Economic, Environmental and Social Impact of Carbon Tax for Iran: A Computable General Equilibrium Analysis

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Abstract

The environmental taxes, such as carbon tax, also affect other economic variables in a different way in addition to the main goal of politicians. The carbon tax aims to reduce energy consumption and pollutant emissions, while it can also reduce labor tax and labor costs which are incentives to create new jobs. It is necessary to evaluate the carbon taxation policy in Iran due to the special circumstances of the budget deficit mainly caused by the decline of exports and oil revenues. The present study is based on a general equilibrium model in the form of a nonlinear equations system. The model has been calibrated for the 2017 reference year using the data table adopted from Iran’s economy. It has been shown that if the carbon tax revenue is employed to decrease the labor income tax, the environmental quality will be improved by reducing pollutant emissions on the one hand, and it will lead to positive effects on the welfare and employment on the other hand. In the present paper, the effect of applying this tax on two policies with redistribution (compensation) and without redistribution (no compensation) of income tax among the households is examined. Maximum, minimum, and optimal values of pollutant emissions reduction under the influence of carbon tax policies were calculated in both scenarios. The simulation results show that the taxation without redistribution of tax revenues decreases the welfare and household’s actual consumed budget by 6.2%, but in policy with compensation of tax revenue, these indices will increase by 0.8%. The gross domestic product (GDP) decreases by about 1.7% and 2.1% in both policies, respectively, while the consumer price index (CPI) in both scenarios will increase by about 6.4% and 8%, respectively. According to this research findings, carbon taxation with the redistribution of revenue is a suitable policy to reduce greenhouse gas emissions and adhere to international commitments at the same time.

Keywords

carbon tax, employment, general equilibrium model, welfare


1 | INTRODUCTION

The reliance on oil revenues and continuity of this approach over years has caused instability in improving economic indices and volatility in the economic growth of oil-exporting countries, so that reduction in oil price and its exports as the main source of government revenue have delayed many government policies and programs. The tax is one of the main components of the government’s sources for revenue, and therefore, each year in preparing the budget bill, it attempts to increase the share of tax revenues compared with the previous year to replace oil revenues. One of the issues that have been considered in recent years is to eliminate subsidies and impose a tax on the consumption of energy carriers for reducing the environmental pollution caused by greenhouse gas emissions, especially carbon dioxide that comes from fossil fuel combustion.

To this end, the carbon tax is considered a common policy of energy, especially in advanced countries. Carbon tax and energy tax are two examples of the most widely used market-based instruments (MBI) that influence both energy consumptions (resulted in carbon dioxide emissions reduction) and other key economic variables.

In general, the carbon tax or the same environmental tax is superior to other ways of eliminating the non-economic externalities of pollutant emissions. This was highlighted for the first time by Pigou. As to the environmental tax rate, Pigou indicated that the optimal taxation for pollutant emissions is equal to the marginal costs of environmental damage. This means that the private marginal cost plus the external cost of pollution should be equal to the ultimate benefit of the consumption of the polluting commodity.

Environmental taxes are divided into two direct and indirect categories. The direct tax is the same Pigouvian tax, which has a certain rate and is considered per unit of pollutant emissions or environment degradation. That is, the tax rate is equal to the marginal social cost of pollution at the socially efficient level, but indirect taxes imposed on the factors of production or consumption goods, the use of which is harmful to the environment, can be considered as a signal to realize the socially efficient level of emissions. Carbon tax and energy tax are indirect taxes. In investigating the carbon tax effects, it is assumed that the labor tax will be reduced simultaneously with the application of carbon tax. Also, the government tax revenue can be realized by two with/without compensation scenarios in this method. That is, the carbon tax revenue will be added to other government tax revenues in the scenario without compensation and will be returned to the income basket of households in the scenario with compensation. According to these assumptions and in the context of involuntary unemployment, the carbon tax has different effects on the important economic and environmental changes. In general, carbon tax affects the pollutant emissions, the welfare of consumers, unemployment, the general level of prices, price index of sectors, conditional demand for factors of production, and GDP value. In the theoretical literature, the following triple effects of the carbon tax have been given more attention:

- The positive effect of the carbon tax on the environmental quality: Internalization of external costs related to pollutant emissions.
- The positive effect of the carbon tax on welfare: Changes in consumption of goods and services, the reduction in other taxes, such as labor tax, and reducing the welfare losses caused by pollutant emissions.
- The positive effect of the carbon tax on unemployment: Reduction in labor tax resulted in reduced labor costs.

The importance of examining the carbon tax effects has been proven in most countries in the world. For example, according to the specific conditions of global warming and the effects of greenhouse gases in China, Lu et al. found that the taxation of 300 Yuan per ton of emitted carbon reduces the pollutant emissions rate by 17.45% and leads to only a 1% reduction in GDP. In a similar study for Australia, Meng et al. observed that the taxation of 23$ per ton of carbon not only improves the emission index but also has effects on economic growth. Alan et al. investigated the impact of imposing the carbon tax in three scenarios by developing an economic-environmental model for Scotland. They found that a 50 £ tax imposed on each ton of carbon dioxide emissions not only cuts 37% of the environmental pollution but also improves some tax-related economic activities. In another study, Mahmoud et al. discussed the carbon tax concept under huge pressure from energy security and climate change issues and expressed that carbon tax has a significant impact on the country’s environmental and economic issues. By presenting a general equilibrium model for the economy of the Philippines, Cabalu et al. stated that the imposition of 5$ tax per ton of carbon dioxide leads to a 0.5% and 9.8% reduction in GDP and greenhouse gas emissions, respectively, which reflects the positive effects of this policy on Philippine’s economy.

Fu et al. developed a factorial computable general equilibrium model of China. They investigated interactions between stepped carbon tax on different fuel types and analyzed stepped carbon tax on fuel types with different carbon emission intensities. Their research showed that carbon taxes of 18.37-38.25 Yuan/ton are a reasonable policy alternative for China. They also concluded that positive effects for reducing carbon emission
intensity can be strengthened with an increasing step range. Ji et al. proposed a stochastic optimization model for carbon and emission reduction investment and sustainable energy planning under cost and risk control applied in the electric power system planning of Zhejiang Province. They indicated that the carbon emission reduction policy could stimulate the development of CCS technology.

