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Full Length Research Paper

Welfare and environmental quality impacts of green taxes in Iran: A computable general equilibrium model

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One of the most important government challenges is the environmental crisis; therefore, governments should strive to implement various policies and programs to overcome environmental problems including air pollution or the reduction of negative effects of human functions on the environment. This study has tried by using an input-output table in 1380, specifically looking at the amount of pollutants and greenhouse gas emissions, to survey the welfare and environmental effects on the green tax in consumer sectors of energy. For this purpose, using Microsoft Certified Professional (MCP) and software general algebraic modeling system (GAMS) welfare changes with and without environmental impact, changes in energy demand and changes in three pollutants CO_2, SO_2 and NOx in the four tax scenarios have been studied. The results of the study showed that a green tax reduces the demand for fossil fuels as intermediate input and final goods. Under the 10% tax rate on fossil fuels, welfare has decreased 47.5%, if the environmental effects are not considered. Furthermore, CO_2, SO_2 and NOx emissions have decreased 50.5, 60.1 and 41.5%, respectively, and welfare increased to 3%, if the environmental effects are considered.

Key words: Green tax, welfare, emission, CGE, Iran.

INTRODUCTION

Since, air pollution in many countries and Iran is so important, governments have to adopt necessary policies on the environmental issues for both the short-term and long-term. Several Organizations for Economic Co-operation and Development (OECD) countries are considering, or have already implemented, some kind of green tax or quota to comply with emission reduction targets at the national and international level (OECD, 2001). The debate on green tax reforms has addressed the question of whether the trade-off between environmental benefits and gross economic costs of environmental taxes (that is, the costs disregarding environmental benefits) prevails in economies where distortionary taxes finance public spending. There are no studies of the effect of a green tax in Iran so far. However, many studies have been conducted for European countries and U.S. Koskela and Schob (1998) developed a model of a small open economy and studied a revenue-neutral green tax reform that substituted energy for wage taxes and found that a green tax reform increases output and welfare and improves the country's competitiveness. Bovenberg (1999) draws on the literature about the double dividend to explore whether an environmental tax reform yields not only a cleaner environment but also non-environmental benefits. In doing so, Bovenberg investigates how environmental tax reforms affect welfare, the distribution of income, and employment. Also, the political economy of environmental

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Abbreviations: GAMS, General algebraic modeling system; **MCP,** microsoft certified professional; **OECD,** organization for economic co-operation and development; **CGE,** computable general equilibrium; **CES,** constant elasticity of substitution; **LPG,** Liquefied petroleum gas; **MPSGE,** mathematical programming system for general equilibrium; **EV,** equivalent variations.

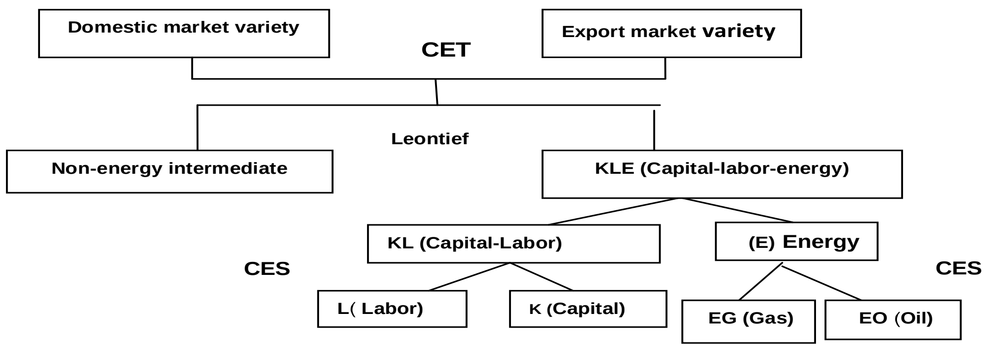

Figure 1. Nesting in non-fossil fuel production.

