Assessing the environmental impacts of energy price reform in Iran (Case Study: Isfahan)

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Abstract

The present paper studies impacts of changes of oil and its products' prices and economic growth on quality of the environment in Iran. Therefore, emission of carbon monoxide is regarded as the pollution index of environment and an Auto-Regressive Distributed Lag (ARDL) econometric model has been used to analyze relations among the variables. The required data has been exploited through energy balance sheets and the related statistical letters. It is considered seasonally for a selected region in Iran (Isfahan province) during the period 2005-2014. Obtained results demonstrate regional economic growth variable as well as population has a significant impact on quality of the environment in Iran under the current regional conditions and according to pollution haven theory. Moreover, it has been led to increased pollution of the environment. Also, changing and increasing of oil and its products' prices have had a significant and decreasing impact on regional environmental pollution in Iran. It is in a way that Iranian targeted subsidy plan has had a decreasing impact on pollution after one period. Given to the obtained coefficients through model estimation, however, this factor could not neutralize the impact of the other two variables.

Keywords: *oil price, regional growth, pollution, Auto-Regressive Distributed Lag Model (ARDL)*

1. Introduction

Except clean energies like the solar energy, consumption of many of energies has caused pollution. From this point, energies have negative externalities and according to the theories they must be taxed; however for a very long time the price of energy and specifically the prices of the fuels have been kept low that has led to pollution. It is expected that as the prices of the energy increase, this trend would be corrected.

On the other hand, the correction of the established technological, consumption and institutional structures based on cheap energies does not happen immediately and the complete effects of this correction will happen with lag. In fact, a structure of consumption and production, based on the cheap energies and specifically cheap oil products, has formed in the long run in the society of Iran; rearranging this structure according to the real relative prices cannot happen immediately. For example, according to the deviated prices of energies in the building sector, the development of this sector has happened with no attention to the phenomenon of the energy waste or at least it has been paid less attention. It is expected as the prices of the oil products and fuels increase and become more realistic in the consumption sector, the consumer shifts from choosing much-consuming energy goods to less-consuming energy ones.

Also in the production sector as the price one of the inputs like energy and/or oil products increase, it is expected that a shift from much-consuming energy technologies to less-consuming energy ones. Specifically, considering the combination of energy and capital in the technological structure of the production, the rearranged combination tends to using more capital for energy.

We, as well, know that the whole and per capita consumption of dirty energies and specially the hydrocarbon products is one of the factors of pollution. Therefore, this study aims to examine the effects of the correction of the prices of the oil products on the regional pollution levels according to empirical evidences.

2. The Theoretical Bases of the Study

2.1 Environmental pollution and economic growth

One of the known factors as a source of environmental pollution is economic growth. As the economic growth increases, the natural resources exploitation increases severely and undesirable externalities destroy the environment. In the economic theories the relationship between the economic growth and the environmental quality is dealt with as the environmental Kuznets curve (EKC). Simon Kuznets developed the environmental curve for the first time in "Economic growth and income inequality"(1955). He believes that over the course of economic development, the relationship between per capita income and income inequality shows the inverted U-shaped curve. According to this hypothesis, in the first phase of the economic development when the per capita income increases the inequality in income distribution raises and after a certain point or return point, the inequality in income distribution decreases gradually. In 1990s, some evidences of existence of an inverted U-shape relation between various indicators of environmental degradation and income per capita (like the relationship between per capita income and income inequality in the first Kuznets curve) were seen and thus the Kuznets curve entered the environmental studies and the inverted U-shape relationship between economic growth and pollution indexes (environmental quality) named environmental Kuznets curve. The first empirical study about EKC was done by Krueger and Grossman and titled "Environmental Impacts of a North America Free Trade Agreement" (1991) and study was a base for the next similar studies.

