The Effects Of Innovations On Carbon Dioxide Emissions: Evidence From The Iran

Forough MOTEVASELI¹, Dr Hashem ZARE²

¹Ms in Economics

²* Assistant Professor, Department of Economics, Shiraz Branch, Islamic Azad University, Shiraz, Iran.

Received: 22.03.2015; Accepted: 29.05.2015

Abstract. The implementation of production plans based on material interests without regard to environmental issues would impose social and economic costs on society. Therefore, achieving sustainable development without considering environmental issues is impossible. As a member of the Kyoto Protocol, a protocol on climate pollution, Iran is required to execute effective measures to reduce emissions of carbon dioxide. Therefore, it is important to investigate factors influencing the reduction in carbon dioxide emissions in the country. This study examines the effects of innovation variables (i.e. patents), the increase in real GDP and oil price on carbon dioxide emission during the period 1987-2010 through vector error-correction model in Iran. The number of patents is intended as a substitute to green innovations. The results of present study show that in long run, innovations (patents), and the dummy variable of Convention on Climate Change have negative effects while real GDP has positive effects upon emission of carbon dioxide.

JEL categorization: O32, Q01, Q53.
Keywords: Patent, sustainable development, climate pollution

1. INTRODUCTION

At the present, attention to sustainable development is an important issue but lack of attention to environmental issues, to realize economic development, has imposed irreversible costs on society. The achievement of sustainable development will be possible through efficient use of all resources, including human resources, finance, and natural resources. Innovation in every sector can accelerate the growth and innovation in other sectors. Therefore, the improvement of innovation and technology in all sectors can lead to balanced growth. Improvement in technology and balanced growth would lead to productivity in all industries which would eventually cause the reduction of environmental problems such as carbon dioxide emissions.

Because the number of registered patents in one country shows the process of improving its technological strength, the increasing the number of patents (as a viable alternative to innovation in production process) is theoretically one of the factors taken into account in reduction of pollution. In this study, vector error-correction model during 1987-2010 was used to determine the long-term effects of real GDP, oil prices and innovation (patents) on carbon dioxide emissions in the Iran. It should be noted that dummy variable for the Iran’s membership in the convention on climate change is considered. In Kyoto Protocol, the main factor behind global warming is greenhouse gas and Iran, as a member of the protocol, is required to take the necessary measures to reduce air pollution. As for the impact of innovation on carbon dioxide emissions, no similar research has been done in Iran so far. Foreign studies on the effect of changes in production and innovation on air pollution (carbon dioxide emissions) are as follows: Vienna et. al (2014) found out that carbon dioxide fluctuations had no important role in green technologies. According to the study by Constantine et. al (2013) the impact of technology on carbon dioxide emissions is not the same in all regions of a country. In a study done by Dina (2011) increase in short-term and long-term production had a positive
impact on air pollution. The impact of technology upon carbon dioxide is positive in short-term but negative in long-term. The results of studies by Karyvn and Ines (2010), Andrew and Levinson (2001), Komen et al. (1997), and Grossman and Krueger (1991) showed that the development of technology might reduce emissions of carbon dioxide. The associated studies on the effects of GDP, innovations and the oil price on carbon emissions in Iran are as follows: Sadeghi and Sadeghi (2015) found out that there is a Kuznets's inverted-U relationship between economic growth and environmental quality. Jalaly Esfand Abadi, Fatemeh Abbasi and Ghasemi (2015) examined the momentum of oil prices on green GDP. (Green GDP = GDP - depreciation of natural capital - human capital depreciation). The results showed that the increase in oil revenues causes real growth of other sectors in the long-term. Therefore, the oil shocks in long-term have a positive impact on green production. Sharzei et.al (2014) found a long-term association among the variables of economic growth, trade and consumption of fossil fuels. Manzor and Haghhighi (2011) found out that as a result of price reform of energy carriers, the technology used and the level of energy consumption has changed and as a result emission of majority of pollutants had reduced. The results of a study by Bagheri (2011) showed that the impact of energy consumption on carbon dioxide emissions is more than the impact of carbon dioxide emissions on economic growth. The main objective of this study is to provide practical approaches to achieve sustainable development in order to reduce environmental pollution. The research questions are:

