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ORIGINAL PAPER

Simulating green tax effects on pollution reduction, mortality and morbidity costs in Iran

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ABSTRACT

The direct association between air pollution and morbidity and mortality rates has been proved. This major environmental risk factor has been mainly due to extensive use of fossil fuels. Increasing pollution caused by fossil fuels can threaten human health. This study simulated the effect of green taxes on Iran's health indicators, i.e., mortality and morbidity. We used a Computable General Equilibrium (CGE) model calibrated by Iran's Social Accounting Matrix (SAM). The results show that when any pollution tax rate is levied on energy products, all eight types of environmental pollutions would be reduced. Almost two thirds of health costs (62%) are related to mortality, one fourth to morbidity (26.4%), and the rest to non-health effects (11.6%). Finally, we found an inverse correlation between green taxes and health costs.

Keywords: Simulation, Green Tax, Environmental Pollutants, Mortality, Morbidity, CGE

Introduction

According to the World Health Organization (WHO), the global mortality rate from outdoor pollutants in 2012 was 3.7 million deaths.[1] A recent World Bank study also shows that air pollution alone is the fourth leading cause of premature mortality in the world.[2] These facts show that environmental pollution is currently considered to be the most important environmental risk to health and highlights the needs to find an effective way, e.g., taxes, to confront the pollution threats.[3-6] CO_2, CH_4, and N_2O are important air pollutants resulting mainly from energy consumption. Iran is among the ten top polluting countries regarding CO_2 emissions.[7] While, a significant percentage of current government payments in developed countries are provided through taxes, the share of taxes in Iran's state budget over the past ten years has been only about 25 to 33 percent.[8] According to the World Bank and WHO statistics, mortality costs in Iran's economy caused by air pollution are about $640 million, equal to 0.57 percent of GDP. Moreover, morbidity costs from air pollution in Iran are estimated at $260 million in a year, which is about 0.023 percent of the GDP.[9] In the presence of negative externalities, e.g., air pollution, there is extensive literature on pollution tax. Similar to our approach, Keshavarz *et al.* used a CGE framework to simulate the effects of Iran's subsidy targeting plan on health cost indices, i.e., 11 health-related goods and services. They showed that subsidy elimination increased the health cost indices between 33.43% and 77.3%.[10] Ghorani-Azam *et al.* evaluated air pollution effects on health indices in Iran. They discussed the toxicology aspect of six major air pollutants and recommended practical solutions to reduce Iran's air pollution.[11] Through a qualitative study, Doshmangir *et al.* assessed the effects of Iran's targeted subsidies policy on health behavior. They collected data through a comprehensive interview using an inductive-deductive method. They concluded that this policy has adverse effects on health habits, so that, increasing health care costs, as a results of targeted subsidies policy, would reduce demands in health services.[12] In most studies, environmental quality is considered as a separate function, so the effects of feedback from environmental quality on the behavior of economic agents are ignored. In a few studies,

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the effect of feedback has also been taken into account.[13] There are also many studies in this area. Jafari and Alizadeh show that with increasing green tax rates economic growth increases.[14] Farajzadeh and Bakhshoodeh showed that price modification of energy products is generally effective in reducing pollutant emissions.[15] Somani considers environmental tax reform and economic welfare in India, using a general equilibrium model. He concludes that the best way to reduce pollution is by applying a suitable tax policy.[16] Dissou and Eyland investigated pollution tax in Canada. Their results show that by imposing $40 carbon tax, GDP decreases 0.13 percent without Border Tax Adjustments (BTAs), whereas with BTA, GDP decrease 0.17 percent.[17] O'Ryan *et al.* evaluated the economic impact against social and environmental policies in Chile with a computable general equilibrium model. Their results show that taxing PM_{10} emission yields better environmental results than SO_2 and NO_2 taxing.[18] On the effects of air pollution and health indicators, a number of studies have also been performed using partial equilibrium approaches. The results show a positive and significant relationship between air pollution and health costs.[19-26]

The method used in related studies is based on partial equilibrium models that take into account only one market and assume the status of the rest of the markets is exogenous, and therefore are far away from the realities of the economy. Specifically, the effect of the pollution tax policy can be directly or indirectly attributed to other sectors of the economy, and therefore the use of general equilibrium models that consider all markets in their calculations is more rational. In this context, we used a CGE model to analyze the effects of a green tax policy on health indicators. Given the necessity of levying the optimal green tax rate and its impact on the indices of health costs, we simulated the effect of green tax on mortality and morbidity in Iran. The main objective was to simulate the effects of green tax on health indicators model by taking into account the effects of the economy, energy, environment and health sectors. We simulated levying green tax on major energy carriers, i.e., natural gas and five petroleum products: gasoline, kerosene, fuel oil, liquefied petroleum gas (LPG) and gasoil. Considering that pollution affects health indicators, we examined different tax scenarios on these carriers and their effects on pollution. Finally, health indicators were measured. To the best of our knowledge, no related study simultaneously analyzes the interactions between the economics, energy, environment, and health indices in Iran. In this study, the effect of applying a green tax policy on health indicators was evaluated.