According to many of the environmental economists the logic for the existence of relationship between per capita income and the indicators of environmental degradation is reasonable intuitively. They believe that in the early phase of the industrialization process and considering the high priority of national product and employment levels in comparison to clean environment, the rate of natural resources and energies exploitation and thus pollution increase. In this phase, the economic firms cannot afford for the costs of pollution reduction because their per capita income is low and the environmental effects of economic growth would be neglected. However in the next phases of the industrialization process when the economy reaches a certain level of national per capita income and the per capita income increases, much importance and value would be paid to environmental quality. In these circumstances and considering the high importance of the environment, the related environmental institutions and organizations enact environmental laws and regulations and the economic firms can afford for financing the costs of technology changes to drive it to environment friendly technologies and pay the environmental taxes and charges on the other hand to reduce the environmental pollution indexes. In the other words, in this phase of economic development since the people treat the environment worthier and tend to pay for protecting and renewing it, the income elasticity of the demand for desirable environment is more than one and clean environment is assumed as a luxury good (Barghi and Behboudi, 2008).

Generally, the effects of economic growth on the environment can be explained as three growth effects:

- Scale effect: when the scale of production increases, given a certain level of technology and inputs composition proportion unchanged, the environment degradation increases, too.
- Inputs composition effect: when the share of the environmental-harmful inputs increases the destructive effect of the economic growth on the environment increases, too.
- Technology effect: when the production productivity increases then the amounts of environmental inputs usage in production decreases. Technological advances decrease the production wastes and environmental degradation (Stern, 1998).

2.2 Environmental Pollution and Population

In the literature of the environmental economics, the population growth is assumed as one of the factors of environmental degradation. When the population number grows, the demand for agricultural land, energy sources, water sources and … increases and this increased demand destroy the forests, decrease the fertility of agricultural land, pollute the air and Many researchers using time series and sectional statistical data studied these implications for developed countries and in international levels. The findings of their studies show that the human factor and population growth are among the main factors of environmental degradation (Sadeghi and Saadat, 2004).

There are two opinions about the relationship between the urban population and environmental pollution. The first believes that the effect of the urban population on the environmental pollution is positive, because as the urban population increase more infrastructures, transportation and energy are used and shifting from agriculture to industry increases the environmental pollution, too. However, the second opinion emphasizes that urban culture cause energy use to become more efficient in the cities than the villages and thus the environmental pollution decrease. So, the relationship between the urban population and environmental pollution can be positive or negative (Alam and Butt, 2007).

2.3 Environmental Pollution and Energy Consumption

Economic literature reveals a strong relationship between economic activities level (economic growth) and energy consumption, because the energy is the motor power of most of the productive and service activities and it has a high rank in the economic growth and development. Ecological economists like Ayres and Nair believe that in the biophysical model of growth, energy is the only and most important factor of growth. They believe that labor and capital are intermediate inputs which need energy to be used (Stern, 2004).

Most of the neoclassical economists like Brandt and Denison do not agree with the ecological economists. They believe that the energy through its effect on the capital and labor, affect the economic growth indirectly and it has no direct effect on the economic growth. Most of the neoclassical economists substantially believe that the energy has a minor role in the production, it is an intermediate input and labor, capital and land are the main inputs (Stern, 1993).

However, the excessive consumption of energy and specially the fossil fuels to achieve the economic growth goals and insufficient efficiency in energy consumption cause the environmental pollution to increase so that one of the important factors of air pollution is carbon dioxide (the main greenhouse gas) that its emission is resulted from the fossil fuels burning in production, commercial, service and housing sector (Alam and Butt, 2007).

Mayer and Kent studied the relationship between energy consumption and environmental degradation and believe although after the industrial revolution and specifically over the recent decades which the energy consumption increased, the average production factors' productivity raised but the pollution implications of energy consumption caused environmental degradation since most of the emitted greenhouse gases in the world is carbon dioxide which is resulted from fossil fuels consumption. This is why the energy has the biggest share in the environmental changes and problems; therefore energy policy and environment policy have very close relationship (Shim, 2006).

3. The Literature

One of the most important studies in this field has been done by Grossman and Krueger (1991) that shows an inverted U-shaped relationship between the two variables economic growth and environmental pollution. Shfik and Bendio Padsi (1992) using time series data did empirical studies which confirmed Grossman and Krueger finding about the environmental Kuznets curve (EKC) theory (Pana, 2000).

Roca, Farre and Galletto (2001) examined the environmental Kuznets theory for some air polluters in Spain and found that the level of SO2 emission is consistent with the environmental Kuznets theory. However there was not such a consistency about the other polluters.