taxation is discussed. Goulder (2002) analyzed compensation and the effects of recycling carbon tax revenue. Goulder investigated policies designed to achieve equity-value neutrality. To maintain constant equity values following the introduction of industry-specific corporate tax credits, around 13% of permits must be allocated freely. Boehringer and Rutherford (1997) analyzed carbon tax exemptions for energy intensive industries and export industries in Germany. They concluded that tax exemptions limit the range of emission abatement and raise marginal abatement costs in the German economy. The main purpose of this article is the survey of welfare and environmental effects on the green tax in Iran by using the model of general equilibrium. In addition, changes in demand and changes in three pollutants CO_2, SO_2 and NO_X in the four tax scenarios have been studied.

MATERIALS AND METHODS

Economic and social effects of green taxes is having a wide range, Therefore, studies and predict the possible effects of different policies is essential. To study the effects of a specific policy, there are two general frameworks: Partial equilibrium analysis and general equilibrium. Since the method of partial equilibrium, to survey these effects on micro-level, are neglected relationships between desired section and other sectors of the economy, Therefore, using this model would not be logical (Adelman and Robinson, 1978). But general equilibrium models that consider the Valera's low are able to encompass many different economic topics. Among the numerical models, computable general equilibrium (CGE) able to considered to simultaneously influence policy interventions on the economy efficiency and the distribution of income (Mojaverhosseini and Fayazmanesh, 1385; Motevaseli and Fouladi, 1385). Model presented in this paper is the comparative static model, which allow simulating the actions or policies and changing variables from outside and thus gives the effect of these changes on the economy can be evaluated.

The structure of the model

The model used for the simulations is a static small open-economy computable general equilibrium model designed to investigate energy and environmental policies. Goods are produced using primary factors and intermediate inputs. The output is sold at perfectly competitive markets in which producers behave according to standard neoclassical microeconomic theory, maximizing their profits by taking market prices as given. Production technology in all sectors exhibits a constant return to scale and is characterized by nested constant elasticity of substitution (CES) production functions (Figure 1). The nesting structure used is not uncommon in CGE studies of energy use and is suggested by empirical studies (Hill, 1998). The top level is a Leontief nest in which the producers use different non-energy intermediate goods, Aji, and an aggregate of energy goods and primary factors, KLEj in fixed proportions.

$$Y_j = Y_j\left(A_{j1}, A_{j2}, \dots, A_{jn}, KLE_j\right)$$

Where

$$KLE_j = KLE_j\left(\left(L_j, K_j\right), E_j\right)$$

L_j is labor; K_j is a CES aggregate of sector specific capital and perfectly mobile capital, and E_j is a CES aggregate of different energy inputs.

All nests except the top level have elasticities greater than zero, reflecting a higher degree of substitutability between different primary factors and energy input, and also between different types of energy goods. Also, CES production functions apply for domestic energy production "E" (Figure 2). The domestic use of primary factors, labor and capital, is fixed at their benchmark level but is assumed to be perfectly mobile between sectors within domestic borders. Output from sectors, Y_j, is transformed into goods, Z_i, using a CES technology. Goods for final consumption, as well as intermediate inputs in production, A_i, are modeled as a CES aggregate of domestically produced and imported inputs. These inputs are assumed to be imperfect substitutes according to the Armington assumption. In the model, the assumed Armington elasticities does not depend on the user of the aggregate good, that is, the relative composition of imported and domestically produced goods will be the same for all users (Figure 3). Goods are then produced either for the domestic market or the export market. This is modeled as a constant elasticity of transformation between goods destined for the domestic market and goods destined for the export market. The final demand by consumers is modeled through a representative agent with preferences represented by a nested CES utility function (Figure 4).

