	Bushehr	70	-11.3	-19.8	-28.3
	Hormozgan	218	-23.1	-40.4	-57.8
	Countrywide measure	10630	-19.1	-33.4	-47.8

Source: Findings of the study.

environmental welfare changes would be possible.

Socio-Environmental Welfare Improvement

Table 3 shows the aforementioned amount of welfare changes. It is observable from Table 3 that MAC of emissions would rise by increasing energy carrier prices in the country, thereby increasing socio-environmental welfare. It is noteworthy to state that the aforesaid emissions are released from the agricultural sector. In other words, MAC increment which is due

to a reduction in energy consumption in the agricultural sector, promotes environmental welfare. These results were previously confirmed by the findings of Esmaeili and Mohsenpour (2010), Alipour (2013) and Alipour *et al.* (2014). Moreover, a remarkable distinction of this study compared to these previous studies is correlating the environmental aspect of energy price reform in Iran and also a regional analysis keeping the concept of MAC in mind. The nationwide MAC would rise (from 600 US\$ per ton) about 37.5, 87.5, and 195.4% in the different scenarios, respectively. In other words, for every

Table 3. Changes in MAC of pollutions.

Geographical position	Provinces	MAC (US\$)	Scenarios (Percent)		
			S ₁	S ₂	S ₃
North	Ardebil	603.1	39.8	78.5	131.7
	Gilan	542.1	44.1	89.5	155.4
	Mazandaran	162.1	60.0	144.8	316.2
	Semnan	868.8	73.5	166.4	349.5
East	Kerman	218.5	8.9	18.2	28.5
	Khorasan	714.4	5.8	14.1	23.2
	Sistan and Baluchestan	422.5	80.1	194.6	452.7
Central	Esfahan	202.3	88.6	233	637.2
	Fars	693.2	71.0	176.6	414.2
	Hamadan	135.9	68.8	169.4	394.3
	Markazi	290.6	71.6	166.4	397.3
	Tehran	178.1	84.2	226.5	611.6
	Yazd	317.6	98.8	263.2	819.1
West	Chaharmahal and Bakhtiyari	986.9	9.4	14.1	19.0
	East Azarbayejan	237.5	10.5	20.4	31.3
	Ilam	1242.4	49.6	100.6	180.0
	Kermanshah	812.5	38.0	77.3	135.9
	Kohgiluyeh and Boyerahmad	1121.1	21.3	35.2	51.1
	Kordestan	1106.3	75.1	196.7	586.9
	Lorestan	615.3	44.9	107.7	204.4
	West Azarbayejan	231.3	7.7	15.2	23.5
South	Zanjan	334.7	59.7	136.9	291.9
	Bushehr	1051.9	33.4	62.3	98.6
	Hormozgan	746.9	64.9	146.9	298.2
	Average Total Country	600.0	37.5	87.5	195.4

Source: Findings of the study.

percent increase in energy carrier prices, MAC will rise by more than one percent.

Comparing Tables 2 and 3, it should be pointed out that the baseline MAC changes in different scenarios in each province is due to differences in the overall impact of price elasticity of demand for all three inputs. Therefore, the reaction of provinces to the energy price liberalization is not just related to energy own-price elasticity of demand. The partial elasticity of substitution also influences MAC changes.

Generally, air pollutant emissions lessen as a result of a reduction in energy consumption in the agricultural sector. Diminishing air pollutants reinforces the

environmental absorption capacity and thereby an increase in the MAC of pollutants. Accordingly, abating the marginal costs of pollutants can be interpreted as socio-environmental welfare improvement since a greater reduction in emissions is associated with more MAC. These outcomes were also approved in previous studies, such as Hailu and Veeman (2000). Moreover, the studied provinces experience different rates of change in the level of emissions and MAC. Hence, the environmental output would be different due to elasticity differences among various provinces.



CONCLUSIONS

This study evaluated the effects of energy price liberalization on MAC of emissions in the Iranian agro-environment. Major aspects of this study were conducted as follows:

Firstly, the demand function of energy was estimated using the ISUR approach to obtain the inputs for the price elasticity of demand. Then, the changes in the input's demand as well as production level were determined in different energy price liberalization scenarios by implementing own and cross price elasticity of energy demand. Also, changes in emission levels in different energy price liberalization scenarios were determined. After that, the potential impacts of the reform on the MAC of emissions were calculated using IDF. Despite the fact that the energy price liberalization reduces energy consumption, the demand for land and labour increased. This is because these two major inputs to the agricultural sector can be interpreted as substitutes for energy in the Iranian agricultural sector.