Tol and Socolow (2006) studied the long term relationship between energy consumption and carbon dioxide emission in USA for the period 1850 – 2002. Their findings showed over this period CO2 has emission increased due to increase in fossil fuels consumption and economic growth and population growth have contributed to CO2 emission, too.

Alam and Butt (2007) studied the determinant factors of environmental pollution in Pakistan for the period 1971 – 2005. Their findings showed that gross domestic production (GDP) increase and energy consumption intensity have caused the environmental pollution to increase.

Song, Zheng and Tong (2008) estimated Kuznets curve for China. They used the data of twenty nine provinces of China for the period 1985–2005 to estimate three Kuznets curves for the relationship between per capita income (based on gross domestic product) and per capita polluters respectively gas polluter, water polluter and solid waste. Cointegration test (using pooled data) showed there is a long term cointegrated relationship between the three per capita polluters and per capita GDP. Their findings showed also all three polluters confirm the inverted U-shape curve hypothesis.

Iwata and Sovannroeun (2009) studied the existence of environmental Kuznets curve in France empirically and included the nuclear energy variable in the first time and included the econometric autoregressive distributed lag (ARDL) variable in the second time in the tests. The findings of their study showed the existence of environmental Kuznets relationship and using nuclear energy can help decreasing carbon dioxide emission in France.

4. The Methodology

All the used micro data in this study for the period 2005-2014 time series are quarterly data and Microfit 4.0 software has been used for regression computations. The statistical data needed for estimating the model were collected from the environment protection department of Isfahan province, energy balance sheet and annual statistical data of Isfahan municipality.

The indexes of environmental sustainability are environmental policies (water quality, air quality …), decreasing environmental pressures and decreasing human destruction. However since the statistical data of air pollution were available only, this index was used for environmental degradation.

The main air polluters are carbon monoxide, hydrogen, sulfur oxides, carbon dioxide, floating particles in air and ozone. Carbon monoxide emission is used as the pollution index (dependent variable) in this study.

According to energy balance sheet department of the ministry of power the gasoil gains the largest amount of the paid subsidy for fuels, it is used as energy index.

4.1 The Model

Our model based on the Ishi's[1] study is specified as follow:

$$LCO_t = \alpha_0 + \beta_1 LGDP_t + \beta_2 LPOP_t + \beta_3 LP_t + U_t \qquad (1)$$

Where,

LCO = logarithm of carbon monoxide emission
$LGDP$ = logarithm of the city gross product
P = energy price adjustment index
$LPOP$ = logarithm of Isfahan city population
That α0 is equal to the model's intercept.
β1 illustrates LGDP elasticity with respect to LCO.
β2 illustrates LPOP elasticity with respect to LCO.
β3 illustrates LP elasticity with respect to LCO.

4.2 Unit Root Test

To be sure about the results of the study, the stationarity of the variables must be tested and the error correction model specified.

A stochastic process is stationary when its average and variance are constant over the time and the covariance value between two time periods is dependent only on the lag between the two time periods and it is not dependent on the real time of the covariance computation.

Nonstationary variables make the F and t tests invalid and the regression spurious. So it is necessary to test the stationarity of the variables, at first.

There are different tests for identification the stationarity of the variables; unit root test is one of them. However, one problem with this test is that the t statistic does not have normal distribution even in large samples and t critical values cannot be used for test. To avoid this problem, the augmented Dicky-Fuller (ADF) test is used. To do this test, the following equations must be solved and then the verification of null hypothesis is done.

$$\Delta Y_t = \delta Y_{t-1} + \theta_i \sum_{i=1}^{m} \Delta Y_{t-1} + \varepsilon_t$$

$$\Delta Y_t = \alpha + \delta Y_{t-1} + \theta_i \sum_{i=1}^{m} \Delta Y_{t-1} + \varepsilon_t$$

$$\Delta Y_t = \alpha + bt + \delta Y_{t-1} + \theta_i \sum_{i=1}^{m} \Delta Y_{t-1} + \varepsilon_t \qquad (2)$$

In these equations δ is $\rho - 1$ and the null hypothesis (unit root exists and the variable is not stationary) is $\delta = 0$ or $\rho = 1$ and the alternative hypothesis (the variable is stationary) includes $\delta < 0$ and $\rho < 1$. Also in estimating these equations, the number of necessary lags for the dependent variables to eliminate the autoregression between error terms of the regression is determined by Akaik information criterion (AIC), Schwarz-Bayesian criterion (SBC) and Hannan-Quinn criterion (HQC).

