

Review Article

INVESTIGATION OF OPTIMAL CARBON TAX RATE IN IRAN USING AN INTEGRATED CLIMATE-ECONOMY MODEL

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Abstract

This study used an integrated climate-economy model for dynamic optimization of the carbon tax rate in Iran, which can serve as a key policy tool for controlling climate change through the internalization of social costs of carbon emissions. For this purpose, the optimal carbon tax rate in Iran for 18 five-year periods from 2011 to 2101 was estimated using the data pertaining to the 2011-2016 period based on three approaches: social cost of carbon, temperature changes, and emission changes. The results showed that using the first approach, the optimal carbon tax rate for the Iranian economy would be 50 Rials/tonne in the beginning and 350 Rials/tonne in the later periods. Using the second and third approaches, this rate would be 15% at the beginning of the period and reach as high as 38% under the worst emission conditions.

JEL classification: Q5, H23, Q54, H4, Q58.

Keywords: Social Cost of Carbon, Climate Change, CO₂, Side Effects.

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INTRODUCTION

Today, the environment is widely regarded as one of the pillars of sustainable development, and environmental stability and sustainability are believed to be a prerequisite for the development of many economic and social sectors. Over the recent decades, especially since the 1992 Earth Summit in Rio de Janeiro, this issue has received increasingly more attention from the international community and several regional and international agreements have been reached to strengthen environmental protection rules and regulations (the 1997 Kyoto Protocol, the Paris Agreement, and the 1992 United Nations Framework Convention on Climate Change). In the meantime, the increasingly visible effects of global climate change and local environmental degradation in Iran have drawn the attention of Iranian policymakers and decision-makers to the issue of environmental protection and have led to growing support for the inclusion of bolder environmental considerations in the national plans and agenda. International reports show that, over the last fifty years, the extremely high and still rising energy consumption in Iran, which is mostly due to abysmal energy efficiency, has made Iran one of the world's leading producers of environmental pollution. According to the latest official energy balance sheets published by the World Bank and United Nations, with an annual CO₂ production of 700 million tonnes, Iran ranks eighth in the world and first among OPEC countries in terms of CO₂ emission. While Iran's population has grown by 39% between 1990 and 2014, during the same time, the country's CO₂ production has risen by 203%. This puts Iran in the third place - after China and India - in terms of carbon emission growth, and this is while most other countries have tried to adopt necessary measures to reduce their pollution levels (UNDP, 2016). This highlights the necessity of acting to control the direct and environmental costs of excessive energy consumption through market control tools.

Given the indisputable effects of economy and environment on each other, especially the direct impacts of economic decisions

on the regional environment, and also the effect of environmental policies on social welfare, governments often find it challenging to balance economic policy choices with environmental considerations. Further, environmental resources can be viewed as public goods, the overexploitation of which results in negative economic consequences. In this analysis, environmental degradation can lead to the failure of market forces to deliver social welfare, in which case competitive markets will not be able to guarantee Pareto optimal solutions (Cullis & Jones, 1998). One of the economic policy instruments that can be leveraged to tackle environmental pollution is fiscal policy. Many believe that the taxation of highly polluting economic activities not only encourages increased energy efficiency but also improves social welfare by expanding the tax base on these types of activities. This type of taxation is called the green tax. The main goal of the green tax is to internalize the costs of pollution in all business activities and promote the improvement of social welfare in parallel with economic growth. Given the importance of the relationship between economic growth and environmental pollution, recent years have seen the development of several endogenous growth models for this area (Hadian et al., 2013). In the present study, we attempt to answer the questions that what will be the effect of carbon emission control policies on domestic consumption, production, and welfare in Iran, what is the proper way to levy carbon tax in Iran, and what will be the optimal and dynamic rate of the carbon tax in Iran. After this introduction, the second section reviews the research literature, the third section describes the research method, and the final two sections present the results of model estimation with different approaches to determining optimal tax rate in Iran and the conclusions.