Secondly, this study proved that the reaction of provinces to the energy price reformation would be different across the country. In addition, the results clearly asserted that the MAC of emissions rise progressively as a consequence of increasing energy prices in the agro-environment. On the other hand, energy price liberalization exponentially decreases energy consumption as well as air pollutant emissions. Indeed, each unit of decrease in air pollutants promotes environmental absorption capacity, which in turn leads to an increase in the MAC of pollutants. Generally speaking, alleviating air pollutants can be interpreted as improving socio-environmental benefits.

In this study, MAC increment is discussed as an interpretation of socio-environmental welfare increment while energy price increases. This interpretation lies in the concept of MAC, which refers to an improvement in the environmental absorption capacity. Nevertheless, social

benefits would not increase equally among provinces, which emphasizes that the provinces have certain characteristics which are different from each other. Increasing environmental gains are more obvious in the central provinces while less noticeable in the southern, mountainous, and border provinces. This fact is the result of demand elasticity diversification among provinces and their various incompressibility by the energy price increment. In other words, the geographic and strategic locations of the provinces would impact their reactions to energy price liberalization. This result emphasizes the importance of economic policies such as energy price reform, based on regional differences in the country.

In the end, it should be mentioned that although energy price reform (as an input) would decrease air pollution and increase environmental well-being, farmers' income and profit would be reduced by energy price increments. In other words, the opportunity cost of having less pollutants and more environmental gain, wipes out some part of farm benefits. Therefore, the reform should be accompanied by a package of supporting policies, to compensate for the reduction in the farmer's welfare. In this regard, it is strongly suggested to pay environmental subsidies to the agricultural sector with the same rate of improving MAC of emissions. Also, the environmental subsidies should be distributed, based on existing differences in MAC among provinces.

REFERENCES

1. Ahmad, I. and Lin, B. 2016. Energy Substitution Effect on Transport Sector of Pakistan Based on Trans-Log Production Function. *Renew. Sustain. Ener. Rev.*, **56**: 1182-1193.
2. Aigner, D. J. and Chu, S. F. 1968. On Estimating the Industry Production Function. *Am. Econ. Rev.*, **58**: 826-839.
3. Alipour, A. R. 2013. Energy Price Liberalization Effects on Marginal Abatement Costs of the Polluting and