According to table 1, the variables LCO and LGDP at level are stationary but for the variables LP and LPOP, the

[1] *Ishi et al (2010)*

absolute value of computed ADF is smaller than MacKinnon critical values and they become stationary after one time differentiation.

Table 1: Summary of the results of Augmented Dicky-Fuller unit root test

	variable	stationarity	Computed ADF	1%	5%	10%
At level	Lco	Intercept and trend	-0.73486	-4.180911	-3.51552	-3.18825
	Lgdp	Intercept and trend	-6.56616	-4.165755	-3.50850	-3.184229
	Lp	Intercept and trend	-0.33007	-4.165755	-3.508507	-3.184229
	Lpop	Intercept and no trend	-3.18551	-3.185512	-3.185512	-3.185512
Differentationed one time	dlp	Intercept and no trend	-7.40788	-4.170582	-3.510739	-3.185512
	dlpop	Intercept and trend	-148.0991	-3.592461	-2.931404	-2.603943

4.3 Vector Autoregressive Distributed Lag Method

Engel–Granger cointegration method has many restrictions. The estimations made by this method in the small samples are biased. Also, the limit distribution of least square estimators is not normal and therefore, testing hypotheses by such ordinary statistics is invalid. Engel–Granger method is based on the assumption of the existence of one cointegration vector a priori and in circumstances that there is more than one cointegration vector, using this method leads to inefficiency. Due to these restrictions for Engel–Granger method, one can uses other methods like augmented lag vector autoregressive method to remove the mentioned restrictions. This method is interested because of using schemes with short run dynamics that make more precise estimations possible. Generally, a dynamic scheme is one that the lags of variables have a relationship as follows:

$$Y_t = aX_t + bX_{t-1} + cY_{t-1} + u_t \qquad (3)$$

To reduce the biasness of model coefficients estimation in small samples, it is better to use a model with as many as possible number of lags like relationship (2):

$$\Phi(L,P)Y_t = \sum_{i=1}^{k} b_i(L,q)X_{it} + c'w_t + u_t \qquad (4)$$

This scheme is an autoregressive distributed lag (ARDL),

$$\Phi(L,P) = 1 - \Phi_1 L - \Phi_2 L^2 - \ldots - \Phi_P L^P$$
$$b_i(L,q) = b_i + b_{i1}L + \ldots + b_{iq}L^q \qquad i = 1,2,\ldots,K \qquad (5)$$

Where, L lag operator, w a vector of constants like intercept, virtual variables, time trend or exogenous variables with fix lag. The Microfit software solves the equations for all forms and all possible arrangements of values, that is, the number of estimations made is $(m+1)^{k+1}$. m is the maximum number of the lags determined by the researcher and k is the number of explanatory variables.

Finally, according to one of Akaik, Schwarz-Bayesian, Hannan-Quinn or adjusted coefficient of determination (adjusted R^2) criteria, one of the equations is chosen. In samples smaller than 100, Schwarz-Bayesian criterion is used to avoid the reduction of the number of degrees of freedom.

In the autoregressive distributed lags model estimation process, the results of short run dynamic model is presented first in table 2 in which the optimum lags number according to Schwarz-Bayesian criterion is ADRL (1, 1, 2, 1).

Table 2: Results of short run dynamic model estimation ADRL (1, 1, 2, 1)

variable	coefficient	standard deviation	t statistic	Prob
Lco(-1)	-0.20531	0.24943	-0.82312	0.438
Lgdp	0.109129	0.048864	2.233329	0.021
Lgdp(-1)	0.92603	0.24177	3.8301	0.006
Lp	-0.13924	0.0.0888	-1.5667	0.161
Lp(-1)	-0.075573	0.0355799	-2.124033	0.0442
Lp(-2)	0.46187	0.18863	2.4485	0.044
Lpop	0.155515	0.0649241	2.395334	0.014
Lpop(-1)	0.163408	0.0633487	2.579510	0.005
C	15.26231	14.59539	1.045694	0.348
R^2=0.89910	D.W=1.68	Prob-f=0.000009		

According to the results reported in table 2, there is a significant and positive relationship between economic growth and Isfahan city population and carbon monoxide emission; also the significance of population lag shows that the population variable effect happens over the time and as the urban population increases and degrades the environment.