$$U = U\left(C(E, NE)\right)$$

The consumer decides how to allocate its income between

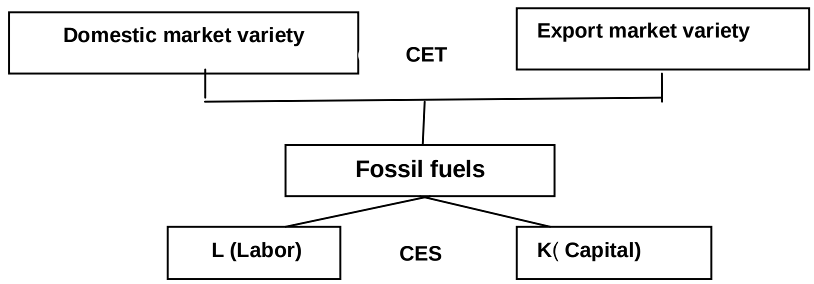

Figure 2. Nesting in fossil fuel production.

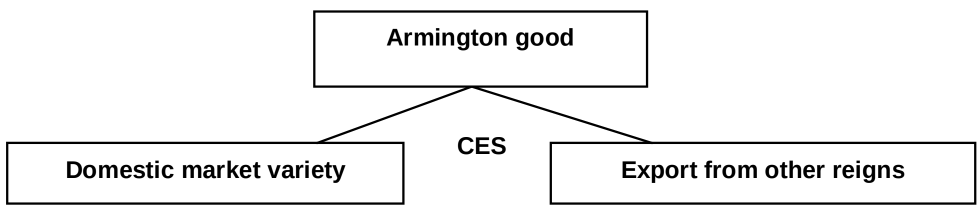

Figure 3. Nesting in armington production.

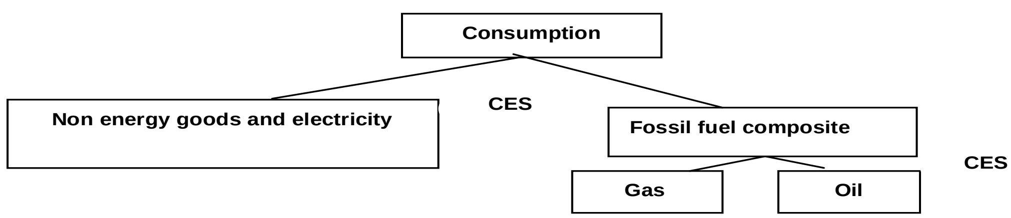

Figure 4. Nesting in consumption.

consumption of a composite of non-energy goods, C, and a composite of energy goods, E. At the second level, the consumer decides how much to spend on different energy goods and how much to spend on different non-energy goods. The consumer income available for consumption consists of payment received from the sale of primary factors plus transfers from the government minus the exogenously fixed private investment. Iran is regarded as a small open economy in this model, that is, the import supply and export demand curves are horizontal at these exogenously fixed international prices. The model closes through balancing of the current account, keeping the capital inflow constant at the benchmark level by adjusting the real exchange rate.

Details of the model

The model is calibrated to fit benchmark data for the year 2001. The input-output data is disaggregated into 99 sectors but the number of sectors in this model is restricted by reliable data on emission and energy use. This restriction allows for a disaggregation level of 15 sectors to match the environmental and economic accounts of Iran. In these accounts the sectors are aggregated in such a way that they should be fairly homogenous with respect to their emissions. These sectors produce 15 different goods, 12 non-energy goods and 3 energy goods. The energy goods are gas, electricity and oil. (Oil is an indicator of the composition of five major oil products: gasoline, diesel, kerosene, fuel oil and Liquefied petroleum gas (LPG.) The division of energy goods into these categories matches differences in benchmark environmental taxation on fossil fuels. The energy taxes consist of a tax on gas and oil input and a tax on gas and oil consumption. If utility is a function of goods consumption, the utility associated with the consumption of goods is captured by the function u (NE, E), where all first partial derivatives are positive (that is, goods consumption increase utility). Also, fossil fuels consumption creates air pollution.