REVIEW OF LITERATURE

Since the 1990s, environmental scientists have developed many methods for predicting the effects of climate change, which have relied on integrated assessment models. While traditional models in this area have been focused on the physical effects of

climate change, today, researchers prefer integrated models that also measure their social effects. The most widely accepted model in this area is the Dynamic Integrated Climate-Economy model (DICE). DICE can assess the economic and environmental aspects of an issue simultaneously by combining economic modeling, mathematical modeling, and other related sciences. This type of model has three features. First, they provide means of control over climate change policies. Second, they integrate the different dimensions of climate change into one framework. Finally, these models help us quantitatively assess the issue of global warming alongside other problems. These models are divided into two general types: policy assessment models and policy optimization models. The second group of models determine the best rate of the carbon tax for maximizing social welfare. One of the most important features of these models is their simple formulations. However, most climate change assessment models do not consider the long-term effect of emissions. Many believe that the DICE model, first introduced by Nordhaus (1989), is the most suitable model for such analyses. This model has been updated several times and its latest version, DLCE-2016R, was introduced in 2016 (Nordhaus, 1992, 2011). Some features of this model that distinguish it from other models are as follows: A) The three inputs of capital, labor, and carbon energy are considered in the production function and the demand for carbon fuels is obtained based on the level of energy demand. B) The model uses a modified energy supply determination method. In previous models, the energy supply is determined by market prices, but in this model, it is determined based on the final cost of energy supply. C) In this model, the global effects of climate change are derived from regional effects and are based on estimations and analyses of the market and non-market variables as well as potential risk effects. In the previous models, however, only the temperature changes are examined. D) The general approach of DICE is based on the development of the growth model, which was first introduced by Frank Ramsey in the 1920s, combined with the growth model by Koopmans et al. (Koopmans, 1965), and developed into the economic growth theory by Solow (1970). This model pays attention to investment and environmental variables (such as greenhouse gases). The extended forms of this model consider greenhouse gas accumulation as a negative capital and treat greenhouse gas reduction as an increase in capital stock. Therefore, the DICE model assesses the three factors of climate, economy and carbon cycle altogether, which results in a better analysis of the costs and benefits of greenhouse gas reduction. This model is one of three models used by the US Environmental Protection Agency and is shown to give intermediate estimates compared to the other two models (Golosov, Hassler, Krusell, Tsyvinski, 2011).

In empirical assessments of different countries, economists have proposed a variety of methods to prevent or control the damaging effects of pollution and emission. Many of these works have been focused on the use of economic tools such as taxes to protect the environment. Koskela & Schokb (1995) advocated the introduction of the green tax in Germany and discussed such reform in the tax system of an open economy. They showed that the green tax internalizes negative externalities, thereby affecting the economic activity of market players. Uri & Boyd (1997) analyzed the effect of rising gasoline and electricity prices using a general equilibrium model in order to evaluate the economic effects of price increases on energy carriers in Mexico. The result of this study suggested that rising prices will reduce energy consumption and environmental effects, ultimately increasing government revenues. Hill (1998) assessed the cost of reducing pollution using environmental taxes as well as the cost of tax breaks with and without employment restrictions. He found that reducing CO₂ emissions by 5-25% will reduce emission costs by more than 9%. Hwan and Shortle (2005) studied the welfare effects of green tax reform in small open economies for Pennsylvania using a computable general

equilibrium model and simulated the possible effects of replacing carbon tax with conventional tax. In a study by Aldy & Pizer (2009) titled "Tax Policies in the USA", they sampled 400 American production units from 1986 to 1994, ultimately concluding that, assuming only the USA implements a carbon tax, this tax has a unilateral effect on production, consumption, and competition. In a study by Johann (2011) titled "the effects of carbon tax on energy industries in the competitive market", the author studied 21 European countries over a 16-year period and concluded that if importing countries levy taxes on industrial imports, this would affect competition negatively. In a study by Wong (2011) titled "short-term effect of carbon tax on competitive sectors", he showed that carbon tax may cause short-term disruption in China's competitive economy and this disruption can potentially affect different sectors of the economy as well as domestic and export markets. Therefore, tax rates play a crucial and decisive role in the competition.