To determine the amount of carbon tax aiming the emissions reduction and evaluating associated impacts on Chile’s economy, Benavente investigated the carbon tax concept and showed that a 26 $ tax per ton could reduce CO2 emissions by 20%. It also stated that the tax would cut down 2%-3% of GDP. Van Heerden et al. discussed the carbon taxation for South Africa. Their results indicated that the taxation of 12 Rand (the official currency of South Africa) per ton of carbon dioxide could reduce CO2 emissions by 1900 tons in 2016 and 2300 tons in 2035. In an analytic study, Calderon et al. discussed the various scenarios regarding carbon tax and its associated requirements in Colombia and stated that the imposition of carbon tax causes a reduction in the GDP and economic growth, but it will have a significant impact on the reduction in environmental pollution that could justify its imposition. In another study, Zhang et al. evaluated the three provinces of Hainan, Fujian, and Chongqing in China. According to the extent of the coal application for producing energy in these provinces, their results showed that the taxation equivalent to 60 Yuan per ton of emissions leads to a significant decrease in the amount of released carbon dioxide. They have also stated that the imposition of carbon tax not only reduces other indirect taxes but also can improve the welfare of households through subsidizing. Newbery et al. studied the carbon tax imposition in Canada, and their results showed that carbon tax practices could reduce emissions by about 75% by 2050 and have some minor effects on the economic growth and GDP value. They also claimed that this tax would improve the welfare of households by changing other tax sectors.

Previous studies show that the study of the carbon tax and energy tax effects, especially using the computable general equilibrium models, has attracted the attention of researchers at the world level and some internal researches. Among the different effects of the carbon tax, its effect on environmental quality, welfare, and unemployment has received more attention.

Concerning many research conducted on carbon and energy taxes in various countries entire the world aiming at the improvement of economic, environmental, and welfare indices and the lack of an investigation on the economic and environmental effects of the carbon tax in the framework of energy, economy, and environment-based interrelations for Iran case study, it is necessary to evaluate the carbon taxation policy in Iran due to the special circumstances of the budget deficit mainly caused by the decline of exports and oil revenues. In other words, the imposition of carbon tax not only can compensate some part of the budget deficit but also will be able to prevent environmental degradation factors and climate changes originate from greenhouse gases, especially carbon dioxide.

The present study presents a general equilibrium model to examine the effect of imposing a carbon tax on environmental issues, household welfare, and employment considering the conditions and regulations of Iran. This study aims to evaluate different scenarios of carbon taxation considering both with/without compensation policies and select the policy which is optimal from the economic, environmental, and welfare points of view. GAMS software has been applied to implement this model. Finally, based on the optimal policy obtained from the modeling stage, some solutions are proposed in the framework of modifying the exploitation of fossil fuel resources for improving the economic and environmental issues and preserving the nonrenewable sources of energy.

2 | METHODOLOGY AND MATHEMATICAL MODELLING

The general equilibrium model provides a simplified picture of the economy, and well indicates the actions and reactions of economic factors. Unlike traditional models that are designed at the macro level, such as input-output models and linear programming models, the general equilibrium model benefits from the simultaneous adjustment of prices and values to establish optimization and equilibrium conditions (ie, zero-profit condition, markets clearing condition, and income equilibrium condition). In other words, unlike input-output and linear programming models, both prices and values are endogenous variables in general equilibrium models. In other words, the main objective of solving the general equilibrium model was to find the endogenous variables (ie, equilibrium prices, values, and incomes).

Unlike econometric models which require statistics and time series data or a wide range of periodic statistics and data, the general equilibrium models require fewer statistics and data and employ statistics and data of a reference year. Statistics and data related to elasticity can also be adopted from other econometric studies. The parameters of the general equilibrium model are obtained
using the calibration method based on statistics and data of the reference year.

2.1 | CGE model description

The model used in this research is the standard model of computational general equilibrium. This model is one of the most famous general balance models that can be designed as standard. The equations of this model are divided into four parts or blocks, which are price block, production and trade block, institution block, and system constraint block. Of course, the necessary adjustments have been made in the equations of the standard model in order to harmonize it with the Iranian economy. This model is designed based on social accounting matrix (SAM) information and includes economic activities, goods, factors of production, and institutions. In this model, labor, capital, and intermediate inputs are used in the production process. Then, the produced goods are converted into export goods and domestic goods with constant traction (CET) using the conversion function. Consumers buy composite goods. These composite goods are either imported or produced domestically. The combination of imports and domestic production is determined by what is known as the function of a production (Armington) with a constant replacement succession. The country in question is the recipient of the global prices of the “average country” of a constant level of exports and imports. By balancing the constraints of the system, including equilibrium in the market of factors of production, equilibrium in the market of composite goods, equilibrium in the foreign market, equilibrium in the public sector, and balance of savings-investment, equilibrium is established in the whole system. The equations of this model, after being explained and specified, have been converted into a programming language in the GAMZ software package, and with this software, the model equations are solved simultaneously.

The components of the computable general equilibrium model (CGE), including factors of production, prices, and commodities, as well as the relationship between each component, are shown in Figure 1.

2.2 | Model framework

Firstly, the model dimensions need to be determined in terms of how portrays the economy and the degree of integration between different economic sectors. In the selected model, the factors of production are limited to labor, capital, and energy. Therefore, primary materials and intermediary inputs are not considered separate factors of production. Therefore, in the present model, capital cost means the cost of inputs or factors of production other than labor and energy.

In the selected model, energy is consumed by household and commodity production sectors. It is also mentioned here that the energy input is not neglected in the case of other sectors such as the public goods production sector the energy production sector, and it is considered in inputs other than the labor sector input. In addition to the energy demand \( E \), it is assumed that households also demand consumption goods \( X \), leisure \( F \), and public good \( G \). For simplicity, it is assumed that the public good (as an exogenous variable) is provided constantly. Therefore, it can be omitted from the household utility function. This causes the utility function to be shown as \( U(X, E, F) \) in the model. The household chooses values of consumption goods, energy demand, and leisure, in such a way as to maximize their utility. Concerning what mentioned above, in addition to the household income equilibrium and government budget equilibrium, the equilibrium in the following markets will be considered: the consumption goods market \( (Y_X) \), energy market \( (Y_E) \), public goods market \( (Y_G) \), labor market \( (L) \), and capital market \( (K) \).