Our results show that in all tax scenarios, mortality and morbidity costs were significantly reduced, so that policy makers are able to reduce mortality and morbidity costs by levying pollution taxes on energy carriers.

Materials and Methods

To achieve our goal, we used a CGE model. In this standard framework model, the economics are considered open, and markets of production factors are in a full employment state. The required data were extracted from the Social Accounting Matrix (SAM) and Input-Output table published in 2011, Office of Electricity & Energy Planning in ministry of Energy of Iran, the World Bank, and WHO.

In this research the entire Iranian economy was divided into 11 sectors: agriculture, crude oil and natural gas, other mines, industry (construction and production), electricity, natural gas distribution, water, buildings, transportation, healthcare, and services. The factors of production were divided into three parts: labor, capital and energy; and households divided into two parts: urban and rural. Considering the goal of the study in the energy sector, six types of energy carriers were considered: gasoline, kerosene, fuel oil, LPG, gasoil and natural gas. Pollution section also includes eight pollutants: NO_X, SO_2, SO_3, CO, SPM, CO_2, CH_4, and N_2O. The health section includes indicators of mortality, morbidity, number of hospital days and medical costs associated with pollution. Due to limitations, we mention only the household, firm, pollution, government revenue and health equations.

Household Section Equations

It is assumed that all income generated by economic activity is distributed among consumers. Each consumer allocates disposable income between consumption of commodities, leisure and health (savings amount is considered zero in this study). We established the utility function based on the LES (Linear Expenditure System) utility function:

$$\text{Max } U^{\circ}=\alpha_1^{\circ}\ln(C-\bar{C})+\alpha_2^{\circ}\ln(l-\bar{l})+\alpha_3^{\circ}\ln(H-\bar{H})-\sum_{m=1}^{M}\alpha_{H,m}^{\circ}.A_m \quad (1)$$

$$s.t. \quad P_C C+wl+P_{MED}MED\leq I$$

Where U° is the maximum level of utility function, excess consumption$(C\text{-}\bar{C})$, excess leisur$(l\text{-}\bar{l})$e and excess health$(H\text{-}\bar{H})$. $\bar{C}$, $\bar{l}$, and $\bar{H}$ are subsistence levels of consumption, leisure and health. It also considers separately the function of the concentration of air pollutants $\sum_{m=1}^{M}\alpha_{H,m}^{\circ}.A_m$. The utility function at the upper level is maximized, subject to the budget constraint. Taking into account the health indicator equation, the total income (I) should not exceed the cost of consumption, leisure and medical care. P_C is the consumer price of C. It is the sum of the producer price q_C and the tax t_C. $P_{MED}=q_{MED}+t_{MED}$ is the consumer price of medical services. Medical taxes on medical services (t_{MED}) would be negative if they were to be funded by a social security system. w is the net wage rate. The total revenue available will be as follows:

$$I=w\left(T-\sum_{m=1}^{M}\theta_m A_m\right)+P \quad (2)$$

P is the non-working income, T is the total available time, and θ_m is the reduction of each unit of the concentration of the air pollutant relative to the reference. H is a health index and is defined as:

$$H=H^{*}-\sum_{m}\beta_{1,m}A_m+\beta_2 MED \quad (3)$$

H^{*} is the exogenous level of health, obtained if there is no air pollution and if the consumer does not consume any medical services. $\beta_{1,m}$ and β_2 are parameters describing the impact on health of air pollution and of the consumption of medical services. From the first-order conditions of maximization of utility, the following equations can be obtained:

$$C=\bar{C}+\frac{\alpha_1^{\circ}I^d}{P_C} \quad (4)$$

$$l=\bar{l}+\frac{\alpha_2^{\circ}I^d}{w}$$

$$MED=\frac{\bar{H}\text{-}H^{*}+\sum_m\beta_{1,m}A_m}{\beta_2}+\frac{\alpha_3^{\circ}I^d}{P_{MED}}$$

$$I^d=w\left(T-\sum_{m}\theta_m A_m\right)+P-P_C\bar{C}-w\bar{l}-P_{MED}\frac{\bar{H}\text{-}H^{*}+\sum_m\beta_{1,m}A_m}{\beta_2} \quad (5)$$