In a study by Noroozi Hasanloui (2014) titled "The Impact of Carbon Tax on International Competition in Energy-Intensive Industries", the author emphasized that carbon or other green taxes act as an indicator for measuring greenhouse gas emissions. Then, the absorption model and the World Bank data were used to analyze the effect of the carbon tax on the energy export sector in ten countries in seven energy-intensive industries over the period 2000-2010. The results showed that the carbon tax had a negative effect on the export of target commodities. Nordhaus (2014) studied the social costs of carbon and compared the results of the DICE-2013R model and alternative approaches. He explained that one of the most important economic consequences of global warming policy-making is the Social Cost of Carbon (SCC). This study showed that based on 2015 prices, SCC was 18.6 dollars per tonne. It was also predicted that given the past trends, SCC will grow 3% by 2050. In a study by Dong et al. (2017) titled "impact of carbon tax on China's CO₂ reductions and provincial financial disparities", the authors examined the relationship between carbon tax and provincial financial disparities. They emphasized that during China's rapid development, carbon reduction goals cannot be feasibly reached using only traditional methods and instead should be met through management and energy efficiency programs. Using a Computable General Equilibrium model (CGE) under different market scenarios and vehicle carbon taxes, this study showed that under different scenarios, China's industrial carbon will decrease by 2030. Nemati (2007) assessed the economic and environmental effects of carbon tax with a general equilibrium model. In this study, the labor supply is endogenous and both the energy and non-energy sectors are modeled. Moghimi et al. (2010) investigated the welfare and environmental effects of green tax and fuel subsidy reduction in Iran using the CGE model. The results of this study showed that as the price of energy carriers increased, the emissions of most pollutants decreased. Ranjbar Fallah et al (2013) studied the effects of CO₂, SO₂ and NO_x emissions on Iran's GDP. In this study, the Cobb-Douglas model and time series data from 1974-2006 were used to analyze the effect of these pollutants on the GDP using OLS (Ordinary Least Squares). The results of this study showed the negative effect of greenhouse gas emissions on GDP. More specifically, a 1% increase in emission of these pollutants led to a 0.0188% decrease in GDP, and a 1% increase in the costs of destruction caused by the emission of these pollutants led to a 0.0231% decrease in GDP. Khodadad Kashi et al. (2015) studied the welfare effects of different types of carbon tax in Iran's provinces. This study used the general equilibrium model to analyze the effects of carbon tax on social welfare over a ten-year period from 2001 to 2011. As these studies indicate, analyzing the relationship between the economy and the environment with a model or framework capable of addresses both aspects can provide valuable insights into the mutual effects of the economy and climate change.

METHODOLOGY AND MODEL ESTIMATION
Model estimation

The formulations used in this study are derived from those provided by Nordhaus and Szorc (2013) and Nordhaus (1992, 2014, 2116). These works have been focused on the impact of economic goals and environmental issues on the quality of life and the present value of consumption over time. Therefore, in the presented model, the consumption function is generalized to include not only the purchase of market goods and services but also non-market ones such as recreation, cultural facilities, and benefit from environmental resources. Structurally, the proposed model consists of an objective function that measures social welfare and a number of economic and environmental constraints. The objective function has three basic assumptions: 1- Social welfare is an increasing function of consumption; 2- Ultimate social welfare is a decreasing function of consumption; 3- The ultimate utility of consumption for any generation has a higher value than that for the next generation. The relative importance of different generations depends on the rate of time preferences. Here, it is assumed that the time preference is positive and the present generation is preferred over future generations. Accordingly, for each region, the objective function is maximized subject to economic, geological, and physical constraints according to the following equation:

$$W = \sum_{t=1}^{T \max} U [c(t), L(t)] R(t) \quad (1)$$

In this equation, $C(t)$ is the per capita consumption, $L(t)$ is the population factor, $R(t) = (1 + \rho)^{-t}$ is the discount factor on utility or welfare, where ρ is the pure rate of social time preference or generational discount rate. Time preference rate is a parameter that is well reflected in many social decisions such as monetary or fiscal policies. This parameter is closely related to the market interest rate (or marginal productivity of capital) and the savings rate. Assuming declining impatience, time preference rate is considered to be decreasing over time.