![Figure 1: Components of the computational general equilibrium model (CGE)](image-url)
Considering that the household produces utility by using consumption goods \((X)\), energy \((E)\), and public goods \((G)\). Therefore, the household sector can also be considered as a production sector. Hence, the production sectors in the model are as follows: consumption goods production, energy production, public goods production, and utility production by households.

It is observed that the model presented in this study has some similarities with the household production function model. Household behavior is similar to market behavior since the household is a utility producer using market goods and available time for leisure. In the present study, as the consumer price index and energy price index are considered for the consumption goods production sector or energy production sector, respectively, a utility price index is also defined for the utility production sector. In the model, the utility price index is a function of the income and consumption goods price index. The other similarity of the present model and the household production function model is that the household income is not limited only to monetary income, but it is considered along with the total amount of time available to household and leisure time: total household income. It should be noted that the market goods and time are not directly entered into the utility function in the household production function model. Therefore, the model applied in the present study differs from the household production function model in this aspect.

### 2.3 Model equations, variables, and parameters

#### 2.3.1 Model equations

In general, the theoretical basis and starting point of all general equilibrium models are the competitive general equilibrium model. However, these models can also incorporate some uncompetitive assumptions such as non-mobility of factors, unemployment, uncompetitive pricing, scale-induced savings, and so on. The uncompetitive assumption, that is considered in the model related to the present study, is the existence of involuntary unemployment. The main idea behind all studies relating to the general equilibrium models is the transformation of the Walras’s general equilibrium structure from an abstraction to the applied mode.

The general equilibrium model selected in the present study consists of three groups of equations as mentioned above. The system of general equilibrium equations, which also consists of nonlinear equations, can be solved by the GAMS software designed to solve the system of nonlinear equations. In this case, three groups of equilibrium variables including equilibrium prices, equilibrium values, and equilibrium revenue can be calculated.

The choice of any particular type of behavioral functions for manufacturers and consumers will give a certain form of unit cost functions and the conditional demand functions for goods and factors of production. The zero-profit condition is expressed through the equality of goods prices with the unit cost function. The market-clearing condition is expressed through the equality of supply of goods or factors of production with the conditional demand for goods and factors of production. Then, prior to the introduction of the zero-profit and market-clearing equations, it is necessary to introduce the selected functional form for production and utility functions.

#### 2.3.2 Unit cost functions or zero-profit condition

According to the production functions of firms and households, the unit cost functions can be obtained through the unit economics optimization and then applied to express the zero-profit condition. The zero-profit condition is expressed as the equality of the commodity price index in different production sectors with the unit cost. The homogenous unit cost functions are one-order functions of the price of factors. That is, an increase in certain ratio at the price of factors increases the unit cost by the same ratio. According to the assumption of constant returns-to-scale efficiency considered in related production functions, the unit cost function is homogeneous of degree zero relative to the production level. That is, changes in the production level do not change the unit cost. Therefore, it can be stated that at the same time, the unit cost function is also the total cost function. Now that the unit cost function is introduced as above, the equality of the produced commodity price with the unit cost expresses a zero-profit condition.

In this model, CES utility and production functions are selected. Therefore, the unit cost function and the composite input price index in the consumption goods section can be defined as Equation (1)- (4):

\[
\left[\theta_{VAX} \rho_Q^{(1-\sigma_{Q})} + (1 + \theta_{VAX}) \rho_E^{(1-\sigma_{E})}\right]^{1/(1-\sigma_{Q})} = P_X \tag{1}
\]

\[
\left[\theta_{k_e} R^{(1-\sigma_{k_e})} + \theta_{t_x} W_G^{(1-\sigma_{t_k})}\right]^{1/(1-\sigma_{k_e})} = P_E \tag{2}
\]

\[
\left[\theta_{k_e} R^{(1-\sigma_{k_e})} + \theta_{t_l} W_G^{(1-\sigma_{t_l})}\right]^{1/(1-\sigma_{k_e})} = P_G \tag{3}
\]
\[
\left[ \theta_{\xi} R^{(1-\sigma_{KL})} + \theta_{\eta} W_G^{(1-\sigma_{KL})} \right]^{1/(1-\sigma_{KL})} = P_Q \quad (4)
\]

In these equations, price variables including \(\theta_{\xi}\) and \(\theta_{\eta}\) represent the distribution parameters, \(R\) is the interest rate, \(W_G\) is the gross wage, \(P_Q\) is the cost of inputs other than energy or the composite cost of labor and capital factors in production of \(x\), \(P_X\), \(P_E\), and \(P_G\) are the producer price indices, \(\sigma_{QE}\) is the energy-capital labor substitution elasticity, \(\sigma_{KL}\) is the labor-capital substitution elasticity in the consumption goods sector, \(\sigma_{KLC}\) is the labor-capital substitution elasticity in the energy sector, and \(\sigma_{KLC}\) is the labor-capital substitution elasticity in the public goods sector. It is noticed that the composite input price index \(Q\) represents a hybrid price index for all inputs other than energy, or expressing a composite price index for primary inputs of labor and capital, and its value is a function of labor wage and interest rate.

The utility function is also a two-level hybrid function (CES), which combines the leisure and composite consumption good. To determine the composite consumption goods (AC), the consumption goods \((X)\) and household's energy consumption \((E)\) are combined together at lower level. At the high level, the composite consumption good \((AC)\) is combined with the leisure \((F)\) and produces utility as expressed by Equation (5):24:

\[
\left\{ C_{\text{TOTSHR}} F_C^{(1-\sigma_{EF})} + F_{\text{SHR}} \left[ W_G (1 - T_R \tau_{TW}) \right]^{1/(1-\sigma_{EF})} \right\}^{1/(1-\sigma_{EF})} = P_U
\]

where \(F_{\text{SHR}}\) and \(C_{\text{TOTSHR}}\) are the distribution (share) parameters, \(T_R\) is the endogenous variable of the fixed tax revenue, \(\tau_{TW}\) is the endogenous variable of the wage tax rate, \(F\) is the leisure time, and \(P_U\) is the utility price index.

It should be noted that the utility \((U)\) is considered as a production sector. Considering the utility function introduced above, utility or \(u\) is derived from consumption of goods, leisure, and energy in the production sector. That is, the general form of the utility function is \(U \left( X, E, F \right) \). Therefore, \(P_U\) is the commodity price index of the production sector \(U\). In other words, as the consumer price index and energy price index are introduced in the consumption goods and energy production sectors, the utility price index is proposed in the utility production sector. It is noted here that the utility price index is a function of the wage and consumer price index.

The consumer price index, which is the same composite price index of commodities, is calculated from Equation (6):25

\[
\left\{ a_x F_X^{(1-\sigma_{XE})} + a \left[ P_E (1 + T_M) \right]^{1/(1-\sigma_{XE})} \right\}^{1/(1-\sigma_{XE})} = P_C
\]

In this equation, \(P_T\) is the composite consumer price index, and \(\sigma_{XE}\) is the elasticity of substitution between consumer goods and energy.

Considering the assumption of stability of public goods supply, public goods \((G)\) is not imported in the utility function. It is noted that, contrary to the household production function method, the leisure time and consumer goods are directly entered into the utility function.

### 2.3.3 Market clearing

The markets clearing condition is expressed through the equality of commodities or factors of production supply with the conditional demand for goods and factors of production. Regarding the introduction of unit cost function, the conditional demand for the factors of production and goods is calculated according to Equation (7)-(9):26

\[
\theta_{\xi} (Q) VA_0 \left( \frac{P_Q}{R} \right)^{\sigma_{KL}} = KD_X KD_0 X \quad (7)
\]

\[
\theta_{\eta} Y_E \left( \frac{P_E}{R} \right)^{\sigma_{KL}} = KD_E KD_0 E \quad (8)
\]

\[
\theta_{\gamma} Y_G \left( \frac{P_G}{R} \right)^{\sigma_{KL}} = KD_G KD_0 G \quad (9)
\]

where \(KD\) is the conditional demand for capital, \(Y_X, Y_E,\) and \(Y_G\) are the activity levels for production amount of sectors, \(KD_X, KD_Y,\) and \(KD_E\) are the capital demands, \(KD_0 X, KD_0 E,\) and \(KD_0 G\) are the capital demands in the reference year, and \(\theta_{\xi}, \theta_{\eta},\) and \(\theta_{\gamma}\) are the capital share parameters in the composite input of labor and capital. Also, considering the conditional demand for labor \((LD)\), the market-clearing condition is defined by Equation (10):21

\[
\sum_i LD_i LD_0_i = \left[ L - (FF) (FF0) \right] (1 - UR) \quad (10)
\]

Parameters applied in Equation (10) are described below. The production labor demand at the sector level in different sectors of production is obtained from Equation (11)-(13):27

\[
\theta_{\xi} (Q) VA_0 \left( \frac{P_Q}{W_G} \right)^{\sigma_{KLC}} = LD_X KD_0 X \quad (11)
\]

\[
\theta_{\eta} Y_E \left( \frac{P_E}{W_G} \right)^{\sigma_{KLC}} = LD_E KD_0 E \quad (12)
\]

\[
\theta_{\gamma} Y_G \left( \frac{P_G}{W_G} \right)^{\sigma_{KLC}} = LD_G KD_0 G \quad (13)
\]
In the above equations, LD_X, LD_E, and LD_G are the labor demands and θ_L_x, θ_L_e, and θ_L_g are the labor share parameters in the capital-labor composite.

Leisure demand:
Since the production and utility functions are the same, the demand for leisure (FF) is expressed as follows:

\[ F_{SHR} \left( HH - I - \frac{F}{P_U} \right) \left[ \frac{P_U}{W_G (1 - T_{TW})} \right]^{\sigma_{FR}} = FF (FF0) \] (14)

Commodities market clearing:
Equation (15)-(17) are related to the commodities market clearing:

\[ Y_x Y_0 x = CD_x C0_x \] (15)
\[ Y_E Y_0 E = CD_E C0_E + IDE (IDE0) \] (16)
\[ Y_G (Y_0 G) P_G = GOVT _I \] (17)

In the above equation, CDX is the marginal demand for consumer goods, CDE is the marginal demand for the energy consumption, GOVT_I is the government revenue, and IDE is the energy intermediary demand.

In the selected model, the conditional demand functions are applied to formulate the equations of the market clearing for commodities and factors of production. These homogeneous functions are first-order functions of the production amount. That is, an increase in given ratio in the production or utility amount increases the demand for factors of production or commodities with the same ratio.

Total consumer market clearing:
Equation (18) can be applied to analyze the total consumer market clearing:

\[ \frac{HH_I_D}{P_C} = INC0 (AC) \] (18)

where AC represents the composite consumer goods (aggregate consumption), HH_I_D is the household disposable income, and INC0 is the reference year income regardless of leisure.

Market clearing for utility:
Equation (19) has been proposed to compute the utility that comes from market clearing:

\[ \frac{HH_I_F}{P_U} = (FULINC0) (U) \] (19)

In this regard, U is the utility or welfare and HH_I_F is the household full income (including leisure).

Marginal demand for commodities:
Equations (20) and (21) have been presented for the analysis of the marginal demand for consumer goods and energy:

\[ \alpha_x \left( \frac{HH_I_D}{P_C} \right) \left[ \frac{P_C}{P_x (1 + T_{HE})} \right]^{\sigma_{XE}} = CD_x C0_x \] (20)
\[ \alpha_E \left( \frac{HH_I_D}{P_C} \right) \left[ \frac{P_C}{P_E (1 + T_{HE})} \right]^{\sigma_{XE}} = CD_E C0_E \] (21)

In the above equations, α represents the constant substitution elasticity. The substitution elasticity indicates the ratio of input changes in percentage to the percentage changes in the technical marginal rate of substitution. In other words, the substitution elasticity indicates how the factors of production or goods are substituted by changing their relative prices. Also, C0_x and CD_E are the households demands for goods and energy, respectively.

Finally, Equation (22) shows the market-clearing condition for the labor and capital composite input for the production of commodity X:

\[ \theta_{VAX} Y_x Y_0 x \left( \frac{P_x}{P_Q} \right)^{\sigma_{OE}} = Q (VA0_x) \] (22)

In the above equation, Q represents inputs other than energy or the total composite input of labor and capital, Y_X is the consumer goods input, and \( q_{VAX} \) is the distribution parameter (share).

Here, the composite input Q is composed of another CES production function where labor and capital factors exist. In other words, the production function of X, which is CES, includes the other CES function (function of labor and capital). Therefore, we deal with the two-level production function of X. At the lower level, the capital and labor force are combined to create a composite input (Q); while at the higher level, the composite input (Q) and energy (Y_E) are combined to produce the consumer goods (X). Briefly, the consumer goods (X) are produced using the composite input and energy input.

The market clearing for intermediary demand of energy in production of X is obtained based on Equation (23):

\[ (1 - \theta_{VAX}) Y_x Y_0 x \left( \frac{P_x}{P_Q (1 + T_{YE})} \right)^{\sigma_{OE}} = IDE (IDE0) \] (23)

2.3.4 | Income equilibrium

To find household full income (including leisure), Equation (24) is presented as follows:

\[ (1 - \theta_{VAX}) Y_x Y_0 x \left( \frac{P_x}{P_Q (1 + T_{YE})} \right)^{\sigma_{OE}} = IDE (IDE0) \] (23)
In this equation, \( UR \) is the unemployment rate and \( T_W \) is the endogenous variable of annual tax revenue.

Household monetary or disposable income:

The monetary or disposable portion of the household income is also calculated according to Equation (25) based on the capital inventory.\(^{35}\)

\[
(K) (R) + W_G \left(1 - T_W \tau_{TW}\right) \sum_i LD_iL_D0_i = HH\_I\_D \tag{25}
\]

Government budget constraint:

The government budget constraint is also calculated based on the parameters introduced in Equation (26).\(^{36}\)

\[
TW \tau_{TW}WG \sum_i LD_iL_D0_i + T_{HFP_C}CD_RCO_E + T_{YPECO}IDE(CO_E) = GOV\_I
\tag{26}
\]

2.3.5 | Equations governing unemployment conditions

Equation (27) is applied for calculating the wages or labor demand.\(^{31}\)

\[
\log(W_G/P_C) = \delta_0 + \delta_1 \log(UR) - \log \rho \tag{27}
\]

In Equation (27), \( \rho \) is the net wage defined as a function of the endogenous variable of the wage tax rate, so that the constant government tax revenue condition is met. Equation (28) is used for calculating this rate\(^{24}\)

\[
\rho = 1 - T_W \tau_{TW} \tag{28}
\]

Finally, as the last condition, it is necessary to satisfy the condition related to the constant provision of public goods. Therefore, Equation (29) is assumed as a condition in modeling procedure.\(^{37}\)

\[
Y_G = G_{FIX} \tag{29}
\]

Table 1 Markets and desired segments in the model and related statistics and information

| Consumer goods and services (X) | Energy (E) | General goods (G) | Household (H) | Government (GOV) |
|--------------------------------|-----------|------------------|--------------|-----------------|
| Consumer goods and services (X) | +6 924 439 346 | - | - | -6 924 439 346 |
| Energy (E) | -155 865 446 | +966 162 395 | - | -810 296 949 |
| General goods (G) | - | - | +517 203 346 | - | -517 203 346 |
| Labor (L) | -906 575 472 | -31 112 191 | -312 248 343 | +1 249 936 006 |
| Capital (K) | -5 861 998 428 | -935 050 204 | -204 955 003 | +7 002 003 635 |
| Wage tax (T_W) | - | - | - | -517 203 346 | +517 203 346 |

In the above equation, \( Y_G \) is the production rate of public goods and \( G_{FIX} \) is the reliability coefficient of government expenditures.

2.4 | The statistical basis and calculation of parameters

In this study, the main part of applied information and data is directly extracted from the input-output table of Iran’s economy (central bank of Iran, 2017) and Table 1 is produced accordingly. Given that the total supply is equal to total demand for all sectors, the values in rows of Table 1 show the equality of total supply and total demand.

According to the rows of Table 1, the supply of each sector for other counterparts is represented by positive values and the demand of each sector from other ones with negative values. Therefore, the sum of the numbers in rows is equal to zero and, which expresses the equality condition between the total supply and total demand. On the contrary, given that the equality of expenditures and revenues for each sector is considered in input-output table, so the sum of values in each column of Table 1 is equal to zero. In Table 1, positive and negative values represent the revenues and expenditures, respectively. In general equilibrium models, zero-profit and market-clearing condition is considered as the basis and start point of the model. This property is also established in the input-output table and Table 1. Using the statistical resource of the input-output table adopted from Iran’s economy, the sum of values in each column (equal to zero) shows the zero-profit condition, and the sum of values in each row (equal to zero) indicates the market-clearing condition. In this table, for example, the consumer goods and services sector earned 6 924 439 346 Million RRI from the sale of goods and services in 2017. The expenditures of this sector, which are shown in the table by negative figures, are related to the purchase of energy (155 865 448 Million RRI), purchase of labor (906 575 472 Million RRI), and purchase...
of capital (5,861,998,428 Million RRI). It is noted that the first column values indicate a zero-profit condition for the consumer goods and services production sector. In this table, according to the first row values, the total supply of goods and services is equivalent to 6,924,439,346 Million RRI which is equal to the total demand for consumer goods and services (market-clearing condition). The model selected in this study limits the factors of production to the labor, capital, and energy labor. Therefore, primary materials and intermediary inputs are not considered as a separate factors of production. In other words, the capital cost means the cost of inputs and factors of production other than labor and energy.

### 2.5 Tax impact index

The ultimate goal of any policy should be to improve the welfare of the people. An index that is more used than other ones to measure welfare changes in the general equilibrium models is the Hicks equivalent variation (EV) that is derived from the utility function. In fact, the welfare indicator is equivalent to change in the monetary income, and it is calculated in the initial time based on prices and earnings prior to change in policy to achieve the level of utility in the new postpolicy equilibrium. Therefore, the welfare indicator (equivalent variation) measures the change in utility in terms of monetary units. In addition to the equivalent variation (EV) measure, changes in real consumption budget of households are evaluated in this study. The consumer price index, which shows the changes in the general price of goods and services, is named as Laspeyres price index.

#### 2.5.1 Carbon tax module

The model assumes that CO₂ emissions related to a given fossil fuel are proportional to its quantity. The carbon tax imposed on fossil fuels is based on their content of CO₂ and is modeled as an excise tax. The tax increases the cost of using fuels and induces firms to reduce their use through substitution effects. The magnitude of the increase in the production cost depends on several factors among which are the energy intensity of the firm and the ease of substitution among inputs. The carbon tax is considered as one of the income streams for government in this study. The carbon tax levied on each fossil energy and the ad valorem duty rate are calculated by equation:

\[
CTAX_f = t_c Q_f \epsilon_f 
\]

\[
t_c = \frac{CTAX_f}{PQ_f QQ_f} 
\]

CTAXₚ represents a carbon tax levied on fossil energy \( f \); \( t_c \) represents the specific duty rate of the carbon tax; \( \epsilon_f \) represents the ad valorem duty rate of carbon tax on fossil energy \( f \); \( QQ_f \) represents the total domestic consumption of on fossil energy \( f \); \( \epsilon_f \) represents the carbon emission coefficient of fossil energy \( f \); \( PQ_f \) represents the price of fossil energy \( f \); \( f \) represents the fossil energy sets.

#### 2.5.2 Development of tax model

The model proposed in the paper has assumed the wages at a fixed level and led to changes in the energy consumption, energy carrier demands, and carbon dioxide emissions by applying the carbon tax policy and changing the energy carriers’ price. The labor demand and supply are also quite flexible and change with the energy demand variation.

The real GDP at basic price also includes the value of the goods and services produced by factors of production and their taxation, and it is deflated by Fisher Price Index.

In general, the model studied in this paper consists of 60 equations and 60 unknown or endogenous variables, which are solved by the related software. The methodology of the present paper consists of four general steps as shown in the flowchart of Figure 2.

### 3 RESULTS AND DISCUSSION

#### 3.1 Model calibration and its initial solution

The information and data of the year 2017 demonstrated in Table 1 are obtained by initially solving and calibrating the proposed model. In the initial solution, the equilibrium values and prices are equal to 1, and the equilibrium income is equal to the value shown in Table 1. The reference equilibrium values and prices are always assumed to be equal to 1. The reason is that the software can determine the percent changes of variables and their deviations from 1 in the secondary solution of the model according to the policy-making parameters.

The results of the model calibration are summarized in Figure 3. According to this table, the results of the calibrated model indicate that the prices have been selected equal to 1, and the model has been calibrated correctly. It is noted that the gross wage, consumer price index, production level of each sector, labor and capital demands, marginal demand, consumer goods, and energy have been assumed to be 1, and income variables, such as household full and disposable incomes, have been considered equivalent to the values in the reference year. The unemployment...
rate in the reference year is 14%, which is regenerated in the model initial equilibrium and calibration. That is, the initial or reference equilibrium has been calibrated correctly, and the model is ready to evaluate the results of making policies in the energy sector such as carbon taxation, given the stability of government tax revenues and the stability of government expenditures.

3.2 Secondary solution of the model concerning the carbon tax policy execution

This section compares the results obtained from solving the proposed model with and without implementing the carbon tax policy. The initial model solution results for the endogenous variables are given in Table 2. Table 2 demonstrates the initial solution of the model without applying the carbon tax policy in which the endogenous variables had chosen the number 1. Here, the deviation of the endogenous variables from 1 and their variation are specified considering the carbon taxation and obtaining the secondary solution of the model, whose results are given in Table 2. In the secondary solution, the uniform tax rate on energy consumption for the household and production sectors is considered as 0%-30%, respectively. The reason for employing 30% carbon tax was because concerning the obligation of Iran to decline the greenhouse gas emissions from 4% to 12% in the COP21 Summit which is 10% till 2025. For the eighth development plant of the Iran’s government policy, it is targeted to reduce 48% of carbon emissions by the year 2040. We have investigated this goal can be achieved by 29.3% carbon tax; therefore, 30% tax policy is employed. Since the model is not dynamic, as a statistical model there was no duration to change from 0% to 30% but instead, there were scenarios of 0%-30% which means the program was run 30 times for each percent as a base model. The value 0 represents the policy without carbon tax. According to
the low price of energy in Iran compared with the world level prices, the higher carbon tax rate (30% tax rate) is the optimal condition. The results of implementing the carbon tax rate equivalent to 30% for Iran are summarized in Table 2 using the input-output statistical data of the year 2017.

According to Table 2, by considering 1.005 for welfare function, it is observed that the implementation of carbon tax policy has increased the consumer welfare even without considering the welfare obtained from the pollutant emissions reduction and environmental quality improvement. If we consider welfare obtained from the pollutant emissions reduction and environmental quality improvement, it will certainly be higher. Also, following the imposition of carbon tax, the composite consumption price index (inflation) has increased from 1 to 1.020, and the level of production has increased in the consumer goods sector because of the increase in employment due to the wage tax reduction.

Moreover, the results demonstrated in Table 2 indicate that the production level in the energy sector has reduced by imposing the carbon tax and increasing the energy price and consumer price index. Concerning the unemployment rate index, which has changed from 0.14 in the initial solution to 0.1 in the secondary solution, the unemployment rate has declined following the implementation of carbon tax policy.

Considering the intermediary and marginal energy demands equal to 0.864 and 0.77, it is observed that the intermediary and marginal energy demands have decreased due to the carbon taxation. By assuming a linear relationship between energy consumption and pollutant emissions, the level of pollutant emissions has decreased. This means the environmental quality improvement following the carbon tax imposition.

In the other part of this study, the effect of environmental taxation on carbon has been simulated. According to the structure of energy carriers pricing system in Iran, the environmental taxation will have different effects. In Table 3, the values of the emission rate and fuel consumption are presented based on the information and data in 2017. To calculate carbon tax, the carbon tax rate is primarily considered as an exogenous variable based on the carbon content of energy carriers. These taxes will also be applied to the consumption of energy carriers as intermediary commodities and energy consumption as a production input.

The carbon dioxide emission tax, proportional to the carbon content of each energy carrier, is considered for the direct and intermediate consumption of all carriers.

### Table 2: Modeling results by applying carbon tax policy

| Variable | Modeling results | Variable | Modeling results |
|----------|-----------------|----------|-----------------|
| Combined consumer price index ($P_C$) | 1.020 | Unemployment rate (UR) | 0.100 |
| The amount of production of consumer goods and services ($X_\text{C}$) | 1.041 | Leisure demand (FF) | 0.944 |
| Demand for consumer goods and services ($D_\text{C}$) | 1.041 | Utility or welfare ($U$) | 1.005 |
| The amount of production of general goods ($G$) | 1.000 | Interest rate ($R$) | 1.000 |
| Capital demand in consumer goods and services ($K_\text{D}_\text{C}$) | 1.036 | Intermediate energy consumption ($E_{\text{IDE}}$) | 0.864 |
| Labor demand in consumer goods and services ($L_\text{D}_\text{C}$) | 1.116 | Final energy consumption ($E$) | 0.777 |

### Table 3: Fuel consumption and emission rates in 2017

| Fuel | Final consumption | Unit | Emission rates | Unit | Final emission rate (Thousand Tons) |
|------|-------------------|------|---------------|------|------------------------------------|
| Coal | 1056              | Thousand Tons | 2.68 | kg/kg | 2830 |
| Natural gas | 91 378 | Million m$^3$ | 2.4 | kg/m$^3$ | 219 000 |
| Electricity | 240 063 | Million kWh | 0.13 | kg/kWh | 30 896 |
| Petrol | 21 879 | Million liters | 2.38 | kg/L | 52 072 |
| Kerosene | 5157 | Million liters | 2.49 | kg/L | 12 840 |
| Gasoline | 36 496 | Million liters | 2.84 | kg/L | 103 648 |
| Fuel oil | 16 250 | Million liters | 2.98 | kg/L | 48 425 |
| Other fuels | 8001 | Million liters | 2.20 | kg/L | 17 602 |
| Total emission (Ton) | | | | | 487 314 790 |
This approach is applied to determine the tax rate per conventional unit of measurement after determining the carbon content of the energy carriers. For this purpose, the price of energy carriers has been obtained from the energy balance sheet in 2017 and the values of energy consumed for each activity or household from the social accounting matrix.

Typically, the carbon emissions tax rate is specified endogenously based on the economic and environmental policies of the countries. In the present study, carbon emissions tax is considered from 0% to 30% in the simulations. Also, concerning the obligation of Iran to decline the greenhouse gas emissions from 4% to 12% in the COP21 Summit, the percentage of carbon tax for decreasing emissions in this range has also been discussed.

To determine the effect of carbon taxation, the emission coefficients for different types of energy carriers have been calculated based on the energy balance sheet of Iran in 2017. Also, the influence of two with/without compensation policies on the carbon tax is also analyzed in this study. The purpose of the tax with/without compensation was to show the policy of importing the proceeds of carbon tax to the state treasury or redistribution and return it to the household income basket. The consumer model parameters were assumed such as household budget and consumer price index, and it can be concluded that with compensation policy, the household budget increases, and without it, the budget decreases. These changes in the household budget will also affect other economic indicators which are examined in the following sections.

### 3.2.1 Carbon tax effects on the emissions reduction

As can be seen in Figure 4, the simulation results show that the imposition of 2% and 4.5% tax on carbon emissions leads to 4% and 12% reduction in carbon emissions, respectively. The imposition of carbon tax equivalent to 30% would reduce emissions by 51.2%. Also, due to the flawed substitution between the production inputs, the emission reduction has a downward trend by increasing taxes. Hence, the execution of the carbon taxation policy with/without redistribution of revenues will reduce energy consumption and carbon dioxide emissions in Iran.

The equilibrium electricity output and prices are shown in Table 4. There are a couple of noticeable features about electricity price. One is that the prices of electricity are slightly higher in scenario B (with compensation) than in scenario A (no compensation). This is well explained by the expansionary effect of household compensation policy. The other feature is that the change in the prices of electricity generation is much higher (over 90%) than that of retailer electricity price (around 25%). This disparity is understandable because the electricity bought by the distributor from generators accounts for only less than half of its total cost.

When it comes to the electricity output, it is apparent that natural gas electricity, gasoline electricity petrol electricity, and fuel oil electricity experience substantial contraction. The remarkable contraction of natural gas electricity is underpinned by the extremely high emission intensity and thus a huge increase in production cost under a carbon tax. Similarly, the gasoline electricity output decreases also due to its large emission intensity.

![Figure 4](image-url) 
Reduce carbon dioxide emissions with carbon tax policy

**Table 4** Equilibrium electricity output and prices (percentage change from baseline)

| Commodities | Electricity output | Electricity prices |
|-------------|--------------------|--------------------|
|             | Carbon tax         | Tax with compensation |
| Natural gas | −17.346            | −17.12             | 82.32 | 83.03 |
| Gasoline    | −7.46              | −7.37              | 71.92 | 72.63 |
| Petrol      | −6.06              | −6.07              | 61.27 | 61.99 |
| Fuel oil    | −2.21              | −2.23              | 51.41 | 52.13 |
3.2.2  Carbon tax effects on the household consumption budget and welfare indicator

Figures 5 and 6 indicate that the carbon taxation policy with redistribution of revenues will lead to an increase in the actual consumption budget of households and equivalent welfare indicator, but both indices will be reduced without the redistribution of tax revenues. The reason for the difference is that an increase in the carbon tax increases the price of energy supply and increases the income and welfare of the household if income from this tax returns back to the household basket, otherwise we face a decrease in both.

Carbon tax of 4% will lead to a 12% reduction in carbon dioxide emissions and, at the same time, will increase the actual consumption budget and equivalent welfare indicator by 0.36% and 0.52%, respectively.

3.2.3  Carbon tax effects on the consumer price index

The carbon tax policies with/without redistribution of revenues will result in an increase in the consumer price index as shown in Figure 7. In the case where tax revenue is not redistributed, price rise will be more severe. The general reason for this increase was the increase in electricity prices mentioned in Table 4 that indirectly affects the consumer model. This is attributed to the contribution of three main production factors of labor, capital, and energy markets in the production and supply of a commodity, which increases the marginal price of consumer goods by increasing the price of each factor while other factors are constant.

3.2.4  Carbon tax effects on the employment

In the proposed model, the unemployment rate and wage level are assumed to be constant. The tax imposition increases the price of the energy input relative to the labor input, and it is expected to increase the labor employment by firms under the influence of substitution between inputs. At the same time, this can increase or decrease the employment of production inputs including labor. According to Figure 8, in the same values of tax, employment levels will increase with a descending trend and then decrease. The imposition of tax, which can reduce emissions by 12%, will be accompanied by 0.18%-0.51% change in employment.
3.2.5  Carbon tax effects on the GDP

As shown in Figure 9, the GDP will be reduced by imposing carbon tax. Also, levying policy without redistribution of revenues has a higher decreasing effect. The reason for the GDP reduction is the increase in the energy carriers price relative to the basic price, and thereby, when the household incomes remain constant or increase lower than the rate of increase in the prices of energy carriers and consumer goods, this will reduce demand and consumption of public goods and, consequently, reduce the GDP.

The taxation policies, which make 12% reduction in pollutant emissions, will lead to a reduction in GDP at the basic price, equal to 0.34-0.56.

3.2.6  Carbon tax effects on industries

When carbon taxes have imposed, the results of production changes in different industries are given in Table 5. As shown in the Table 5, carbon tax on fossil fuels reduces production of sectors: agriculture, food industries, textile, wood and paper, chemical industries, steel industries, other industries, electricity, natural gas, transport and trade and services. While production of mining, construction and petroleum product increases. As the tax rates increase, the production of sectors (except for gas and oil sectors) is little changed.

3.2.7  Carbon tax effects on macroeconomic

In Table 6, the impact of carbon tax on the GDP, inflation rate, the total export level, and import has been demonstrated in presenting of 10, 20, and 30 percent.

As it is discerned from table 10, GDP level at current prices in the studied scenarios has fallen to 1.38%, 1.55%, 3.40%, and 1.91% respectively. By comparing scenarios 10% and 30%, it is deduced that, by the increase in carbon tax paid to households in scenario 30% and consequently by the demand increase from households for goods and services, the GDP growth rate will decrease from −1.38 to −1.91 percent. In other words, the GDP decline is increased by 0.53 percent due to the increase in the general level of prices. Of course, other factors have a role in these statistics along with the subsidy targeting.

4  CONCLUSION

There is no doubt about the level of ambition of the Iran Government’s emissions targets, but there must be some doubt about whether it has sufficient policy instruments under its direct control to induce households and firms to behave in a way that ensures these targets are met. Since there was no previous research that studied the effect of carbon tax in the triple domain of energy, economic and environmental fields of Iran, this research is done to cover that gap.

The analysis of the carbon tax effects on the economy of Iran shows that both types of taxation, with and without redistribution of tax revenues, will reduce energy consumption and carbon dioxide emissions in Iran’s economy.

The results of this study showed that

1. The effect of taxation without compensation on carbon dioxide emissions is slightly more than once taxes are repaid to households in a lump sum. The taxation without compensation (without redistribution of tax
revenues between households) leads to a reduction in welfare by 6.2%.

2. The adoption of the tax policy increases the consumer price index by 8%, but redistribution of revenues causes a lower rate of 6.4%. GDP will also be reduced in all scenarios. The redistribution scenarios that increase demand and production greater than other scenarios lead to a 1.5% further increase in labor supply and employment, while a 0.9% reduction in the employment index is observed in the scenarios without redistribution.

3. It is observed that if the government has no budget deficit and its main objective is to reduce greenhouse gas emissions, the use of carbon tax, in which the tax is determined according to the carbon content of each energy carrier, will remain independent from other policy considerations in energy pricing and have better conformance with the emissions control goal. Therefore, even without considering external effects owing to the environmental quality improvement, carbon taxation with the redistribution of revenues will be an effective policy for reducing emissions and increasing the welfare of society. According to model simulations, the maximum reduction in pollutant emissions due to the execution of tax policies is 166%, and a 100% decrease in pollutant emissions requires a 60% carbon tax. The minimum reduction is related to the without tax case, and the optimal reduction in emissions under the effect of imposing tax in both scenarios is 50%.

Considering the positive results of the carbon taxation policy in terms of welfare improvement, unemployment reduction, and saving energy, and reducing pollutant emissions, it is recommended to implement the carbon tax policy regardless of any suitable basis for energy pricing; as long as the labor tax is reduced and the government total tax revenues does not change. That is, the implementation of the carbon tax policy is recommended in a condition that the taxes and proceeds, such as taxes on wages and salaries, proceeds from the employer for the unemployment insurance and Social Security Insurance, and so on are reduced. So that the total tax revenues to be constant, the labor tax can even be negative.

In future works, the selected model can be extended to include more production inputs (rather than labor, capital, and energy), more production sectors, and more markets. Therefore, the selection of more flexible production functions instead of the CES function, such as the translog production function, can be an important consideration. In most general equilibrium studies, the starting point in the selection of equations is based on competitive conditions and comes within the framework of competitive conditions the constraints, and uncompetitive conditions. In the present study, it has been done similarly, and among the uncompetitive condition, only the involuntary unemployment confirmed with Iran’s economy is considered in the model. In future studies, other conditions of uncompetitive economics can be introduced into the general equilibrium model.

In general, since the purpose of implementing the carbon tax policy is to internalize the external costs of
emissions, the imposition of a uniform carbon tax for different economic sectors, different types of fossil fuels, and regions and different regions of the country cannot meet the above objective. Thus, the uniform tax rate of 30% presented in this study does not mean that the above considerations do not matter. The comparison of the economic and environmental impacts of different tax rates with the same carbon tax in different sectors, including household and production sectors, can be conducted in future studies.

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ENDNOTE

1 RRI is the national currency of Iran and in 2017, 1$ = 36 000 RRI.

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