- Greenhouse Gas in the Iranian Agricultural Sector. MSc. Dissertation of Agricultural Economics, Tarbiat Modares University.
4. Alipour, A. R., Mosavi, S. H and Khalilian, S., 2014. Energy Price Liberalization in Iran, a Threat or an Opportunity for the Agricultural Sector? *Appl. Econ. Stud. Iran*, **3(11)**: 219-238. (in Persian)
 5. Alipour, A. R., Mosavi, S. H. and Khalilian, S. 2014. Valuation of Carbon Dioxide Emissions Obtained from Agricultural Development in Iran. *Agri. Econ.*, **8(1)**: 104-125. (in Persian).
 6. Bijani, M. and Heyati, D. 2015. Farmers' Perceptions toward Agricultural Water Conflict: The Case of Doroodzan Dam Irrigation Network, Iran. *J. Agri. Sci. Tech.***17(3)**:561-575.
 7. Boluk, G. and Ali Koc, A. 2010. Electricity Demand of Manufacturing Sector in Turkey: A Translog Cost Approach. *Ener. Econ.*, **32(3)**: 609–615.
 8. Breusch, T. S. and Pagan, A. R. 1979. A Simple Test for Heteroscedasticity and Random Coefficient Variation. *Econometrica*, **47(5)**: 1287–1294.
 9. Christensen, L., Jorgenson, D. and Lau, L. 1973. Transcendental Logarithmic Production Frontiers. *Rev. Econ. Stat.*, February, **55(1)**: 28-45.
 10. Darijani, A., Yazdani, S., Sharzei, Gh., Sadralashrafy, M. and Peykani, G. 2006. Extraction of Shadow Prices of Environmental Pollutants: The Application of Output Distance Function. *J. Agri. Sci. Technol.*, **20(3)**: 176-165. (in Persian)
 11. Esmaeili, A. and Mohsenpour, R. 2010. Measuring the Shadow Price of Pollutants in the Iranian Electric Industry. *Econ. Res.*, **4(10)**: 69-86. (in Persian)
 12. Faber, M. and Proops, J. L. R. 1991. National Accounting, Time and the Environment: A Neo-Austrian Approach. In: Costanza, R. (ed.)1991
 13. Fare, R. and Grosskopf, S. 1990. A Distance Function Approach to Measuring Price Efficiency. *J. Public Econ.*, **43**: 123–126.
 14. Fare, R., Grosskopf, S., Lovell, K. and Pasurka, C. 1998. Multilateral Productivity Comparison When Some Products Are Undesirable: A Non-Parametric Approach. *Rev. Econ. Stat.*, **71**: 90-98.
 15. Fare, R., Grosskopf, S., Lowell, C. and Yaisawarng, S. 1993. Derivation of Shadow Prices for Undesirable Outputs: A Distance Function Approach. *Rev. Econ. Stat.*, **75**: 374-380.
 16. Gooday, R. D., Anthony, S. G., Chadwick, D. R., Newell- Price, P., Harris, D. Fish, Duethmann, R. Collins, A. L. and Winter, M. 2014. Modelling the Cost-Effectiveness of Mitigation Methods for Multiple Pollutants at Farm Scale. *Sci. Total Environ.*, **468–469**: 1198-1209.
 17. Griliches, Z. and Mairesse, J. 1993. Productivity Issues in Services at the Micro Level: A Special Issue of the Journal of Productivity Analysis. Boston: Klower Academic Publishers, 230p.
 18. Guillaume, D. and Roman, Z. 2010.Reducing the Staggering Costs of Cheap Energy. *Finance Dev.*, **47(2)**:39-41.
 19. Hailu, A. 2003. Pollution Abatement and Productivity Performance of Regional Canadian Pulp and Paper Industries. *J. For. Econ.*, **9(1)**: 5-25.
 20. Hailu, A. and Veeman, T. S. 2000. Environmentally Sensitive Productivity Analysis of the Canadian Pulp and Paper Industry. 1959–1994: An Input Distance Function Approach. *J. Environ. Econ. Manage.*, **40**: 251-274.
 21. Hausman, J. A. 1978. Specification Tests in Econometrics. *Econometrica*, **46**: 1251-71.
 22. Hessari, F. A. 2005. Sectoral Energy Consumption in Iran. *Renew. Sustain. Ener. Rev.*, **9(2)**: 203-214. (in Persian)
 23. Jacobsen, S. E. 1972. On Shepherd's Duality Theorem. *J. Econ. Theory*, **4**: 458–464.
 24. Kamel, H. 2015. Estimate of the Elasticities of Substitution of the CES and Translog Production Functions in Tunisia. *Int. J. Econ. Business Res.*, **9(3)**: 245-253.
 25. Kanlaya, J. B., Bruce, A. B., Miguel, C., Andre, N. and Leila, H. 2010. *Agricultural Land Elasticities in the United States and Brazil*. Working Paper 10-WP 505.
 26. Lechtenbohmer, S., Altmann, M., Capito, S., Matra, Z., Weindorf, W. and Zittel, W. 2011. *Impacts of Shale Gas and Shale Oil Extraction on the Environment and on*