The relationship between the energy price and environmental degradation shows that the effect of energy price adjustment on the carbon monoxide emission over the time is insignificant and after one lag it is negative and significant; that is, when the price of energy increase the pollution decrease after one time period although this coefficient is very small and as the price of energy raises one percent, carbon monoxide emission decrease .75%.

F statistic shows the overall significance of the regression is accepted at a high level of confidence and the null hypothesis that all the coefficients are zero can be rejected.

Since the dependent variable with lag is included in the model as an independent variable, Durbin-Watson d statistic cannot be used for verifying the autocorrelation between error terms; so Durbin-Watson h statistic is used which is calculated by Microfit software as default. The value of this statistic is .956 and it is between ± 1.96, so there is no correlation with .95 percent probability.

Diagnostic tests are done for checking classical assumptions violation; the results presented in table 3.

Table 3: Results of diagnostic Test

Diagnostic Test		
Test Statistics	LMVersion	FVersion
Serial Correlation	8.7699(0.067)	1.9820(0.134)
Functional Form	1.16801(0.682)	0.12668(0.725)
Normality	1.0687(0.586)	Not applicable
Heteroscedasticity	1.8637(0.172)	1.8552(0.183)

LM statistic is used for verifying serial autocorrelation in models including dependent variable with and without lagged values. According to the estimated value for this statistic at 5% error and comparing it with the least level of significance, the null hypothesis that there is no correlation cannot be rejected. Also according to this statistic for verifying the correct or incorrect functional form, the null hypothesis that the functional form is correct can be accepted, that is, the model is specified well.

LM statistic is used for verifying the normality of residual terms and according to the estimated value for this statistic at 5% error, the null hypothesis that the residual terms have normal distribution is accepted and thus there is no Heteroscedasticity problem.

To be sure about that the long run relationship is not a spurious one, it is tested by a method developed by Pesaran.

Pesaran, Shin and Smith (1999) proposed the "bounds test" for testing these hypotheses. In this method there are two bounded values for each test (according to the number of the variables). The lower bound is computed as all the variables are zero order integrated and the upper bound is computed as all the variables are first order integrated. If the estimated F statistic value for the hypotheses becomes larger than the upper bound, then the null hypothesis can be rejected and the existence of long run relationship is accepted.

The estimated F statistic value is 5/0022 and it is larger than upper bound at 90 percent confidence level (table of the critical values, Pesaran, et al, 1999) 4/788. So, the null hypothesis is rejected and long run relationship is accepted.

According to the results (that presented in table 4), there is a positive significant long run relationship between carbon monoxide emission and economic growth and urban population growth and as the economic growth and urban population increase, the environmental degradation increases, too. Since the significance level of energy price variable is less than 0.05, its coefficient is significant at 95 percent probability. And for each percent increase in energy price, environmental pollution decrease 0.15%.

Table 4: Results for long run model estimation

	coefficient	Standard deviation	t statistic	Prob
Lgdp	0.20877	0.08782	2.37735	0.0375
Lpop	0.21130	0.09858	2.14334	0.0449
Lp	-0.15479	0.06723	-0.76979	0.030

4.4 Error Correction Model

The variables of the model can be cointegrated and convergent but it is possible that these variables become disequilibria in short run. So, the error term can assumed as "equilibrium error". This error included to relate the short run behavior of the dependent variable to its long run equilibrium value. For this purpose, the following error correction model is used:

$$\Delta Y_t = \lambda_0 + \alpha_0 \Delta x_{1t} + \alpha_1 \Delta x_{1t-1} + \alpha_2 \Delta x_{1t-2} + \ldots + \beta_0 \Delta Y_{1t} + \beta_2 \Delta Y_{1t-2} + \ldots + \delta ECM_{t-1} \quad (6)$$

The value of δ shows how much the deviation and disequilibrium of Y in one period is adjusted (corrected) in the next period. The larger value of deviation, correction and returning back to long run equilibrium happens faster.