- Is innovation in the field of climate changes affective?
- Do innovation and improvement of production technology reduce consumption of fossil fuels and reduce carbon dioxide emissions?
- Have the activities carried out to join the Convention on Climate Change been effective in reducing carbon dioxide emissions?
- Does the increase of real GDP lead to increase of carbon dioxide emission?
- Does increase of oil prices reduce emissions?

This research is presented in three section. The first section includes the theoretical framework and research model. In the second section, the results vector error-correction model will be analyzed. Finally, the third part offers conclusion and practical solutions.

**Theoretical Framework**

One of the major environmental issues in the past decades has been the increase of air pollution. Increased carbon dioxide gas, as one of the major factors of environmental crises, has drawn the attention of many countries, including Iran. Air pollution is inevitable during production. In addition, with no growth in national production development will not be realized. The application of technological innovations and increase of efficient use of domestic power resources can reduce the use of fossil fuels. This would also reduce pollution which might result in economic growth and reduction of environmental pollution. The advancement of technology in this sector could accelerate the pace of innovations in other sectors. This might lead to balanced growth in all sectors. An up-to-date technology can improve manufacturing processes in all industries and reduce carbon dioxide emissions.

**Environmental Conferences and Protocols**

The Stockholm Conference (1972) was held by the United Nations in Sweden. In the conference, one statement on dependence of human on the environment and 106 recommendations on the same subject were issued. Protection of the environment, promotion of environmental activities at international level, codification of regional development laws and international treaties to control pollution and environmental degradation caused by human activity were major concerns raised in the conference.

The United Nations Framework Convention on Climate Change (UNFCCC, 1992) was approved in New York City. This convention was signed by 154 countries during Earth Summit in Rio de Janeiro (Brazil). The purpose of the convention was stabilization of greenhouse gas concentrations in the atmosphere at a
low level so that ecosystems could have the opportunity to recover to their natural cycle. The Islamic Republic of Iran's membership in convention in 1994 was also announced.

In 1985, the Vienna Convention for the Protection of the Ozone Layer was adopted and it got official in 1998. The purpose of the Vienna Convention is protecting human health and the environment from the risks of change and reduction in thickness of ozone layer. The Islamic Republic of Iran's membership Vienna Convention in 1990 was followed by adoption of its amendments in 1997 and officially executed in 2011. Montreal Protocol on protection of the ozone layer was adopted in 1987. The aim of the protocol was to establish criteria for controlling the release of ozone-layer-reducing substances in the world to protect it. The Kyoto Protocol was signed in 1997 in Kyoto, Japan. Based on this protocol, industrialized countries should have decreased their emissions greenhouse gas by a five percent decrease in 2012 compared to 1990. The Kyoto Protocol is one of the branches of the Convention on Climate Change (UNFCCC). The Islamic Republic of Iran's membership in Kyoto Protocol on climate change was accepted in 2006. In the Kyoto Protocol, greenhouse gas emissions, especially carbon dioxide emissions, was introduced as the main cause of climate change. Because Iran is also a member of the convention, it is committed to report the status quo and rate of greenhouse gas emission. It should also provide necessary arrangements for the reduction of emissions.

**B. Innovation (patents)**

The invention as a new and innovative solution to deal with a technical problem can make it possible to apply new techniques so to increase production efficiency and optimize the factors of production. Therefore, using less raw materials can lead to the desired production. With regard to the finiteness of natural resources, their efficient use plays an important role in alignment of development and environmental protection. On the other hand, innovation in a sector can lead in accelerating the innovation in other sectors. This might lead to balanced growth in all sectors Improvement of manufacturing processes in all industries might in turn reduce the carbon dioxide emissions. The judicial system and the state, passed some legislations to protect the rights of inventors and contribute to research and development.