I^d is the disposable income that can be allocated to the consumption of C, l and MED. $\alpha_n^{\circ}(n=1, 2, 3)$ are parameters of the LES function. $\alpha_{H,m}^{\circ}$ is the marginal utility of a decrease in the ambient concentration of pollutant m $(m=1, \ldots, M)(\alpha_{H,m}^{\circ}>0)$. A_m is the ambient concentration of air pollutant m and includes the eight types of pollutants that are calculated as follows:

$$A_m=A_m(EM_1, \ldots, EM_{po}) \quad \forall m \quad (6)$$

So that the concentration of the environment is a collection of m pollutants. A_m is considered exogenous. It is assumed that a function of different pollutants is a reference equilibrium $(EM_{po}$ *with* $po=1, \ldots, 8)$.

Firm, Pollution and Governmental Revenue Equations

We consider production technology based on a nested structure. By assuming cost minimization, each sector generates domestic production (X_D) using inputs of capital, labor, and energy (O'Ryan *et al.*):[18]

$$s.t. \quad XP_i=\left[a_{kel,i}KEL_i^{\rho_i^P}+a_{abnd,i}ABND_i^{\rho_i^P}\right]^{\frac{1}{\rho_i^P}} \quad (7)$$

So that KEL_i is Non-energy intermediate inputs (labor and capital) and energy inputs, $ABND_i$ represents Pollution (from energy and non-energy sources), P is the relevant price and XP_i is the production in sector i. a_{kel} and a_{abnd} are the CES share parameters, and ρ is the

CES exponent.

The nested function of energy with respect to the six main carriers of energy—gasoline, kerosene, fuel oil, LPG, gasoil and natural gas—are defined as follows:

$$E_i = a_i^{ve}\left(\sum_{e=1}^{6} \delta_i^{ve} QFE_{i,e}^{-\rho_i^{ve}}\right)^{\frac{-1}{-\rho_i^{ve}}} \quad (8)$$

According to Beghin *et al.*[27] we define the pollution function as follows:

$$E_P = \sum_i v_i^P . XP_i + \sum_i \pi_i^P \left(\sum_j XA_{P_{ij}} + \sum_h XA_{C_{ih}} + \sum_f XAFD_f^i\right) \quad (9)$$

Whereas, i indicates sector index, j product index, h is household index, P is production index, XP represents product produced, and XA_C is the final consumption of polluting goods. v_i^P shows the emission of pollutant P for a unit of production in i sector. E_P is the sum of all contaminations (total pollution levels for each pollutant). The expression $\sum_i v_i^P .XP_i$ is the amount of residual pollution in the production, which is not explained by the consumption of inputs. Parameter π_i^P is the emission coefficient of pollutant 'p' from the consumption of energy product 'i'. $\sum_j XA_{P_{ij}}$ is energy consumption by firms, $\sum_h XA_{C_{ih}}$ is energy consumption by households and $\sum_f XAFD_f^i$ is the final demand.

The pollution tax policy is determined by a specified amount per unit (tons) of pollutants. Given the difference in emission levels of different energy carriers, receiving the tax amount from the pollutants means receiving different rates of tax from energy products.

Government derives most of its revenues from direct corporate and household taxes, and indirect taxes. Subsidies are also provided which enter as negative revenues.[27]

$$GRev = MiscRev + \sum_h Tax_h^H + I_{oil} + \sum_p \tau_{poll} E_p \quad (10)$$

In this study, the equation describes the sum of all taxes. $GRev$ represents total government revenue. So that $MiscRev$, $\sum_h Tax_h^H$, I_{oil}, and $\sum_p \tau_{poll} E_p$ are represents identifying miscellaneous government revenues, household direct taxes, oil revenues and green taxes, respectively.

By levying green tax on energy carriers, pollutions are reduced, resulting in reduction in household health costs. That is modeled in household equation.

Health Effects

Estimating the health effects of air pollution entials their explicit identification and evaluation through several steps, in the following way. Specifically, the release of PM_{10} and $PM_{2.5}$ contaminants (equivalent to suspended particles of less than 10 and 2.5 microns in diameter, respectively) cause significant damage and have significant health effects.[28] Sulphur dioxide (SO_2) and nitrogen oxides (NO_X) may also have important consequences because they can react with other substances in the atmosphere to form particulates. Short-term exposure to PM_{10} causes mortality of children due to respiratory diseases, while long-term exposure to $PM_{2.5}$ causes mortality of adults due to cardiopulmonary diseases. Furthermore, exposure to SO_2 causes mortality of all ages. