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Maritime Transportation, Environmental Pollution, and Economic Growth in Iran: Using Dynamic Log Linear Model and Granger Causality Approach

Saeed Mohamad Taghvaee*[1], Behrouz Omaraee[2], Vahid Mohamad Taghvaee[3]

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Abstract

The main purpose of this study is to estimate the maritime transportation elasticities of the environmental pollution and economic growth in Iran within the short-run and long-run to find out the relationships among maritime transportation, environmental pollution and economic growth. The lagged endogenous model (a dynamic log-linear model that we used) is estimated using two distinctive approaches: single-equation one with OLS and simultaneous-equations with GMM. The results of both methods unanimously show that the maritime transportation elasticities of both environmental pollution and economic growth are low and positive just like the economic growth elasticities of environmental pollution. Therefore, environmental pollution has a positive relationship with the maritime transportation and economic growth, confirming the Pollution Haven Hypothesis; and the economic growth responds to the maritime transportation slightly and slowly. The policy-makers are advised to improve the environmentally-polluting infrastructure of the maritime transportation rather than restricting the growth of this sector.

Keywords: Maritime Transportation, Environmental Pollution, Economic Growth, Trade, CO2 Emissions.

JEL Classification: C22, Q18, Q44.

1. Introduction

The global warming, if not global burning, is a dire warning about environmental pollution dangers to everyone, living on the Earth including environmentalists, literati, politicians, and religious people

1. Ports and Maritime Organization, Bushehr Ports and Maritime Authority, Bushehr, Iran (Corresponding Author: taghvaee.saeed@gmail.com).

2. Department of Maritime Transportation, Islamic Azad University of Khark, Bushehr, Iran (b.omaraee@ics.org.ir).

3. Department of Economics, Persian Gulf University, Bushehr, Iran (vtaghvaee@mehr.pgu.ac.ir).

(Taghvaee & Parsa, 2015). “Nobody on the planet will be untouched by climate change”, said Rajendra K. Pachauri, the chairman of the Intergovernmental Panel on Climate Change (IPCC) in a press conference in Japan in 2014 after the meeting on the IPCC report. In the next year, Carol & Duffy composed the subsequent poem “What have you done; with what was given you; what have you done with; the blue, beautiful world?” (Duffy, 2015). In the same year, Francis said “This sister now cries out to us because of the harm we have inflicted on her by our irresponsible use and abuse of the goods with which God has endowed her” and he mentioned “a seedbed of collective selfishness” to the global warming (Francis, 2015). Moreover, Barak Obama, the US president said “Today, there is no greater threat to our planet than climate change” (Obama, 2015). This great threat is deeply rooted in the economic activities such as maritime transportation.

Maritime transportation plays an important role in both the environmental pollution and economic growth, especially in the developing and oil-exporting economies, linked to the open sea like Iran. This transportation mode emits a high rate of Carbon Dioxide (CO2), although it provides an effective channel to conduct the international trade. Many believe that ships increase the CO2 emissions since they carry the huge bulk of cargos, which requires a tremendous amount of energy, leading to greenhouse gas emissions (Taghvaee & Hajiani, 2015). However, the others claim that sea transportation decreases the CO2 emissions owing to its higher capability of carrying bulk cargos, compared with the other transportation modes. The direction and intensity of the relationship among maritime transportation, environmental pollution, and economic growth play a helpful role in the environmental and economic policy-making.

On the one hand, maritime transportation expands the CO2 emissions. Many studies believe that the vessels are considered as a main source for CO2 emissions (European Sea Ports Organization, 2010; Gibbs et al., 2014; International Association of Ports and Harbors, 2007). Compared with the other transportation modes, ships are carrying hugest amount of cargos, which needs to burn a high level of fuel leading to emit a considerable rate of CO2 emissions

(Taghavee & Hajiani, 2016). Moreover, maritime transportation is the origin of about 2.2% CO2 emissions made by human activities in the world in 2012 (International Maritime Organization, 2016). Based on the Pollution Haven Hypothesis, trade openness increases the environmental pollution in the developing countries like Iran (Tang, 2015; Almulali & Tang, 2013). Since maritime transportation is a channel, through which the international trade is conducted towards Iran, indirectly heightening the environmental pollution in the country. On the other hand, maritime transportation lowers the CO2 emissions. Although ships burn a large amount of energy, which causes CO2 emissions, they are transporting the largest volume of cargos among the other kinds of vehicles. From energy-consumption-perspective, it implies the high efficiency of the maritime transportation mode (United Nations Framework Convention on Climate Change, 2014). Which relationship is the dominated one in Iran?

The above-mentioned issues launch the stronger challenges in the developing and oil-exporting economies, linked to the open sea like Iran. Due to the more threatening status of developing countries in the environmental and economic issues, this challenge needs more attention in Iran (Taghavee et al., 2016; Taghvaee & Shirazi, 2014). Furthermore, the economy of Iran is based on the environmentally polluting industry of fossil fuels like oil and gas needing super tankers to carry. It severs the link among maritime transportation, environmental pollution, and economic growth in Iran. Therefore, the direction and intensity estimations of the relationship among maritime transportation, environmental pollution, and economic growth guide the environmentalists and economists through policy-making in the maritime transportation of Iran.

The main purpose of this study is to estimate the maritime transportation elasticities of the environment and economy of Iran in the short-run and long-run to find out the relationship between maritime transportation on the one hand, and environmental pollution and economic growth on the other hand. These relationships in short- and long-run provide the policy-makers with the broader perspective on their strategies with regard to their periods, short- and long-term plans. In this case, they are likely suggested to develop relatively distinctive policies within various time-spans. The rest of the paper is as follows: the next section reviews the methodology and models; the third section deals with the data; the fourth section explains the results; the fifth section is a discussion about the subject and the results; and the final part is the conclusion.

2. Methodology

The elasticities of environmental pollution and economics growth are estimated in two intervals, short-run and long-run, in Iran during 1978-2012, using one dynamic log-linear model including two equations. These equations are estimated with two various approaches: A) single-equation approach with Ordinary Least Squares (OLS); and B) simultaneous-equations approach with Generalized Method of Moments (GMM). Each approach produces two kinds of elasticities: 1) explicit elasticities; and 2) full elasticities including both explicit and hidden effects. Before the estimation of coefficients, the variables are put into the Augmented Dickey-Fuller (ADF) test and Granger causality test. The former estimates the stationarity degree of the variables to avoid the threat of spurious regression; and the latter detects those variables, which have causal relationship with the environmental pollution and those, which have causal relationship with the economic growth. It is highly beneficial for the model specification. After the estimation of coefficients, the estimated residual series are checked for the econometric classical-assumptions to analyze the reliability of the estimated coefficients.

Augmented Dickey-Fuller (ADF) unit root test put the variables to the stationarity test, avoiding the spurious regression threat. Regression of none-stationary variables might produce unreliable coefficients and statistics. The regression is spurious if the integration degrees of the variables are neither zero nor similar. ADF is used to find the integration and stationarity of the variables. (Dickey & Fuller, 1979; Greene, 2012; Gujarati, 2004)

Granger causality test is to find which causes which, helping the model specification (Arvin et al., 2015). Theoretically, this study considers two possible variables, playing the role of endogenous variable for CO2 emissions as the dependent variable, maritime transportation and GDP (see European Sea Ports Organization, 2010; Gibbs et al., 2014; International Association of Ports and Harbors, 2007; International Maritime Organization, 2016). It considers two possible variables, playing the role of endogenous variable for GDP as the dependent variable; maritime transportation and trade volume (see Tang, 2015; Almulali & Tang, 2013). It determines those variables, which have the causal relationship with environmental pollution and those, which have causal relationship with the economic growth (see Farhani et al., 2014; Granger, 1969; Sims, 1972; Greene, 2012; Gujarati, 2004; Omri et al., 2015). Then the actual endogenous variables are put into the corresponding models and the variables without causal relationship are removed from. Therefore, CO2 and GDP functions are theoretically as follows:

$$CO_2 = f\,(M,Y) \tag{1}$$

$$Y = f\,(M,TR) \tag{2}$$

where CO_2 is environmental pollution, M is maritime transportation, Y is economic growth, and TR is trade openness. Finally, we estimate the coefficients using two distinctive approaches: single-equation one with OLS and simultaneous-equations one with GMM. In the former, each equation is regressed separately to estimate the coefficients and statistics, while in the latter, both the equations are regressed simultaneously as a whole system for the estimation of coefficients and statistics. These elasticities show the direct or explicit effects of maritime transportation and economic growth on environmental pollution; and maritime transportation and trade volume on economic growth, which are as follows respectively:

$$EE_{CO2.M} = \frac{\%\Delta \mathrm{CO2}}{\%\Delta \mathrm{M}} \tag{3}$$

$$EE_{CO2.Y} = \frac{\%\Delta \mathrm{CO2}}{\%\Delta \mathrm{Y}} \tag{4}$$

$$EE_{Y.M} = \frac{\%\Delta \mathrm{Y}}{\%\Delta \mathrm{M}} \tag{5}$$

$$EE_{Y.TR} = \frac{\%\Delta \mathrm{Y}}{\%\Delta \mathrm{TR}} \tag{6}$$

where EE is the explicit elasticity as $EE_{CO2,M}$ shows the maritime transportation explicit elasticity of environmental pollution; $EE_{CO2,Y}$ is the economic growth explicit elasticity of environmental pollution; $EE_{Y,M}$ is the maritime transportation explicit elasticity of economic growth; $EE_{Y,TR}$ is the trade explicit elasticity of economic growth; and

%Δ presents the percent changes of a variable. It is worth mentioning that these changes are directly made by the independent variable according to what we have studied in the previous studies. However, we introduce another dimension of elasticity concept to open a new horizon to elasticity concept as implicit elasticity. After the estimation of explicit elasticities by running the two equations, we plug the estimated equation 2 in equation 1 to estimate the implicit effects on environmental pollution. This produces what we refer to as implicit elasticities. It is the appellation as they show the implicit, indirect, or hidden effect of the independent variable on the dependent one; so they can be named as implicit, indirect, or hidden elasticities. They are mathematically described as below:

$$IE_{CO2.M} = \frac{\%\Delta \mathrm{CO2}}{\%\Delta \mathrm{Y}} \times \frac{\%\Delta \mathrm{Y}}{\%\Delta \mathrm{M}} \tag{7}$$

$$IE_{CO2.TR} = \frac{\%\Delta \mathrm{CO2}}{\%\Delta \mathrm{Y}} \times \frac{\%\Delta \mathrm{Y}}{\%\Delta \mathrm{TR}} \tag{8}$$

where $IE_{CO2.M}$ shows the maritime transportation implicit elasticity of environmental pollution; and $IE_{CO2.TR}$ is the trade one. In more details, they represent how much the change in CO2 emissions can be explained by maritime transportation or trade volume indirectly through changes in economic growth, rather than their direct or explicit effects. Therefore, we can introduce another proxy for elasticity as full elasticity including both explicit and implicit elasticity, which is more comprehensive than what is studied in the previous researches yet. The full elasticity can be mathematically described as below:

$$FE_{CO2.M} = \left(\frac{\%\Delta \mathrm{CO2}}{\%\Delta \mathrm{M}}\right) + \left(\frac{\%\Delta \mathrm{CO2}}{\%\Delta \mathrm{Y}} \times \frac{\%\Delta \mathrm{Y}}{\%\Delta \mathrm{M}}\right) = (EE_{CO2.M}) + (IE_{CO2.M}) \tag{9}$$

where $FE_{CO2.M}$ is maritime transportation full elasticity of environmental pollution. By introducing this new concept, we are aiming to investigate the maritime transportation effect on CO2 emissions in a more comprehensive way. Not only does it show the direct environmental effects of maritime transportation under the title of explicit elasticity, but also it covers the indirect ones under the title of implicit elasticity since maritime transportation might affect economic growth which in turn can cause effect on environmental pollution. In this way, we analyze the maritime transportation effect on environmental pollution from a broader perspective. Although the trade implicit elasticity on environmental pollution is estimated, the explicit one is left. Before these estimations, the variables of model are described and analyzed in the following section.

3. Data

This study employs the annual time series dataset during 1978-2012 due to the unavailability of data for the recent years.

All the data are derived from various versions of World Development Indicator, except for the maritime transportation, which is come from the economic time series database of the Economic Research and Policy Department of Iran. The per capita sea transportation of goods, as the maritime transportation proxy and measured in ton, is the sea transportation of goods divided by the total population, derived from the same database; the per capita CO2 emissions, measured in metric ton, is the proxy for the environmental pollution; the per capita GDP, measured in the constant 2005 US Dollar, is the proxy for the economic growth; and trade, measured as the percentage of GDP, is the proxy for trade openness. All the data are in natural logarithm.

As shown in the appendices, the GDP and CO2 processes are both autocorrelation of degree one or AR(1). In the correlogram of an AR(p) process, the autocorrelation decays exponentially and the partial autocorrelation shows the significant spikes through lags p. Since both the GDP and CO2 follow the mentioned pattern for the first lag, they are the process of AR(1), implying that they are the function of their own quantities in the last period. It proposes a dynamic model- specification (Dahl & Sterner, 1991; Gujarati, 2004).

Regarding figures 1 and 2, both the CO2 and GDP show a downward trend in the first years and an upward one in the later years. They are decreasing until 1988 and since then they are increasing, except for the years 1981-1988, which the patterns are different. Irrespective of the seven years, their trends decline regularly in the first third of the period and they rise uniformly in the next two-thirds. However, they indicate a failure in their homogenous patterns, like a parabola, within 1981-1988, which is simultaneous with the years of war between Iran and Iraq. Since they play the role of dependent variable, it signals to need dummy variable in the war years for the model specifications.

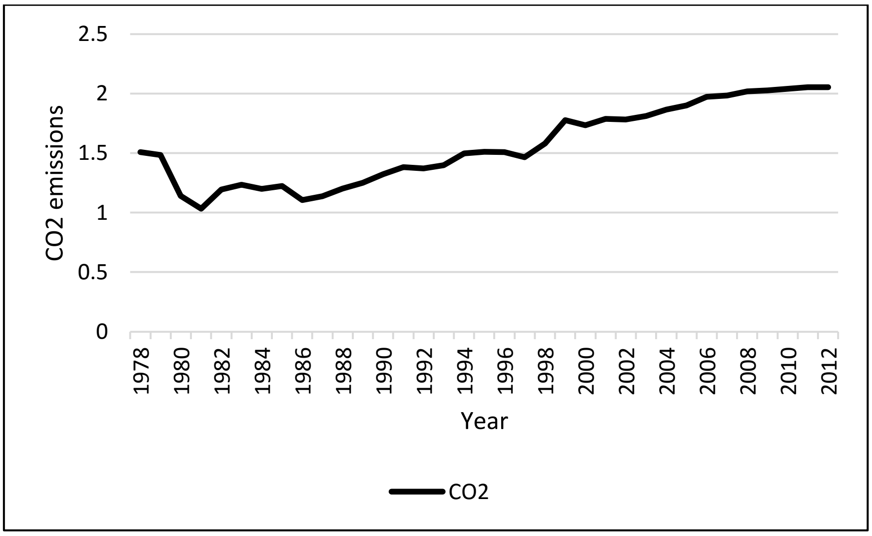

Figure 1: Natural Logarithm of per capita CO2 Emissions in Metric Ton in Iran
Source: World Development Indicator

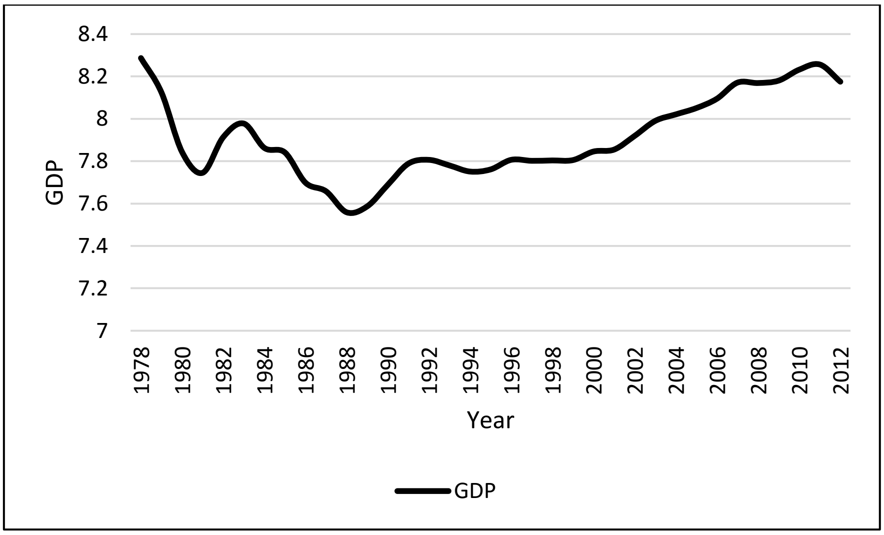

Figure 2: Natural Logarithm of per capita GDP in Constant 2005 US Dollar in Iran
Source: World Development Indicator

All the data are derived from the datasets for the years 1978-2012 and transformed into the natural logarithm form. Their trends and correlograms provide strong evidence for two properties in the model specification: 1) the dynamism of the model with the one degree lagged value of the dependent variables among the independent ones; and 2) the dummy variable for the war years.

4. Models and Results

Based on the results, the maritime transportation elasticities of environmental pollution and economic growth are low both in the short-run and long-run in Iran during 1978-2012. Firstly, the ADF unit root tests show the stationarity of the variables in level; and the Granger causality test indicates which variables play as the endogenous variables in the per capita CO2 emissions and GDP. Then using the dynamic log-linear model, they are regressed on those endogenous variables, which show the causal relationship in the Granger test to estimate the maritime transportation elasticities. They are estimated using two distinctive approaches: A) single-equation one with OLS method; and B) simultaneous-equations one with GMM method. Having the estimated residuals, they are checked for the normality, autocorrelation, and heteroscedasticity; and the results satisfy the econometric classical-assumptions providing evidence of reliably estimated coefficients and statistics in both methods, OLS and GMM. Finally, we plug the estimated equation 2 into equation 1 to derive indirect, implicit, or hidden elasticities. First, the preliminary tests are run in the next section.

4.1. Unit Root Test

Table 1 illustrates the results of the Augmented Dickey-Fuller unit root test on the variables, involving intercept and trend with six maximum lag lengths. Based on the table, all the τ-statistics imply the stationarity of all the variables in level. The null hypothesis of unit root presence is rejected in all the variables at 1% and 5% significance levels. Owing to the stationarity of the variables, they can be regressed on each other without the spurious regression threat.