To get familiar with the patent registration in Iran, articles 1, 2, 3 and 16 of the Law of Registration of Patents, Industrial Designs and Trademarks (2008) are added in the following. Article 1 states:

“Invention is result of thought of an individual or individuals to provides a process or specific products for the first time or solve certain problems in a professional, technology, industry, etc.”

Article 2 states:

“An invention is patent able if it contains a new initiative and industrial application. The new initiative is the on for which there is no previous industry and not evident and which is not explicit to an expert of ordinary skill in the associated technical subject. And from the industrial point of view, an invention is industrially applicable that could be manufactured or us. By industry, its broad meaning is intended and it includes items such as hand craft, agriculture, fishing and services”.

Article 3 states:

“The patent certificate is a document issued by the Office of Industrial Property for patent protection and patent holder can benefit its exclusive rights”.

Article 16 states:

“The patent certificate with respect to this matter, after the patent expires twenty years from the date of filing the tax return.” (Mansour, 2010).

The number of patents in that country will create new manufacturing capabilities, and it will be considered as an alternative to. Innovation In this study the effect of invention and its role in reducing carbon dioxide emissions of production process will be studied.
C. Environmental Kuznets curve

In 1955, Kuznets studied the issue of the changes and inequality of incomes during economic growth. The economists studying in the field of environments used Kuznets theory to examine the relationship between economic growth and environmental degradation. As a result, they found that the relationship between economic growth and environmental degradation is in the form of an inverted U. This relation came to be known as Kuznets curve (curve). The curve represents the long-term relationship between economic growth and environmental quality. In this regard and during early stages of industrialization, increased production is of high importance. Moreover awareness of environmental issues was too low. at the beginning of economic growth Therefore, economic growth cause environmental degradation. In the later stages of industrialization, increasing revenue and improved technology, and information on environmental pollution increased production and economic growth led environmental Kuznets curve to get a downward slope. So, the advancement of technology along with achievement of the desired growth led to less damage to the environment and sustainable development. Numerous studies have been done in Iran in this regard the results of which are described in the following: the results of a study of Saadat and Sadeghi (2005) showed a two-way causal relationship between economic growth and environmental impacts. Pour-Kazemi and Abraham (2009) found out that that the hypothesis regarding Environmental Kuznets Curve cannot be rejected in the Middle East. In a study by Amir Timur and Khalilian (2010), they concluded that Kuznets hypothesis is not applicable for OPEC members and by increase of economic growth among the members, the carbon dioxide emissions is constantly rising. Amade et.al (2010) investigated the effect of per capita GDP on the volume of greenhouse gases and came to the conclusion that the Iranian model of determining per capita GDP is incomplete. Studies by Behboudi et.al (2011) and Fallahi et.al (2012) showed that the increase in per-capita GDP has caused an increase in carbon dioxide emissions. In sum, based on the above results, Iran is in the early stages of development and GDP growth might increase environmental pollution.

D. Production function

In this section, the production function of Solow model (1956) is presented. In this function developed for a particular technology, the entire production is a function of capital in the form below.

\[ y = f(k) \text{, } f_k > 0 \text{ and } f_{kk} < 0 \]  

(1)

In the above equation, which represents production, \( k \) is the function of capital and the pollution generation is considered as side product.