The production function of the model is based on the modified neoclassical model and has three inputs of labor, capital, and fossil energies. In this function, technological changes are considered in two forms: change in the general economic technology and change in the carbon control technology. All technological changes are considered to be Hicks-neutral. Changes in carbon control technology are assumed to result in pollution reduction. Therefore, the gross production function is formulated as follows.

$$Q(t) = \Omega(t) [1 - \Lambda(t)] Y(t) = C(t) + I(t) \quad (2)$$

Where $Q(t)$ is gross production minus costs and losses, $Y(t)$ is gross output, which is a Cobb-Douglas function of capital, labor, and technology, $C(t)$ is consumption, $I(t)$ is gross investment. Labor is proportional to population, while capital accumulates according to an optimized savings rate. The additional variables in the production function are $\Omega(t)$ and $\Lambda(t)$, which represent the damage function and the abatement-cost function, respectively. The damage function is defined as $\Omega(t) = D(t) / [1 + D(t)]$, where

$$D(t) = \psi_1 T_{AT}(t) + \psi_2 [T_{AT}(t)]^2 \quad (3)$$

(Assuming that the carbon emission and commodity trading is allowed, the budget constraint will be:

$$Q(t) + \tau(t) [\Pi(t) - E(t)] = C(t) + I(t) \quad (4)$$

In this equation, $\Pi(t)$ the cap of the carbon emission permit, $\tau(t)$ is the per-unit price of permit or per-unit carbon tax, and $\Pi(t) - E(t)$ is the net income from permit trading. Uncontrolled greenhouse gas emissions are obtained from the carbon intensity level).

Carbon emission is assumed to depend on the energy use and the technology level. It is also assumed that the efficiency of technologies will increase over time as they change. Assuming that $\sigma(t)$ is the CO₂ emission of an industry, $E(t)$ is the total CO₂ emitted, and $\mu(t)$ is the rate of reduction in greenhouse gas emissions, then:

$$E(t) = \sigma(t) [1 - \mu(t)] Y(t) + E_{land}(t) \quad (5)$$

If emission exceeds the permissible limit, then the industry must purchase permits. Permits are allocated on a contractual basis and as a carbon tax.

Other constraints and limitations must also be considered in the model. As the amount of CO₂ in the atmosphere increases, so does the amount of solar energy it absorbs and also the damage due to rising temperatures. Therefore, the relationship between CO₂ concentration in the atmosphere and climate change needs to be included in the environmental equations. In the proposed model, it is assumed that CO₂ can be stored in three places: atmosphere, land biosphere, and deep oceans. Accordingly, the geophysical equation for the carbon cycle under the effect of climate change is defined as follows.

$$M_j(t) = \varphi_{0j} E(t) + \sum_{i=1}^3 \varphi_{ij} M_i(t-1) \quad (6)$$

The three reservoirs are $j = AT, UP,$ and LO , which are the atmosphere, the upper oceans and biosphere, and the lower

oceans, respectively. The parameters φ_{ij} represent the flow parameters between reservoirs per period. The relationship between GHG accumulations and increased radiative forcing is shown in equation (7).

$$F(t) = \eta \left\{ \log_2 \left[\frac{M_{AT}(t)}{M_{AT}(1750)} \right] \right\} + F_{EX}(t) \quad (7)$$

Where $F(t)$ is the change in total radiative forcings of greenhouse gases from anthropogenic sources such as CO₂, $F_{EX}(t)$ is exogenous forcings, and the first term is the forcings due to atmospheric concentrations of CO₂. Forcing lead to warming according to a simplified two-level global climate model:

$$T_{AT}(t) = T_{AT}(t-1) + \xi_1 \left\{ F(t) - \xi_2 T_{AT}(t-1) - \xi_3 [T_{AT}(t-1) - T_{LO}(t-1)] \right\} \quad (8)$$

$$T_{LO}(t) = T_{LO}(t-1) + \xi_4 [T_{AT}(t-1) - T_{LO}(t-1)] \quad (9)$$

Where T_{AT} is the global mean surface temperature and T_{LO} is the mean temperature of the lower oceans, which is assumed to be an indicator of the loss of net production because of environmental effects of policies and can be formulated as a quadratic function of temperature changes.

Social cost of carbon

The social cost of carbon (SCC) approach seeks to quantify the overall marginal cost caused by the emission of one extra tonne of carbon (through climate change). In this context, carbon price can be viewed as the price that society is willing to pay to avoid the negative impacts of climate change. In other words, SCC is equal to the increase in social welfare because of environmental improvement following the reduction in carbon footprint (Tol, 2009). This refers to the amount a society has to pay to compensate for climate change damage (Nordhaus, 2010). Here, SCC is obtained from the following formula:

$$SCC(t) = - \frac{\partial W}{\partial E(t)} / \frac{\partial W}{\partial C(t)} \quad (10)$$

On the right side of the above equation, the numerator of the fraction represents the negative impact of greenhouse gas emissions at time t on social welfare, and the denominator is the total welfare resulting from one unit of consumption in period t . This ratio calculates the economic impact of one unit of greenhouse gas emission in terms of consumption in period t as a numeraire, but in actual calculations, a discrete approximation of this formula is used. Regarding Equation (10), it should be noted that this formula shows that the total cost of emission at time t (in terms of consumption in time t as a numeraire) changes over time. In climate-economy models, policy-making takes into account a trade-off between present and future consumption, whereby reducing greenhouse gas emissions at the present time will decrease the current economic output, which can be devoted to consumption or investment, but it will also decrease the climate damage and increase future consumption (Nordhaus, 2014).

Investment in the climate takes place by reducing fossil fuel consumption or shifting the consumption towards low-carbon fuel consumption and renewable energies. Hence, climate damage is expected to be reduced by the modification of production energy or resources. Therefore, the optimal tax rate

should be determined so that it would be economically equivalent to the level of pollution. This can be done by setting the carbon tax equal to the shadow price of carbon emissions. To determine this price, the exogenous and policy parameters and variables and the DICE model are used in an analysis carried out with the help of software GAMS and Excel to compute the optimal value of the target variable, that is, the optimal carbon price in Iran. The optimal value of the target or endogenous variable depends on the type of policy adopted, which can be done according to objectives such as the level of welfare, utility, production, present value and trend of consumption, carbon emission trend, carbon price trend, and the relationship between climate damage and production.

A zero-carbon tax rate means that the government asserts no control over the risk of emissions, and the emission volume is determined by an unregulated market. In the Pareto optimal solution, however, the emission level allowed for each economic sector is equal to the social price or shadow price of its emissions. The social or shadow price of carbon reflects the effect of environmental change of an additional unit of emission on the present value of society's consumption.

Social carbon price data and estimation

The model is estimated using the socioeconomic information provided in Iran's energy balance sheets for the years 2011 to 2016. According to these reports, because of the state promotion of the use of natural gas, in recent years, natural gas has accounted for over 60% of total energy consumption in Iran (Energy Balance Sheet of Iran, 2015). Also, of the 721 million tonnes of greenhouse gas produced in 2015, 700 million tonnes have been carbon (Ibid). Studies show that the effects of greenhouse gases are not limited to one region and have global consequences such as widespread drought, change in transmission patterns of infectious diseases, etc. The main parameters used in model estimation are presented in the table below.

Table 1: exogenous parameters of the model

No.	Parameter	Source	Value
1	Depreciation rate	Direct tax law (Iran)	13.5
2	Output elasticity of capital	Central Bank of Iran, 2016	0.42
3	Carbon emission intensity	Nordhaus (2016)	0.274
4	Initial population growth rate per period	Statistical Center of Iran	0.064
5	Population growth decline rate	Khodadad Kashi et al., 2015	0.215
6	Technology growth rate	Central Bank of Iran	0.04
7	Initial social discount rate	European Commission (recommended rate)	0.03
8	Growth of social discount rate per period	Nordhaus, 2016	0.0026
9	Production elasticity to carbon energy	Khodadad Kashi et al., 2015	0.05
10	Energy share of GDP	Energy Balance Sheet of Iran, 2016	0.32
11	Clean energy efficiency rate	Nordhaus, 2016	0.42
12	Capital productivity rate	Central Bank of Iran, 2016	0.3731
13	Economic growth rate per period	Central Bank of Iran, 2016	0.03
14	Loss factor (as a percentage of domestic production)	Fattahi et al., 2013	0.02
15	Capital stock decline rate	Central Bank of Iran, 2016	0.0101
16	Household consumption expenditure growth rate	Central Bank of Iran, 2016	0.114
17	Government spending growth rate	Central Bank of Iran, 2016	0.01
18	Carbon growth rate per period	Fattahi et al., 2015	0.05
19	Capital stock growth rate	Central Bank of Iran, 2016	0.02

The social (shadow) price of carbon can be estimated by several indicators. Some have used hedonic pricing and the cost of reducing the effects of emission and others have used the mean years of life lost (YLL) and the medical costs due to pollution for this purpose. In this study, the social cost of carbon is estimated using the mean YLL and the medical costs due to pollution.

MODEL ESTIMATION AND EVALUATION

Estimation of pollution and social costs of carbon

After obtaining the pollution cost from the World Bank data, the studies conducted by the World Bank and the Iranian Department of Environment are reviewed to estimate the social costs of carbon dioxide emissions in Iran's economy. Using the figures reported in the energy balance sheet of Iran and World Bank report, according to which the cost of CO2 emission (per tonne) for the base year 2011 is 300 Rials, the average social cost of CO2 emissions in the economic sectors of Iran is estimated to 173924 million Rials per tonne. This cost covers a wide range of consequences, such as warming, drought, change in the pattern of infectious diseases, increased energy consumption, respiratory problems, and change in the pattern of cultivation. Since power plants (51602 million Rials), residential, commercial, and public sectors (41368 million Rials) and transportation (44018 million Rials) have the greatest contribution to the social cost of pollution for the Iranian economy, the carbon tax rate is estimated in proportion to the volume of pollution generated by

these sectors. In the second approach, the carbon tax is estimated based on the mortality rates, the imposed medical costs, the decline in labor productivity, and the increase in health costs due to carbon emission. Another indicator of the social cost of carbon is the cost of reducing the effects of carbon emissions due to economic activities.

Estimation of the optimal carbon tax rate

The most important factor in determining the optimal carbon tax rate is the initial carbon concentration. In this step, the method of Jones, Manuel, and Rossi (1992) is used to perform an analysis with the annual and cumulative data based on the model's base year. First, the national economy is defined as an integrated entity. Here, decision variables include consumption, tangible investment rate, investment in climate, and initial reduction in greenhouse gas emissions. It is assumed that the country produces a commodity that can be consumed or invested. It is also assumed that the national economy has an initial level of capital, labor, and technology, technological growth is exogenous, and capital accumulation is obtained by the optimization of consumption over time.

To evaluate the state of production in different scenarios, we first examine the production process. In the following diagram, the social price of carbon in Iran (in billion Rials) is plotted for 18 five-year periods from 2011 to 2101.

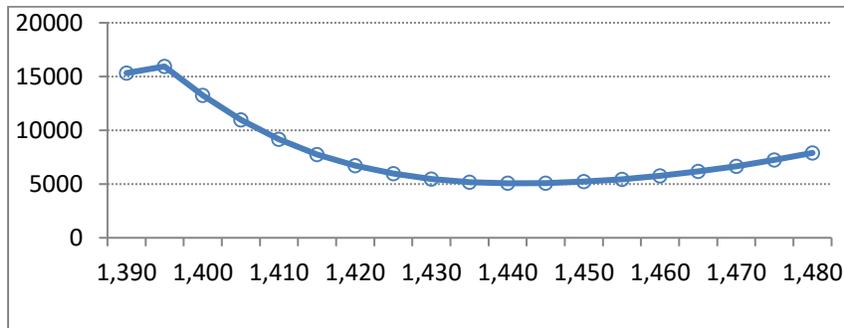


Figure 1: Domestic production trend with respect to the base year

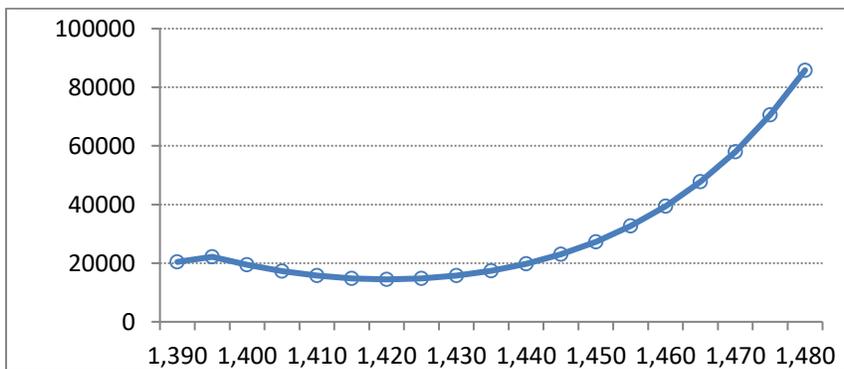


Figure 2: Optimal domestic production trend with a discount rate of 8% and a technological growth factor of 4

As the above diagrams demonstrate, after levying carbon tax based on the social cost of carbon with the maximum social discount rate and the technological growth factor of two-times the base scenario, initially, there will be a decline in domestic production, but after several periods and the replacement of

technology, production will return to the uptrend. Figure 2 shows that the optimal tax rate and higher technological growth factor not only lead to higher levels of production growth rate but will also accelerate the return to the upward trend.

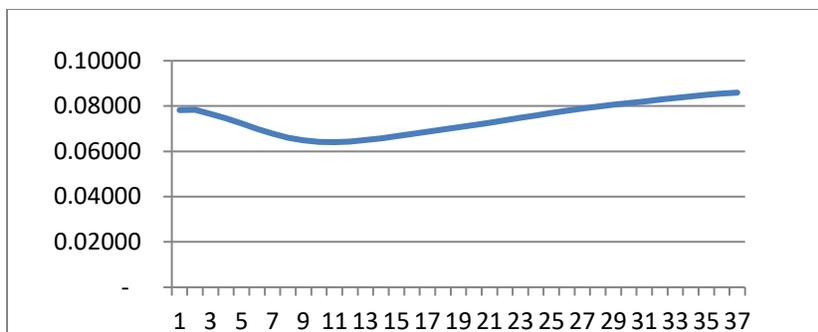


Figure 3: Estimation of the per capita welfare trend over the period

Figure 3 shows that with the increase in the social carbon tax, in the initial periods, the per capita social welfare per unit of additional consumption decreases, but after technology replacement in the subsequent periods, this factor starts to increase.

Using the integrated SCC analysis model, the central bank's estimated productivity rate, the international social price of carbon, the social discount rate of 8%, and the economic growth rate of 4%, the social price of carbon in the Iranian economy was estimated to 513891.23 Rials per tonne. However, the results show that because of the trend of production technology

replacement, this price initially increases but then with the arrival of new technologies and the improvement of energy efficiency, it starts to decrease. Therefore, carbon taxing strategy should be devised to encourage and accelerate the use of new technologies in the early periods. One can consider three approaches to optimizing the social cost of carbon: a) optimizing carbon price; b) considering emission change; c) considering temperature change. The following diagram illustrates the results of the estimation of the optimal social cost of carbon based on the optimal carbon price or tax.

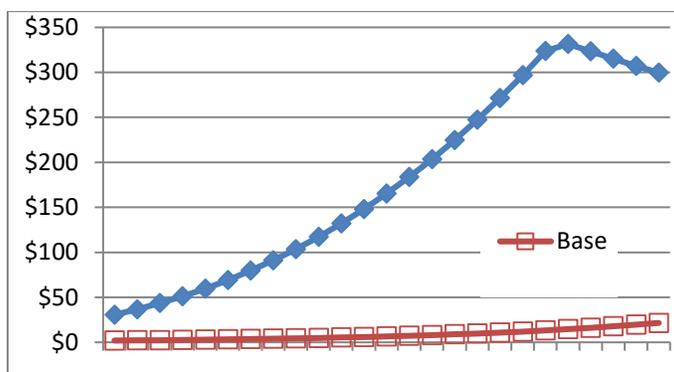


Figure 4: Optimal carbon price in Rials per tonne

As shown in Figure 4, the optimal carbon price or tax is much higher than the rate in the base state. The optimal carbon tax rate estimates obtained using the second approach, which is,

considering changes in emissions, are plotted in Figure 5. These results show that the optimal carbon tax rate will be lower than the base rate.

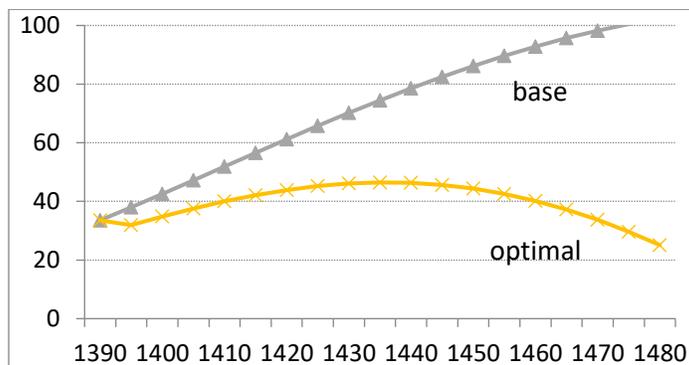


Figure 5: Optimal carbon tax rate considering emission change (percent)

The results of the third approach based on climate data for the years 2013 and 2016 are presented in Figure 6. As can be seen, the optimal carbon tax rate in 2013 is lower than the base rate.

However, because of the warming weather, the optimum rate for 2016 is higher than the base rate.

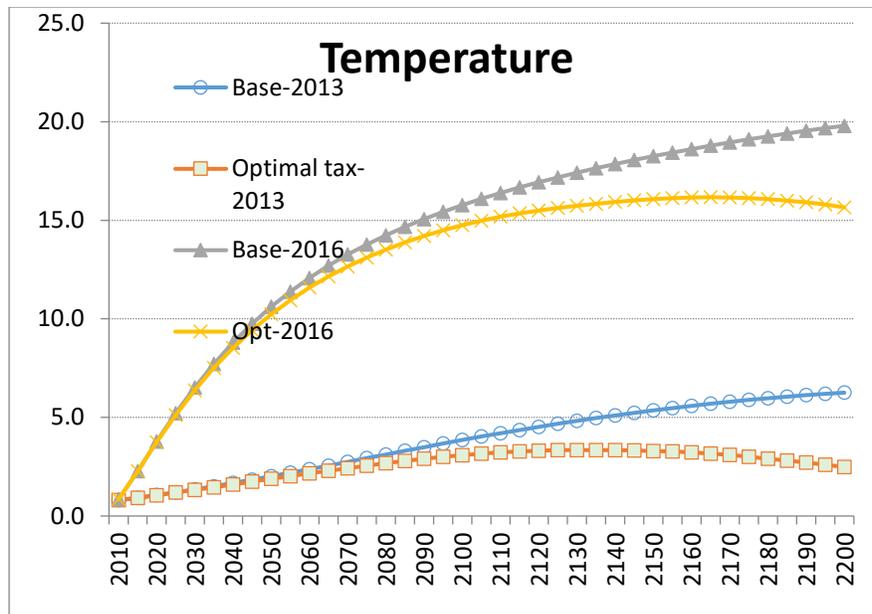


Figure 6: Optimal carbon tax rate considering temperature changes (percent)

According to the chart presented in Figure 6, to reach the optimal tax rate based on temperature changes, it should be computed as an increasing percentage of carbon emission. In this approach, the optimal carbon tax rate is 5% at the beginning of the period, increases to 10-15% after a few periods, and then becomes a fixed rate after the intermediate periods. In contrast, the chart plotted in Figure 5 shows a higher optimal carbon tax rate, that is, 33% at the beginning of the period, 38% in the intermediate periods, and lower rates after about ten periods because of the reduction of carbon emission.

CONCLUSION

In this paper, the optimal carbon tax rate in Iran for 18 five-year periods was estimated based on three approaches using the data for the period 2011-2016. The results showed an inverse relationship between carbon control policies and domestic production and consumption in the initial periods. The results obtained from different approaches to the estimation of the effects of carbon emission showed that the direct methods of the energy balance sheet will underestimate the cost and the YLL (years of life lost) method will overestimate the cost of emissions. A major problem of other conventional methods for estimating carbon emission costs is their inability to reflect the long-term impacts of social and economic costs. The estimation results of this study showed that the technology growth factor has a positive effect on the emission rate. Therefore, to reduce the social costs of carbon, it is recommended to levy carbon taxation in such a way as to increase the speed of technology growth and replacement, thereby preventing the reduction of social welfare due to pollution. Since the optimal carbon tax must be equal to the social cost of carbon emission, after any change in ultimate emission costs, it is necessary to recalculate the optimal carbon tax rate.

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