Air pollution is a commodity that reduces utility. Therefore, environmental damages associated with emissions from consumption of energy are represented by means of the *v (e)* with *v* < 0. For simplicity, a linear relationship between energy use and emissions is assumed. Furthermore, utility from consumption and dis-utility from environmental damages are assumed to be separable. In this case, utility function is as follows:

$$W = w(NE, E) + v(E) \qquad w > 0 \ , \ v < 0$$

In this paper, for consideration of emissions, variations of 3 pollutants (carbon dioxide (CO_2), sulfur dioxide (SO_2) and nitrogen oxides (NOx)) are calculated with variations of energy. The emissions of CO_2, SO_2 and NOx depend on each sector's use of each type of fossil fuel that is, each sector has a sector specific

Table 1. Variation of fossil fuels' demand.

Scenario/ variation	Gas demand	Oil demand
Scenario I	-37.5	60.1-
Scenario II	37.7 -	60.1-
Scenario III	37.6-	60-
Scenario IV	87.5-	59.5-

Source: The paper's findings.

Table 2. Share of fossil fuels in emission.

Fossil fuels/ emission	CO_2	SO_2	NO_X
Fuel oil	14.9	60.9	12
Gas oil	22	35.1	48
Kerosene	7.2	1.8	0.4
Petrol	12.9	2.2	22.7
Natural Gas	43	-	16.9
total	100	100	100

Source: Department of energy 2001.

emission factor for each type of fuel used. Since, the share of CO_2, SO_2 and NOx in the total amount of emission is 99.6, 0.26 and 0.14%, respectively (Department of Energy, 2001), the positive effects of welfare resulting from the reduction of these pollutants is considered to be dependent on their share. The emission data used in the model describes each sector's emission of CO_2, SO_2 and NOx divided into the use of different fossil fuels and by emission from industrial combustion. The sector specific emission coefficients are based on Energy balance, 2001. The CGE model has been programmed in GAMS and mathematical programming system for general equilibrium (MPSGE) and we calibrated the model following the procedure in Rutherford (1999) by using the solver MCP.

SCENARIOS AND RESULTS

One of the main goals in implementing a CGE model is simulation. Simulation provides a study of different policies quantitatively. Therefore, this paper surveys the welfare and environmental effects on the green tax; 4 scenarios are considered as follows:

i) Impose a 5% tax on gas and oil.
ii) Impose a 10% tax on gas and oil.
iii) Impose a 25% tax on gas and oil.
iv) Impose a 50% tax on gas and oil.

Effects of green tax on oil and gas demand

As shown in Table 1, in all four scenarios, a green tax reduces demand for fossil fuel both as an intermediate input and as a final good. If a 5% tax is imposed, oil and gas demand will decrease 60.1 and 37.7%, respectively. In scenarios I, II and III the variation of demand reduction is negligible compared with the first scenario (37.7% reduction in first scenario, 37.7 and 37.6% in the second and third scenario, respectively), but in the fourth scenario, gas demand is reduced sharply (87.5%).

The demand for oil has decreased 60.1, 60 and 59.5% for the second, third and fourth scenarios, respectively.

Effect of green tax on emission

Based on the information on balanced energy from 2001, the share of fossil fuels in emission pollutants are shown in Table 2. Using these numbers, gas has 43% CO_2 and 16.9% NO_X pollution, and no SO_2 pollution. But oil, an aggregate of 4 products, fuel oil, gas oil, kerosene and petrol, has 57% CO_2 pollution**,** 100% SO_2 pollution and 83.1% NO_X pollution. Based on the share of fossil fuels in pollutant emissions, the variation of these three pollutants for each of the four scenarios is calculated. The results are given in Table 3. If a 5% tax is imposed, CO_2, SO_2 and NO_X emissions reduce by 50.5, 60.1 and 41.5%, respectively; by increasing the tax rate to 25%, the variation of emission reduction is negligible compared with the first scenario.

Note that the amount of reduction in CO_2 and NO_X emissions are significant in the fourth scenario rather than in the other scenarios (for NO_X in the third scenario, 41.4% and the last scenario, 82.7%). Among the pollutants, the rate of change of SO_2 emission is more than that of other pollutants.