Table 5: Results for ECM estimation

	coefficient	Standard deviation	t statistic	Prob
Dlgdp	0.16070	0.06599	2.435	0.023
Dlp	-0.15970	0.05593	2.855	0.012
Dlpop	0.15165	0.07323	2.0709	0.048
Dc	27.3301	27.2247	1.0039	0.324
Ecm	-0.66975	0.24518	-3.1396	0.004
	R^2=0.71	D.W=1.9165	F=0.000	

The results of error correction model estimation for the long run relationship are presented in table 5; error correction coefficient 0.669 is significant. Therefore, if any deviation happens in the long run relationship, then correcting the error takes two periods. Estimated Durbin-Watson statistic value 1.91shows there is no serial autocorrelation between error terms.

5. Conclusions

Energy consumption, production (national income) and (air) pollution, all are parts of the production system of the economy. The findings of this study about the possible relationships between these variables make it possible to know the nature of the mentioned variables and the relationship between the emission of the polluters and economic growth and also how to find and develop more efficient ways for energy consumption to achieve economic growth and goals.

The findings of this study show a positive and significant relationship between economic growth and urban population growth of Isfahan city and carbon monoxide emission which is expected theoretically. The relationship between environmental quality shows that the effect of energy prices adjustment on the carbon monoxide emission with one lag is significant and negative; that is due to the formation of energy consumption structure according to unrealistic relative prices and thus technologic and structural lags, it takes one period to happen the effect of the energy prices adjustment on the energy consumption and then on the pollution.

References

Alam, S., Fatima, A., & Butt. M. (2007). Sustainable development in Pakistan in the context of energy consumption demand and environmental degradation. *Journal of Asian Economics*, Vol. 18, Issue 5, 825-837

Behboudi, D., & Barghi, A. (2008).Environmental impacts of energy consumption and economic growth in Iran. *Quarterly Journal of Quantitative Economics*, Vol 20, Issue 6, 25-45

Grossman, G.M., & Kruger, A.B. (1991). *Environmental Impact of the North American free trade agreemen*t. The us Mexico Free Trade Agreement, ed.P.Garber, Cambrifge, MA: MIT Press

Ishii, S., Tabushi, S., Aramaki, T., & Hanaki, K. (2010). Impact of future urban form on the potential to reduce greenhouse gas emissions from residential, commercial and public buildings in Utsunomiya, Japan. *Energy Policy*, Vol.38,4888–4896

Iwata, H., Okada, K., & Sovannroeun, S. (2009). Empirical Study on the Environmental Kuznets Curve for CO2 in France: TheRole of Nuclear Energy. *Journal Energy Policy*, Vol.38, Issue8, 4057-4063

Pana, Y. (2000). The Economic Growth and Environmental. *Working Paper 56*, Harvard University

Roca, J., Padilla, E., Farré, M., & Galletto, V. (2001). Economic growth and Atmospheric pollution in Spain: Discussing the environmental Kuznets curve Hypothesis. *Ecological Economics*, Vol. 39, No.1,85-99

Sadeghi, H., & Saadat, R. (2004). Population growth, economic growth and environmental impacts in Iran. *Economic Research Journal(journal of University of Tehran)*,Vol 14, No 23, 58-78

Shim, J.H. (2006). The Reform of Energy Subsidies for the Enhancement of Marine Sustainability: An Empirical Analysis of Energy

Subsidies Worldwide and an In-Depth Case Study of South Korea's Energy Subsidy Policies. *Journal of Asian Economics*

Song, T., Zheng, T., & Tong, L. (2008).An Empirical test of the environmental Kuznets Curve in China: A panel cointegration approach**.** *China Economic Review*, Vol 19, Issue 3, 381–392

Stern, D.I. (2004). Energy and Economic Growth, *Rensselaer Working Paper*, No 0410

Stern, D.I. (1998). Progress on the Environmental Kuznets curve. *Environment and Development Economics*, Vol.3, Issue 2, 173-196

Stern, D.I. (1993).Energy and Economic Growth in the USA: A Multivariate Approach. *Energy Economics*, Vol.15, Issue 2, 137–150

Tol, R., Pacala, S., & Socolow, R. (2006).Understanding Long-Term Energy Use and Carbon Dioxide Emissions in the USA. *Working Papers*,University of Hamburg