Pollution and selection of technology

Manufacturing process using any technology is causing environmental pollution. It is only with the advent of technology that we can reduce pollution. In this regard, \( \mu \) indicates the ratio of pollution to production. Rate of pollution \( (\mu) \) might increase or decrease with improved technology may. First, it is assumed for simplicity that \( (\mu) \) is fixed at a specified time. The increase in production, increased pollution and technological progress (in order to improve the environment) reduce pollution. So at a certain time, the pollution is linked with increased production and has an inverse relationship with technology. The impact of these variables on pollution will be embodied in the following equation.

\[ p = \frac{\mu y}{A}, \quad 0 < \mu < 1 \]  

(2)

In which \( p \) represents pollution and \( A \) presents the number of clean technology and pollution (pollution reduction). Higher value of \( A \) shows that there is higher number of technologies available for production. This results in a more efficient technology of production. Therefore, the selected technology is cleaner for environment and creates less pollution. Here, any up-to-date technology will be considered as clean technology (to reduce emissions). At a given time and with a specific technology, the amount of pollution
is directly related to the production. But every country, with time and with continuous updating of existing technology or innovation would move towards cleaner technology (Andreoni and Levinson, 2001). By taking the logarithm of equation 2, a long-term relationship can be achieved:

\[ \ln p = \ln \mu + \ln y - \ln A \]  

(3)

Determining the differential from equation 3 leads to obtaining equation 4 as follows. This relationship suggests that the growth of clean technology is able to reduce pollution

\[ \frac{\dot{p}}{p} = \frac{\dot{y}}{y} - \frac{\dot{A}}{A} \]  

(4)

With a fixed time, the contamination rate is presumed to be fixed. But over time, the rate of contamination (the ratio of pollution to production) is variable and defined as follows:

\[ \mu = \mu_0 e^{\theta t} \]  

(5)

In which \( (\mu_0) \) \( \mu_0 \) the primary infection rates, \( \theta \) constant \( \theta(0) \) or \( \theta(0) \), \( t \) represents the time. After obtaining the logarithm of the above equation, the equation 6 will be as follows:

\[ \ln \mu = \ln \mu_0 + \theta t \]  

(6)

Then equation (6) is substituted in equation (3) to give:

\[ \ln p = \ln \mu_0 + \theta t + \ln y - \ln A \]  

(7)

In reference to the equation 4, the relationship is stable and will be defined as follows:

\[ \frac{\dot{p}}{p} = \theta + \frac{\dot{y}}{y} - \frac{\dot{A}}{A} \]  

(8)

Theoretically, in the long run growth rate of contamination is directly related to economic growth and technological advances increase production and reduce pollution. But this has been tested empirically in Iran using vector error correction the data of which will be described below.

E. Data research methodology

Over time, the annual number of registered patients show each country’s technological improvement. In the present study, the number of patents per capita is considered as a substitute for innovation. In the following, the number of registered patents per capita was taken from the World Intellectual Property Organization. Annual data time-series of carbon dioxide gas emissions per capita was extracted from the World Bank website. For the statistics of per capita real GDP per capita and oil price, time series data of the Central Bank was used. In this study, using vector error correction and time series data from 1987-2010, the impact of production shocks, innovation (patents) and the oil price on carbon dioxide emissions of Iran are studied. Adding the random interference (\( \nu \)) in equation 3, the long-term equation 9 will be obtained. It
is worth noting that all the variables are logarithmic\(^1\). Moreover, for the implementation of the model for Iran’s economy as a major exporter of oil, the price of oil also has been considered in the model

\[
\text{co}2 = \alpha_1 p + \alpha_2 \text{GDP} + \alpha_3 o + \nu_i
\]  

(9)

Where \(o\): represents the price of oil. Vector error-correction model is defined in the form of equation 10 as:

\[
\Delta X = \Omega \Delta X_{t-1} + \eta \text{ECM}_{t-1} + \epsilon_i
\]  

(10)

Where \(x\) is the vector of variables and ECM is the long-term vector (i.e. \(\text{ECM}_t = \text{co}2 - \hat{\alpha}_1 p - \hat{\alpha}_2 \text{GDP} - \hat{\alpha}_3 o\)), \(\Omega\) is coefficient matrix and \(\epsilon, \eta\) are respectively error correction coefficients and random interference terms respectively. A dummy variable is also added to consider membership in convention on climate change.