Effect of green tax on welfare

Consumption of fossil fuels reduces by implementing a

Table 3. Variation of CO_2, SO_2 and NO_X emission.

Scenario/ variation	Variation CO2	Variation SO2	Variation NO_X
Scenario I	-50.5	-60.1	-41.5
Scenario II	-50.5	-60.1	-41.5
Scenario III	-50.4	-60	-41.4
Scenario IV	-71.5	-59.5	-82.7

Source: The paper's findings.

Table 4. Variation of welfare with and without environmental effects by different tax scenarios.

Scenario/ var	Welfare with environmental effects	Welfare without environmental effects
Scenario I		-
Scenario II		-
Scenario III		-
Scenario IV		-

Source: The paper's findings.

Table 5. Elasticity of substitution in the different activities.

Sectors/ elastisities	$\sigma_{KLE(S)}$	$\sigma_{KL(S)}$	σ_N	σ_E	$\sigma_{EG(S)}$	$\sigma_{M(G)}$
Agriculture	0.5	0.5	0.5	0.5	2	2.2
Food	0.5	0.4	0.5	0.5	2	2.8
Textile	0.5	0.4	0.5	0.5	2	1.9
Wood and paper	0.5	0.4	0.5	0.5	2	1.5
Chemical	0.98	0.45	0.5	0.5	2	1.9
steel and metal	0.88	0.35	0.5	0.5	2	-
Mining	0.96	0.3	0.5	0.5	2	-
Other industry	0.5	0.4	0.5	0.5	2	-
Construction	0.5	0.75	0.5	0.5	2	-
Water	0.5	0.75	0.5	0.5	2	-
Transport	0.5	0.75	0.5	0.5	2	1.9
Trade and services	0.5	0.75	0.5	0.5	2	-
Electricity	0.5	0.5	0.5	0.5	2	-
Gas	0.5	0.5	0.5	0.5	2	2.9
Oil	0.5	0.3	0.5	0.5	2	0.5

Source: De Melo and Tarr, 1992; Kemfert and Welsh, 2000; Bohringer and Partners, 2002.

green tax and welfare also decreases. The Hicksian equivalent variations in income (EV) for the representative consumer are used as a measure of the welfare effect from different tax policies. In the first case, the welfare is considered only a function of goods' consumption (energy and non energy), while in the second case the assumed welfare or utility is a function of goods' consumption and environmental impacts (particularly air pollution). If a linear relationship between fuel consumption and pollution is assumed, as consumption is reduced, pollution decreases too. Thus that will lead to positive effects on environmental quality. The shares of pollutants in the total emissions are as follows: CO_2 99.6, SO_2 0.26 and NO_X 0.14% (Department of Energy, 2001). Table 4 and 5 shows the welfare results from the green tax. If the utility is a function of goods' consumption, under the 5 and 10% tax rate on fossil fuel, welfare decreases 47.5%. In the third scenario, welfare will decrease 47.3% and for the last scenario, welfare will decrease 50.7%. While considering the undesirability of environmental damages, welfare increases. In the first scenario, the welfare change is positive (3%). Under the 10% tax rate on fossil fuel, CO_2, SO_2 and NO_X emissions decreased 50.5, 60.1and 41.5%, respectively, and cause welfare to rise to 3%. In all of the scenarios, welfare changes have been positive; as the tax increases the welfare will also increase by an increasing rate. In the last scenario, variations of fossil fuels' demand are high; if imposing a 50% tax on gas and oil, welfare rises to 20.8%.

SUMMARY AND CONCLUSION

Oil products and gas products are consumed as consumer inputs as well as intermediate inputs in the production of other goods. However, there is no state green tax (or energy tax) in Iran; even the government is paid subsidies for these products. Uncontrolled increase in consumption of such goods not only is a limitation for future consumption but the negative environmental effects is an important issue too. This research has intended to investigate welfare and environmental effects resulting from a green tax on fuel in the four scenarios (Scenario I: impose a 5% tax on gas and oil; scenario II: impose a 10% tax on gas and oil; scenario III: impose 25% tax on gas and oil; and scenario IV: impose a 50% tax on gas and oil). In all four scenarios, green taxes reduce demand for fossil fuels as intermediate input and final goods. If a 5% tax is imposed, oil and gas demand will decrease by 60.1 and 37.7%, respectively. In this scenario, CO_2, SO_2 and NO_X emissions are reduced by 50.5%, 60.1% and 41.5% respectively and cause to welfare rise to 3%. CO_2 emissions have the most effect on the increase in welfare. Therefore, more serious decisions must be made to reduce their consumption. By a larger tax rate for oil, and less for gas, a more favorable effect on welfare can be achieved.

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APPENDIX

variables and parameters	Variables and parameters description
S	Production sector index
G	Goods index
Yj	Domestic production from sector *S*
Z(S)	Domestic production of good *G*
D i	Domestic sales of good *G*
M(S)	Import aggregate of good *G*
X(S)	Export of good *G*
A(S)	Armington aggregate of good *G*
K	Input of primary factor capital
L	Input of primary factor labor
V	Environmental benefits
Z(S)	Sectoral output index
A(G)	Supply index
M(G)	Import index
X(G)	Export index
U	Utility index
C(G)	Production cost index
W	welfare
$\sigma_{KLE(S)}$	Elasticity of substitution between non-energy intermediate inputs and the composite of primary factors and energy inputs
$\sigma_{KL(S)}$	Elasticity of substitution between labor aggregate and a composite of energy goods and capital
$\sigma_{EG(S)}$	Elasticity of substitution between gas and oil.
$\sigma_{M(G)}$	Armington elasticity of substitution between imported and domestically produced goods
δ	Elasticity of substitution between aggregate non-energy goods and a composite of energy goods
σ_N	Elasticity of substitution between different non-energy goods 1.0
σ_E	Elasticity of substitution between gas and oil.
a , *c*	Scaling and share parameters
e	Emission

Function

$$Z(S) = \min \left(\frac{KLE}{C_0}, \frac{A_i}{C_1}, \ldots, \frac{A_n}{C_n} \right)$$

$$KLE(S) = \alpha_{KLE(S)} \left[\alpha_{KLE(S)}\ KL(S)^{(1-\sigma_{KLE(S)})} + \left(1-\alpha_{KLE(S)}\right) E\,(S)^{(1-\sigma_{KLE(S)})} \right]^{\frac{1}{(1-\sigma_{KLE(S)})}}$$

$$KL(S) = \alpha_{KL(S)} \left[\alpha_{K(S)}\, K^{(1-\sigma_{KL(S)})} + \left(1-\alpha_{K(S)}\right) L^{\,(1-\sigma_{KL(S)})} \right]^{\frac{1}{(1-\sigma_{KL(S)})}}$$

$$E(S) = \alpha_{E(S)} \left[\alpha_{EG(S)}\, EG^{(1-\sigma_{EG(S)})} + \left(1-\alpha_{EG(S)}\right) EO^{\,(1-\sigma_{EG(S)})} \right]^{\frac{1}{(1-\sigma_{EG(S)})}}$$

$$A(G) = \left[\alpha_{M(G)} C(G)^{(1-\sigma_{M(S)})} + \left(1-\alpha_{M(G)}\right) M(G)^{(1-\sigma_{M(S)})} \right]^{\frac{1}{(1-\sigma_{M(S)})}}$$

$$U = \left[\alpha_N\, NE^{(1-\delta)} + (1-\alpha_N) E^{(1-\delta)} \right]^{\frac{1}{(1-\delta)}}$$

$$NE = \left[\sum_{NE} \alpha_N\ NE^{(1-\sigma_N)} \right]^{\frac{1}{(1-\sigma_N)}}$$

$$E = \left[\sum_{NE} \alpha_{EG}\ E^{(1-\sigma_E)} \right]^{\frac{1}{(1-\sigma_E)}}$$

$$W = U\,(NE, E) + V(e)$$