- Human Health*. Report# IP/NENVI/ST/2011-07, Policy Department A: Economic and Scientific Policy, European Parliament.
27. Lee, C. and Zhou, Y. 2015. Directional Shadow Price Estimation of CO₂, SO₂ and NO_x in the United States Coal Power Industry 1990–2010. *Ener. Econ.*, **51**: 493-502.
 28. Lee, M. and Zhang, N. 2012. Technical Efficiency, Shadow Price of Carbon Dioxide Emissions, and Substitutability for Energy in the Chinese Manufacturing Industries. *Ener. Econ.*, **34**(5): 1492-1497.
 29. Ma, H. Oxley, L. Gibson, J. and kim, B. 2008. China's Economy: Technical Change, Factor Demand and Inter Factor/Inter Fuel Substitution. *Energy Econ.* **30**:2167-2183.
 30. Mosavi, S. H. 2016. Energy Price Reform and Food Markets: The Case of Bread Supply Chain in Iran. *Agr. Econ.*, **47**:169-179.
 31. Mosavi, S. H. 2014. Positive Agricultural and Food Trade Model with ad Valorem Tariffs. *J. Agric. Sci. Tech.* **16**: 1481–1492.
 32. Najafi Alamdarlo, H. 2016. Water Consumption, Agriculture Value Added and CO₂ Emission in Iran, Environmental Kuznets Curve Hypothesis. *Int. J Environ. Sci. Tech.* **13**(8): 2079-2090.
 33. Najafi Alamdarlo H., Ahmadian M. and Khalilian S. 2016. Groundwater Management at Varamin Plain: The Consideration of Stochastic and Environmental Effects. *Int. J Environ. Res.*, **10**(1): 21-30.
 34. Nasrnia, F. and Esmaeili, K. 2009. Causal Relationship between Energy and Employment, Investment and Value Added in Agriculture. *The 7th Conference of Iranian Agricultural Economics*, Tehran University, College of Agriculture and Natural Resources. (in Persian)
 35. Rasmussen, S. 2012. *Production Economics: The Basic Theory of Production Optimization*. Springer Science and Business Media Press, 292 PP.
 36. Recka, L. 2011. Shadow Price of Air Pollution Emissions in the Czech Energy Sector Estimation from Distance Function. Institute of Economic Studies, Faculty of Social Sciences, Charles University, Prague.
 37. Rodseth, L. K. 2013. Capturing the Least Costly Way of Reducing Pollution: A Shadow Price Approach. *Ecol. Econ.*, **92**: 16-24.
 38. Schmitt, L. H. M. 2016. QALY Gain and Health Care Resource Impacts of Air Pollution Control: A Markov Modelling Approach. *Environ. Sci. Policy*, **63**: 35-43.
 39. Shahidipour, G. R. 2011. Surveying the Relationship between Emissions, Energy Consumption and Value Added in Iranian Economic Sectors with Emphasis on the Elasticity of Pollution Severity. Master Thesis of Environmental Economics, Faculty of Economics, University of Tehran, Iran. (in Farsi)
 40. Shephard, R. W. 1970. *Theory of Cost and Production Function*. Princeton Univ. Press, Princeton, NJ.
 41. The Annual National Budget Act of the Islamic Republic of Iran. 2013. Iranian Parliament Research Center.
 42. Zellner, A. 1962. An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias. *J. Am. Stat. Assoc.*, **57**(298): 348-368.
 43. Zha, D. and Ding, N. 2015. Elasticities of Substitution between Energy and Non-Energy Inputs in China Power Sector. *Econ. Model.*, **38**: 564–571.

آزادسازی قیمت انرژی و هزینه کنترل گازهای آلاینده: شواهدی از کشاورزی و محیط زیست ایران

س. ح. موسوی، ع. علی پور، و ن. شهوری

چکیده

ایران یکی از کشورهای غنی از انرژی است که یارانه‌های انرژی قابل توجهی به منظور رشد بخش‌های مختلف و به ویژه در بخش کشاورزی پرداخت می‌نماید؛ به گونه‌ای که رشد بدست آمده به بهای تخریب محیط زیست تمام می‌شود. هدف پژوهش حاضر، بررسی اثرات بالقوه اصلاح قیمت انرژی بر ارتباط بین کشاورزی و محیط زیست ایران بر اساس مفهوم هزینه نهایی کنترل گازهای آلاینده (MAC) است. بنابراین در مرحله اول، تابع تقاضای انرژی در بخش کشاورزی و واکنش احتمالی نهاده‌ها و ستانده‌های بخش کشاورزی نسبت به آزادسازی قیمت انرژی برآورد شد. سپس، با استفاده از تابع مسافت نهاده (IDF) تغییرات هزینه نهایی کنترل گازهای آلاینده به تفکیک استان‌های کشور و نیز به صورت کلی برای کل کشور در سناریوهای مختلف اصلاح قیمت انرژی شبیه‌سازی شد. نتایج نشان داد که اصلاح قیمت انرژی با وجود آن که درآمد تولیدکنندگان بخش کشاورزی را تحت تأثیر قرار می‌دهد، باعث افزایش هزینه‌های نهایی کنترل گازهای آلاینده که به مفهوم ارتقای منافع زیست محیطی و اجتماعی است، خواهد شد. همچنین، نتایج بدست آمده در هر دو مقیاس ملی و استانی ارائه شده است. در نهایت، به منظور جبران کاهش درآمد بهره‌برداران بخش کشاورزی، اجرای سیاست‌های جبرانی در کنار اصلاح قیمت انرژی پیشنهاد شد.