Table 1: Results of the Augmented Dickey-Fuller Unit Root Tests

	Ln M	**Ln Y**	**Ln CO_2**	**Ln TR**
τ -statistic	-4.0290	-3.7746	-4.3402	-5.1688
Prob.	0.01	0.03	0.00	0.00
Stationarity	I(0)	I(0)	I(0)	I(0)

All the tests are in level with 6 maximum lag length including intercept and trend in level.

4.2 Granger Causal Test

Table 2 represents the Granger causality test results for the four variables to detect which variables have causal relationship with either per capita CO2 emissions or per capita GDP.

Table 2: Results of the Granger Causal Relationship Tests

Causal Flow	F Statistic	Prob.	Causal Flow	F Statistic	Prob.	Accepted Causal Flow
$M \rightarrow CO_2$	3.4518	0.02	$M \leftarrow CO_2$	1.0221	0.44	$M \rightarrow CO_2$
$M \rightarrow Y$	2.5549	0.06	$M \leftarrow Y$	1.2668	0.32	$M \rightarrow Y$
$M \rightarrow TR$	3.7403	0.01	$M \leftarrow TR$	0.4318	0.84	$M \rightarrow TR$
$TR \rightarrow CO_2$	0.6967	0.65	$TR \leftarrow CO_2$	3.5024	0.02	$TR \leftarrow CO_2$
$TR \rightarrow Y$	4.9604	0.00	$TR \leftarrow Y$	3.9143	0.01	$TR \leftrightarrow Y$
$Y \rightarrow CO_2$	2.4730	0.06	$Y \leftarrow CO_2$	3.4537	0.02	$Y \leftrightarrow CO_2$

All the variables are in natural logarithm and per capita; the Ln sign is disappeared to make a simple formatted table.

Regarding the table, there is a unidirectional Granger causal relationship from maritime transportation to CO2 emissions, GDP, and trade at 5%, 10%, and 5% significance level, respectively; there is a unidirectional Granger causal relationship from CO2 emissions to trade at 5% significance level; the Granger causal relationship between trade and GDP is bidirectional at 1% significance level; and it is bidirectional between GDP and CO2 emissions. These Granger causal relationships are presented graphically in figure 1.

Figure 1 represents the causal relationships among the variables, graphically and briefly to perceive which variables play the causal role as the exogenous variable in the CO2 emissions or GDP. Based on the graph, CO2 emissions are affected by maritime transportation and GDP; and GDP is affected by maritime transportation, trade, and CO2 emissions. In the model specification, the causal relationship from CO2 emissions to GDP is ignored due to the shortage of theoretical foundation of how CO2 emissions affects upon GDP. Therefore, maritime transportation and GDP are the exogenous variables for the model whose dependent variable is CO2 emissions; and maritime transportation and trade are the exogenous variables for the model whose dependent variable is GDP.

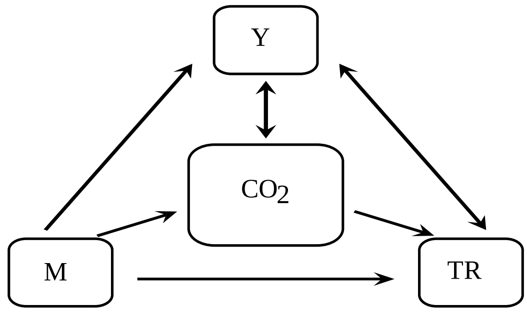

Figure 1: Estimated Granger Causal Relationships among the Variables at a Glance

Figure 1 shows the significant causal relationships among all the variables in the study. Since the objective of study can be achieved in the models whose dependent variables are CO2 and Y, we consider merely those nexuses which flow from the independent variables to either CO2 or Y as the dependent ones, in model specification.

4.3. Model Specification

Using the dynamic log-linear model, the maritime transportation elasticities in Iran are estimated in the short-run and long-run with two distinctive regressions: 1) environmental pollution regression; and 2) economic growth regression; and two different methods: OLS and GMM. In this study, a dynamic model is employed which is called "the partial adjustment model" or "the lagged endogenous model" (Dahl & Sterner, 1991; Sene, 2012; Taghvaee & Hajiani, 2014). The models of CO2 emissions or environmental pollution, and GDP or economic growth are as follows respectively:

$$Ln\, CO_{2_t} = \alpha_0 + \alpha_1 Ln\, M_t + \alpha_2 Ln\, Y_t + \alpha_3 Ln\, CO_{2_{t-1}} + \alpha_4 DW + \varepsilon_t \qquad (10)$$

$$Ln\, Y_t = \beta_0 + \beta_1 Ln\, M_t + \beta_2 Ln\, TR_t + \beta_3 Ln\, Y_{t-1} + \beta_4 MA(1) + \mu_t \qquad (11)$$

where "α" and "β" show the parameters of CO2 and GDP models which are interpreted as the elasticities of environmental pollution and economic growth, respectively. DW is the dummy variable which is zero for the war years (1980-1989) and one for the remaining years; the presence of DW and the endogenous lagged variables is justified in section 3 (Data). Ln is the natural logarithm; t is year; MA(1) is the moving average of degree one. The symbols ε and μ are the residual series with the usual classic characteristics $\varepsilon \sim NID(0. \bar{\sigma}_\varepsilon)$ and $\mu \sim NID(0. \bar{\sigma}_\mu)$; they are examined for the econometric classical-assumptions to assess the reliability of the estimated coefficients.; and the remaining symbols were explained in the previous section.

This study runs the two equations (10) and (11) which are different regarding their independent and dependent variables. The difference in independent variables (TR) is resulted from the estimated causal flow in the Granger causal test. Although trade can be theoretically among the explanatory variables in the environmental pollution model, it is ignored in the first econometric regression due to the insignificant causal relationship resulted in the Granger test. The difference in dependent variables (CO2 and Y) paves the way for estimating the maritime transportation elasticities of both environmental pollution and economic growth. In these models, not only are two various elasticities estimated: environmental pollution and economic growth, but also each is estimated in two time-periods, long- and short-term.