**Results of Model Estimation**

Dickey-Fuller generalized test is used for evaluation of static conditions of variables. The null hypothesis of this test indicates the absences of static variables and the results of this test show that all variables become static after one-time differencing. Based on the minimum criteria according to Schwarz bayesian and akaike information criteria, three optimal lags were chosen.

**A. Johansen and Juselius Co-integration Test**

Static test results show that the variables are not in a static level but become static after one time of making a difference. Therefore, the possibility of co-integration between model variables should be examined. In this regard, we used Trace test and Maximum eigen values. According to the test in the tables 1 and 2, the existence of three vectors are confirmed. If the variables are not in static level, all of them have similar static level and there is no long-term vector, vector autoregressive model vector must be used, but because there are three verified vectors in confidence level of 95 percent here, the error correction model should be used.

**Table 1. Review of Johansen and Juselius Co-integration Vector – Trace.**

<table>
<thead>
<tr>
<th>Maximum Number of Long-term Vectors</th>
<th>Trace</th>
<th>Critical Value at 0.05</th>
<th>H1</th>
<th>H0</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Long-term Vector</td>
<td>306.0506</td>
<td>68.100</td>
<td>(r \geq 1)</td>
<td>(r = 0)</td>
</tr>
<tr>
<td>1</td>
<td>107.1631</td>
<td>46.5800</td>
<td>(r \geq 2)</td>
<td>(r \leq 1)</td>
</tr>
<tr>
<td>2</td>
<td>50.4189</td>
<td>28.7600</td>
<td>(r \geq 3)</td>
<td>(r \leq 2)</td>
</tr>
<tr>
<td>3</td>
<td>13.7943</td>
<td>14.5300</td>
<td>(r \geq 4)</td>
<td>(r \leq 3)</td>
</tr>
</tbody>
</table>

**Table 2. Review of Johansen and Juselius Co-integration Vector - Maximum Eigenvalue.**

<table>
<thead>
<tr>
<th>Maximum Number of Long-term Vectors</th>
<th>Eigenvalue</th>
<th>Critical Value at 0.05</th>
<th>H1</th>
<th>H0</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Long-term Vector</td>
<td>198.8875</td>
<td>33.9700</td>
<td>(r = 1)</td>
<td>(r = 0)</td>
</tr>
<tr>
<td>1</td>
<td>56.7442</td>
<td>27.9600</td>
<td>(r = 2)</td>
<td>(r \leq 1)</td>
</tr>
<tr>
<td>2</td>
<td>36.6274</td>
<td>21.2100</td>
<td>(r = 3)</td>
<td>(r \leq 2)</td>
</tr>
<tr>
<td>3</td>
<td>13.7943</td>
<td>14.5300</td>
<td>(r = 4)</td>
<td>(r \leq 3)</td>
</tr>
</tbody>
</table>

\(^1\) Dina.S , (2011).
B. Diagnostic Tests

To determine the reliability of the results of the vector error correction model, determination of autocorrelation and normality of test results is critical. In auto correlation test, Lagrange coefficient of the null hypothesis indicates lack of autocorrelation in residual sentences. Therefore, based on the results of residual sentences, the model has no autocorrelation in delay 3. The null hypothesis of normality on normality test of residual sentences presume the normality of such sentences. In this study, to evaluate the normality of the residual terms, the inverse Cholesky Triangular matrix was used. The results of these test showed that all of the variables are normal. In addition, the hypothesis of lack of difference variance (the null hypothesis) is not denied based on the test results. Therefore, the problem of variance difference is not the case.

C. Long-Term Vector Estimation

According to effect statistics, and Johansen and Juselius co-integration vector in particular, there are three long-term vectors. According to the error correction factor, first and third vectors were not significant and only the second vector is significant which is defined as follows. (Error correction factor table is in the appendix).

Table 3. Co-integration vector based on carbon dioxide emission.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Real GDP</th>
<th>Innovation (Patent)</th>
<th>Oil Price</th>
<th>Dummy Variable of Convention on Climate Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long-term Coefficient</td>
<td>17.8787</td>
<td>-16.8125</td>
<td>-3.3311</td>
<td>-0.39984</td>
</tr>
</tbody>
</table>

Based on results from long-term co-integration vector calculated in Table 3, GDP has a positive effect on the increase of carbon dioxide emissions which is due to the greater use of fossil fuels in production process. Innovation (patents), rising oil prices and the dummy variable of Convention on Climate Change have reduced carbon dioxide emissions in long-term. With regard to Iran, the country's single-product exportation and the bulk of the country's revenue comes from oil. So, the rise of oil prices will increase the country's income. This leads to the growth of other sectors as well as increase in budget allocated to research and development in such sectors. The negative impact of climate change can also indicate the impact of the convention on the virtual range of successful activities carried out in this direction.

D. Granger Causality Test

To assess significant effects of model variables on carbon dioxide emissions, Granger causality test was used. Based on the results of the estimation of Granger causality test in table 4, the null hypothesis that the lack of effect of the carbon dioxide emissions on the model variables is denied at the level of 95%.

Table 4. Granger Causality Test for Dependent Variable of Carbon Dioxide.

<table>
<thead>
<tr>
<th>Minimum</th>
<th>Significant Level</th>
<th>Statistics LR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.001</td>
<td>26.394</td>
</tr>
</tbody>
</table>

CONCLUSION

The present study aimed to investigate the long-term effects of innovation (patents), real GDP and oil prices in on environmental pollution (carbon dioxide emissions). The dummy variable of Convention on Climate Change was considered as well to assess the effectiveness of measures taken in the years following the date of membership of Iran in convention. In this context, the annual time-series data of 1987-2010 and structural vector error correction model was used. The main objective of this study was to provide practical approaches to reduction air pollution in order to achieve sustainable development. Results of vector error
An increase in real GDP, oil prices and the improvement of innovation (patents) have long-term effect on gas emissions of carbon dioxide. The dummy variable of convention on Climate Change can reduce carbon dioxide emissions. The actions taken appear to be in line with the objectives of the Convention. In the long-term, the impact of patent (technology) is negative, so this shows that the updated technology can reduce carbon dioxide emissions. The results by Karyvn- and Ines Flores (2010) also matched the above facts. The rise in oil prices has an impact on carbon dioxide emissions. The results of Jalaei Abadi et.al (2014) also corresponded with the present study concerning the fact that GDP growth in the long-term increases carbon dioxide emissions. Therefore, Iran is in the first phase of the environmental Kuznets curve and within the early stages of industrialization,. The results of Amir Timur and Khalilian (2010), Behboudi et.al (2011), Fallahi et al (2012) and Sharzei et.al (2014) the same statements. Considering the results of the estimation model, the following practical suggestions are provided. The support of establishment of knowledge-based companies in order to accelerate the entry of new technology can be beneficial to the industry. Since innovation (patents) in the first periods of industrialization is accompanied with a high cost for deployment, it is recommended to accelerate the deployment of new innovations in the production process. In addition, the commercialization of new technologies should be considered by economic planners. Considering the fact that some innovations can be directly and indirectly developed in the production of machines with low pollution, it seems that legislation to facilitate the process of patent and intellectual property protection can play an important role in reducing environmental pollution. With regard to the long-term effect of rising oil prices upon reduction of carbon dioxide emissions, such a decline would be due to the increased share of the budget allocated to research and development. Therefore, it seems that more investment in research would lead to improved technology. This could be a perfect solution for reducing carbon dioxide emissions. Therefore, new innovations must be made on an ongoing basis. Constantly updated technology would make it possible to achieve the desired economic growth, reduce air emissions, and achieve sustainable development. With regard to the above issues, constant monitoring of factories and industries in regard to application of new technologies in the production process and fining the use of old machines (which are pollution-increasing) can be effective.

REFERENCES

1912