Elasticities are expected to be different in short- and long-run. In these models, α_1 and α_2 are the short-run explicit elasticities of environmental pollution and β_1 and β_2 are interpreted as the short-run ones of the economic growth; the long-run ones are $\alpha_1/1-\alpha_3$ and $\alpha_2/1-\alpha_3$ for the environmental pollution and $\beta_1/1-\beta_3$ and $\beta_2/1-\beta_3$ for the economic growth (Sene, 2012). The short-run elasticities are, very probably, less than the long-run ones since the independent variables need sufficient time to cause their full effects on the dependent one. The longer the period is, the higher the elasticities are (Dah and Sterner, 1991; Sene, 2012). These properties are expected to be the same for the full elasticities, which are including both the Explicit Elasticities (EE), and Implicit Elasticities (IE).

Having the coefficients estimated, the estimated equation (11) is plugged into equation (10) to produce the maritime transportation implicit elasticities of environmental pollution; and the trade one.

$$\begin{aligned} Ln\, CO_{2_t} = {} & \hat{\alpha}_0 + \hat{\alpha}_1 Ln\, M_t \\ & + \hat{\alpha}_2\{\hat{\beta}_0 + \hat{\beta}_1 Ln\, M_t + \hat{\beta}_2 Ln\, TR_t + \hat{\beta}_3 Ln\, Y_{t-1} + \hat{\beta}_4 MA(1) \\ & + \hat{\mu}_t\} + \hat{\alpha}_3 Ln\, CO_{2_{t-1}} + \hat{\alpha}_4 DW + \hat{\varepsilon}_t \end{aligned} \tag{12}$$

where hat sign ˆ shows the estimated coefficients or statistics. By simplifying:

$$Ln\, CO_{2_t} = (\hat{\alpha}_0 + \hat{\alpha}_2\hat{\beta}_0) + (\hat{\alpha}_1 + \hat{\alpha}_2\hat{\beta}_1)Ln\, M_t + (\hat{\alpha}_2\hat{\beta}_2)Ln\, TR_t + (\hat{\alpha}_2\hat{\beta}_3)Ln\, Y_{t-1} + \hat{\alpha}_3 Ln\, CO_{2_{t-1}} + (\hat{\alpha}_2\hat{\beta}_4)MA(1) + \hat{\alpha}_4 DW + \hat{\alpha}_2\hat{\mu}_t + \hat{\varepsilon}_t \quad (13)$$

where $\hat{\alpha}_2\hat{\beta}_1$ is the maritime transportation implicit elasticity of environmental pollution in short run ($IE_{CO2,M}$); SFE=$(\hat{\alpha}_1 + \hat{\alpha}_2\hat{\beta}_1)$ is the corresponding full elasticity; its long-run one is $LFE_{CO2,M}$= $\left(\hat{\alpha}_1 + \frac{\hat{\alpha}_2\hat{\beta}_1}{1-\hat{\beta}_3}\right)/(1-\hat{\alpha}_3)$; the trade implicit elasticity of environmental pollution in short run is $(\hat{\alpha}_2\hat{\beta}_2)$ which can be considered as the full one too ($SFE_{CO2,TR}$), since its corresponding explicit one is assumed as zero in this model; and its long-run one is $LFE_{CO2,TR}$= $\left(\frac{\hat{\alpha}_2\hat{\beta}_2}{1-\hat{\beta}_3}\right)/(1-\hat{\alpha}_3)$. These elasticities are estimated employing two various methods: OLS and GMM in the subsequent section.

4.4. Model Estimations

In the following paragraphs, we represent the estimation results of both models using a single-equation approach with OLS method, and a simultaneous-equations approach with GMM method. Not only do we merge both the equations via estimation method of GMM but also we go further to merge the estimated coefficients of equation 2 into equation 1 in order to achieve a wider perspective into the elasticities.

4.4.1 Single Equation Approach Using OLS Method

In this section, the results of single-equation (with OLS method) are represented, using two separate subsections: A for the environmental pollution and B for the economic growth model.

A- Environmental Pollution Model Estimation

Table 3 offers the estimated coefficients, statistics and probabilities of the environmental pollution model including the results of classical assumption tests on the estimated residual series and the explanatory power of the model. The coefficients are useful to estimate the elasticities as mentioned in the previous section, model specification; the statistics and probabilities show the degree of statistical significance. The statistical significance degrees can be estimated by comparing the estimated statistics with their corresponding critical values. If the t-statistics are greater than the critical one, the independent variable has a statistically significant effect on the dependent variable. Also, the probability values represent the statistical significance regarding the confidence intervals. If they are less than 0.10, 0.05, 0.1, the independent variable has statistically significant effect on the dependent variable in 90%, 95%, 99% confidence level respectively.

Table 3: Results of OLS Estimation of the CO2 Model Estimation

Variable	Coefficient	t-statistic	Prob.
Ln M	0.1959	4.8441	0.00
Ln Y	0.2919	2.6870	0.01
Ln $CO2_{t-1}$	0.3467	2.9307	0.00
α_0	-1.2833	-1.698	0.10
DW	0.1073	2.9940	0.00
$\alpha_1/1-\alpha_3$	0.2998		
$\alpha_2/1-\alpha_3$	0.4468		
Jarque Bera Statistic	3.6037		0.16
Durbin h statistic	1.2124		
Breusch Godfrey serial correlation LM test (F statistic), including two lags[a]	1.8049		0.18
Breusch-Pagan-Godfrey heteroscedasticity test (F statistic)	1.8180		0.15
R squared	0.96		
Adjusted R squared	0.96		
F statistic	234.0224		0.00

[a]. The results will be the same, if it includes more lags.

Regarding the table, all the elasticities are low and positive in the CO2 emissions model. The nexus between maritime transportation and CO2 emissions is positive in Iran. The short-run maritime transportation and GDP elasticities of CO2 emissions are 0.1959 and 0.2919 (statistically significant at 1% and 5%); and the long-run ones are 0.2998 and 0.4468, respectively. The lagged CO2 emissions are statistically significant at 1% level, which is a further evidence for the accuracy of the dynamically specified model. In addition, the dummy variable is statistically significant at 1% level confirming the effect of war years on the CO2 emissions trend. The results of diagnostic tests support the validity of the estimated coefficients and statistics.

The diagnostic tests' results accede that the residual series satisfy the econometric classical-assumptions and the explanatory variables can explain the dependent variable well enough. Jarque-Bera statistic cannot reject the null hypothesis of normality in the residuals. The absolute value of Durbin h-statistic is less than 0.96 rejecting the autocorrelation of first-order; and the Breusch Godfrey serial correlation LM test with F statistic can reject the autocorrelation of more than one degree, although the table shows only the result of LM test with two lags. In addition to the no-autocorrelation, Breusch-Pagan-Godfrey heteroscedasticity test with F statistic cannot reject the null hypothesis of homoscedasticity in the residuals. Both the determination and adjusted determination degrees are 0.96 and the statistically significant of F-statistic at 1% supports the explanatory power and accuracy of the model specification.

As a result, the maritime transportation elasticities of CO2 emissions are higher than the GDP ones and the long-run ones are greater than the short-run ones but all of them are low. The estimated elasticities are reliable because the residuals satisfy the classical assumptions and the determination coefficients show the high explanatory power of the model, confirming the reasonably accurate specification of the model.

B- Economic Growth Model Estimation

Table 4 offers the estimated coefficients and statistics of the economic growth model including the results of classical assumption tests on the estimated residual series and the explanatory power of the model.

Regarding the table, all the elasticities are low in the GDP model. The nexus between maritime transportation and GDP is positive in Iran. The short-run maritime transportation and trade elasticities of GDP are 0.0882 and 0.1647 (statistically significant at 1%); and the long-run ones are 0.1581 and 0.2952, respectively. The lagged GDP is statistically significant at 1% level, which is a further evidence for the accuracy of the dynamically specified model. In addition, the dummy variable is statistically significant at 1% level confirming the effect of war years on the GDP trend. The presence of MA(1) makes the reseals in consistent with the classical assumptions. Its high t-statistic is another evidence for accuracy of the presence of MA(1). The results of diagnostic tests support the validity of the estimated coefficients and statistics.

Table 4: Results of OLS Estimation of the GDP Model Estimation

Variable	Coefficient	t-statistic	Prob.
Ln M	0.0882	2.8944	0.00
Ln TR	0.1647	3.0201	0.00
Ln Y_{t-1}	0.4422	5.2182	0.00
β_0	3.8346	5.1435	0.00
MA(1)	0.9632	51.0801	0.00
$\beta_1/1-\beta_3$	0.1581		
$\beta_2/1-\beta_3$	0.2952		
Jarque Bera Statistic	3.3546		0.18
Durbin h statistic	0.2015		
Breusch Godfrey serial correlation LM test (F statistic), including two lags[a]	1.1811		0.32
Breusch-Pagan-Godfrey heteroskedasticity test (F statistic)	0.4577		0.71
R squared	0.93		
Adjusted R squared	0.92		
F statistic	101.3655		0.00

[a]. The results will be the same, if it includes more lags.

The diagnostic tests' results accede that the residual series satisfy the econometric classical-assumptions and the explanatory variables can explain the dependent variable well enough. Jarque-Bera statistic cannot reject the null hypothesis of normality in the residuals. The absolute value of Durbin h-statistic is less than 0.96 rejecting the autocorrelation of first-order; and the Breusch Godfrey serial correlation LM test with F statistic can reject the autocorrelation of more than one degree, although the table shows only the result of LM test with two lags. In addition to the no-autocorrelation, Breusch-Pagan-Godfrey heteroscedasticity test with F statistic cannot reject the null hypothesis of homoscedasticity in the residuals. Determination and adjusted determination degrees are 0.93 and 0.92, respectively, and the statistically significant of F-statistic at 1% supports the explanatory power and accuracy of the model specification.

As a result, the maritime transportation elasticities of GDP are higher than the trade ones and the long-run ones are greater than the short-run ones but all of them are low. Moreover, the elasticities in GDP model are less than CO2 emissions ones. The estimated elasticities are reliable because the residuals satisfy the classical assumptions and the determination coefficients show the high explanatory power of the model, confirming the reasonably accurate specification of the model.

4.4.2. Simultaneous Equations System Approach Using GMM Method

In this section, we show the estimation results of simultaneous-equations approach using GMM method. The results of both equations are in the following table. Table 5 presents the estimation results of simultaneous equations system using GMM method. The first part shows the coefficients and statistics of environmental pollution model and the second one indicates those of economic growth model.

Table 5: Results of GMM Estimation of the Simultaneous Equations Model

Variable	Coefficient	t-statistic	Prob.
Equation 1			
Ln M	0.1642	5.8071	0.00
Ln Y	0.1414	1.8795	0.06
Ln $CO2_{t-1}$	0.5195	7.3243	0.00
α_0	-0.3514	-0.6317	0.53
DW	0.0785	3.3915	0.00
$\alpha_1/1-\alpha_3$	0.3417		
$\alpha_2/1-\alpha_3$	0.2942		
R squared	0.96		
Adjusted R squared	0.96		
Equation 2			
Ln M	0.0631	4.4927	0.00
Ln TR	0.0947	3.7020	0.00
Ln Y_{t-1}	0.7213	19.3338	0.00
β_0	1.8762	6.6504	0.00
$\beta_1/1-\beta_3$	0.2264		
$\beta_2/1-\beta_3$	0.3397		
R squared	0.90		
Adjusted R squared	0.89		
Joint Jarque Bera Statistic (Doornik-Hansen test)	9.8388		0.36

Based on the first part, all the elasticities are low and positive in environmental pollution model. In this model, the maritime transportation and GDP elasticities are 0.1642 and 0.1414 in short run (statistically significant at 1% and %10 levels); and they are 0.3417 and 0.2942 in long run respectively. The dummy variable is statically significant at 1%. It confirms what proposed in the figures of data section about the positive effect of war on environmental pollution. Moreover, the lagged CO2 emissions coefficient is statistically significant at 1%, offering further proof that the dynamic model specification is a proper alternative. It can be applied in the economic growth model too.

Regarding the results economic growth model, all the elasticities are low and positive. In this model, the maritime transportation and trade elasticities are 0.0631 and 0.0947 in short run (statistically significant at 1%); and they are 0.2264 and 0.3397 in long run respectively. As mentioned in the environmental pollution model, the lagged GDP coefficient is statistically significant at 1%, offering further proof that the dynamic model specification is a proper alternative too. The R squared and Adjusted R squared values are 0.96 in the former model and they are 0.90 and 0.89 in the latter, confirming the high explanatory power of the models. In addition, the joint Jarque Bera statistic affirms that the residuals are normally distributed and they are consistent with the econometric classical assumptions.

As a conclusion, the results of both models are consistent with each other. All the elasticities are low and positive in both models, both methods, and both periods. As expected, all the long run elasticities are greater than the corresponding short run ones. In both methods, the maritime transportation elasticities of environmental pollution are more than the maritime transportation elasticities of economic growth.

4.4.3. Explicit, Implicit, and Full Elasticities of Environmental Pollution by Plugging Equation 2 into 1

Table 6 represents the explicit, implicit, and full elasticities of environmental pollution. They are estimated by plugging the estimated equation 2 into equation 1. The results are consistent with those of both the OLS and GMM.

All the elasticities are positive and low. The explicit ones are exactly equal to the estimated coefficients in OLS and GMM. The maritime transportation implicit elasticities of environmental pollution is considerably lower than the explicit ones, estimated to be 0.0257 and 0.0471 for OLS and 0.0089 and 0.0205 for GMM in short-run and long-run, respectively. The trade ones are 0.0480 and 0.0880 for OLS and 0.0133 and 0.0307 for GMM. It suggests that environmental pollution is being unaffected by the changes of economic growth which are rooted maritime transportation or trade activities.

Table 6: Environmental Pollution Elasticities Resulted by Merging the Estimated Equations

Elasticities[a]	Method	Maritime Transportation		Trade Volume	
		Short-run	Long-run	Short-run	Long-run
EE	OLS	0.1959	0.2998	_	_
	GMM	0.1642	0.3417	_	_
IE	OLS	0.0257	0.0471	0.0480	0.0880
	GMM	0.0089	0.0205	0.0133	0.0307
FE	OLS	0.2216	0.3469	0.0480	0.0880
	GMM	0.1731	0.3622	0.0133	0.0307

a. Explicit, implicit, and full elasticities are shown by EE, IE, and FE, respectively.

In another word, maritime transportation and trade activities are mainly raising the environmental pollution directly, rather than their indirectly positive effect on economic growth; although neither their direct nor their indirect effects are insignificant. These insignificant effects are confirmed by the values of full elasticities. The maritime transportation full elasticities of environmental pollution are 0.2216 and 0.3469 for OLS and 0.1731 and 0.3622 for GMM in short- and long-run, respectively. The trade full elasticities of environmental pollution are exactly equal to their corresponding implicit ones.

As a result, all the estimated elasticities are positive and low; and expectedly all the long-run elasticities are greater than their corresponding short-run ones, in this method. They are supporting the results of previous methods.

5. Discussion

Table 7 indicates all the elasticities of environmental pollution and economic growth in the short-run and long run in Iran, which are estimated in this study. All the elasticities are positive and low; and all the variables are per capita. Although the elasticities of two methods, OLS and GMM, are not exactly equal, they unanimously propose the same conclusions and implications as we offer a single interpretation for both the results. In the following paragraphs, firstly, the environmental column and then the economic column are analyzed and finally they are compared with one another.

Based on the environmental column in the table, all the elasticities of environmental pollution are positive and low. Increment of either maritime transportation or GDP increases the level of CO_2 emissions, supporting the Pollution Haven Hypothesis for Iran as a developing country, although the CO_2 emissions are inelastic to both maritime transportation and economic growth in short-run and long-run, it responds to the changes in the maritime transportation slighter than the GDP, necessitating the more stringently environmental policy development in the economic infrastructure; and, as expected, the environmental elasticities in the short-run are lower than those in the long-run, implying that the environmental response to maritime transportation or economic growth is not only slight but also it is slow. So the long-run perspective for the environment is more influential; and the implement of environmental policies needs sufficient time to exert the entirely possible effects.

Based on the economic column in the table, all the elasticities of economic growth are positive and low. Increment of either maritime transportation or trade increases the level of CO_2 emissions, although the GDP is inelastic to both maritime transportation and trade in short-run and long-run, it responds to the changes in the maritime transportation slighter than the trade, suggesting that the trade policies are more economically effective than the maritime transportation ones; and the economic elasticities in the short-run are, expectedly, lower than those in the long-run, implying that the economic response to maritime transportation or trade is not only slight but also it is slow. So the long-run perspective for the economic growth is more influential; and the implement of economic policies needs sufficient time to exert the entirely possible effects.

Comparing both the environmental and economic columns, CO_2 emissions response is stronger and more considerable than the GDP one, despite the inelasticity of both the CO_2 emissions and GDP to the maritime transportation. It implies that the maritime transportation in Iran is more effective in polluting the environment than in growing the economy. It is worth mentioning that both the CO_2 emissions and GDP respond to the changes in short-run slighter than in the long-run, signing the slow response of environmental pollution and economic growth to the transportation, economic, and trade changes.

Table 7: Estimated Elasticities in the Short-Run and Long-Run at a Glance

Variable		Method	Elasticities of environmental pollution		Elasticities of economic growth	
			Short-run	Long-run	Short-run	Long-run
Ln M	EE*	OLS	0.1959	0.2998	0.0882	0.1581
		GMM	0.1642	0.3417	0.0631	0.2264
Ln M	FE*	OLS	0.2216	0.3469	NA	NA
		GMM	0.1731	0.3622	NA	NA
Ln Y		OLS	0.2919	0.4468	NA	NA
		GMM	0.1414	0.2942	NA	NA
Ln TR		OLS	0.0480	0.0880	0.1647	0.2952
		GMM	0.0133	0.0307	0.0947	0.3397

*. EE and FE show the explicit elasticities and full elasticities, respectively.

Overall, the infrastructure of maritime transportation in Iran should be improved both environmentally and economically because its negative role in environmental quality is more dominant than its benefits in the economic growth. Undoubtedly, the long-run perspective is more influential in those policy-makings. Compared with the maritime transportation, the economic infrastructure should be improved environmentally due to its stronger effect on the environmental pollution; and the trade infrastructure should be improved economically owing to its more substantial impact on the economic growth.

6. Conclusion

This study estimates the maritime transportation elasticities of environmental pollution and economic growth in short-run and long-run in Iran during 1978-2012, using the dynamic log-linear model with two distinctive methods: OLS and GMM. Firstly, the elasticities are analyzed, then the recommendations are presented, and finally the future research potentials are offered. All the elasticities are low and positive in both the intervals.

The nexus between maritime transportation and CO_2 emissions follows the Pollution Haven Hypothesis in Iran both in short-run and long-run. Maritime transportation and economic activities pollute the environment in Iran as a developing country, which is consistent with the Pollution Haven Hypothesis. It urges the development in the environmental policies for the economic activities and maritime transportation framework. The CO_2

emissions respond more considerably to the changes in the GDP than to changes in the maritime transportation.

The nexus between maritime transportation and GDP is positive in Iran both in short-run and long-run. Maritime transportation and trade openness increase the economic growth. It implies that the environmental pollution provides a flimsy pretext to impose a limit on the maritime transportation or economic activities. The policy-makers are advised to improve the environmentally polluting infrastructure of the maritime transportation rather than restricting the growth of this sector. Clearly, those policies with long-run perspective are more efficient than the short-run ones due to the higher long-run elasticities in both the environmental pollution and economic growth.

For the future studies, the other modes of transportation or other kinds of pollution might be analyzed environmentally and economically. For example, it can be a research question whether the aviation transportation mode is related with the emission of greenhouse gases positively.

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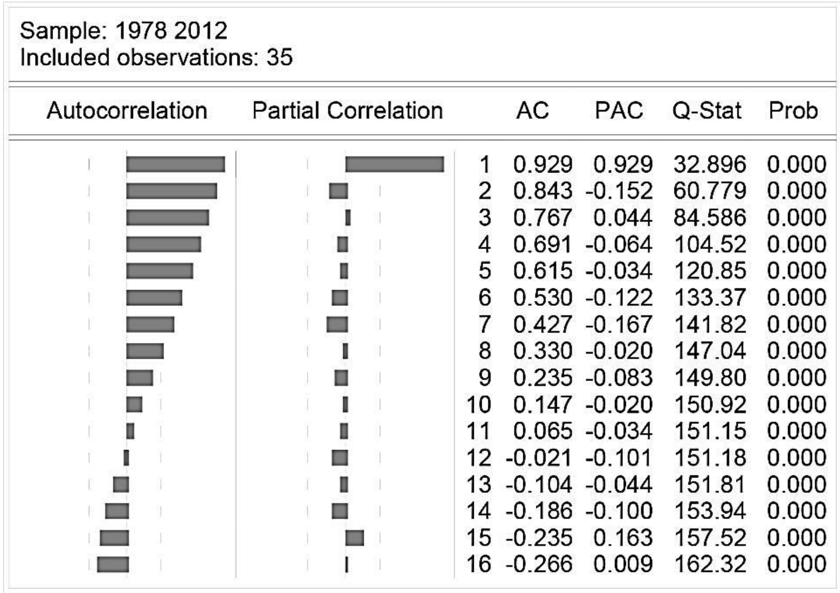
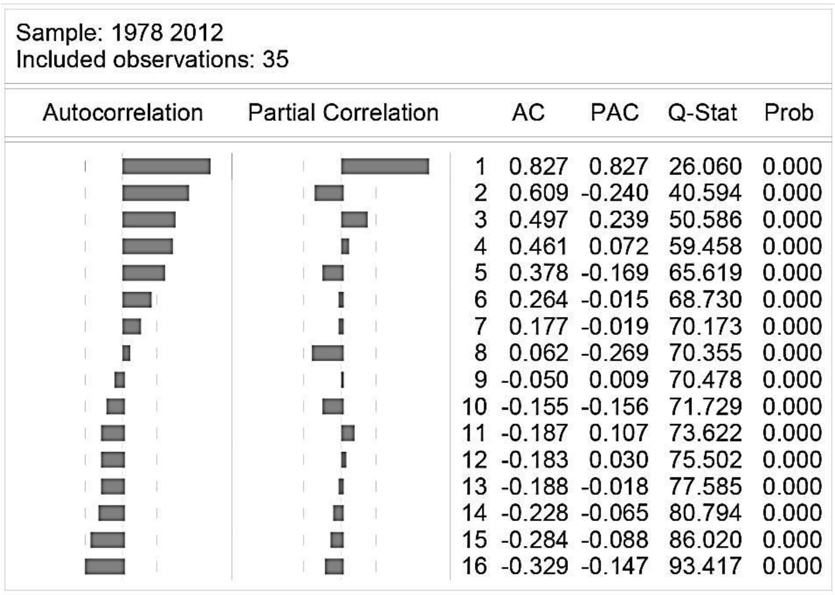
Appendices:



Sample: 1978 2012
Included observations: 35

Lag	AC	PAC	Q-Stat	Prob
1	0.929	0.929	32.896	0.000
2	0.843	-0.152	60.779	0.000
3	0.767	0.044	84.586	0.000
4	0.691	-0.064	104.52	0.000
5	0.615	-0.034	120.85	0.000
6	0.530	-0.122	133.37	0.000
7	0.427	-0.167	141.82	0.000
8	0.330	-0.020	147.04	0.000
9	0.235	-0.083	149.80	0.000
10	0.147	-0.020	150.92	0.000
11	0.065	-0.034	151.15	0.000
12	-0.021	-0.101	151.18	0.000
13	-0.104	-0.044	151.81	0.000
14	-0.186	-0.100	153.94	0.000
15	-0.235	0.163	157.52	0.000
16	-0.266	0.009	162.32	0.000

A) CO2 Correlogram



Sample: 1978 2012
Included observations: 35

Lag	AC	PAC	Q-Stat	Prob
1	0.827	0.827	26.060	0.000
2	0.609	-0.240	40.594	0.000
3	0.497	0.239	50.586	0.000
4	0.461	0.072	59.458	0.000
5	0.378	-0.169	65.619	0.000
6	0.264	-0.015	68.730	0.000
7	0.177	-0.019	70.173	0.000
8	0.062	-0.269	70.355	0.000
9	-0.050	0.009	70.478	0.000
10	-0.155	-0.156	71.729	0.000
11	-0.187	0.107	73.622	0.000
12	-0.183	0.030	75.502	0.000
13	-0.188	-0.018	77.585	0.000
14	-0.228	-0.065	80.794	0.000
15	-0.284	-0.088	86.020	0.000
16	-0.329	-0.147	93.417	0.000

B) Y Correlogram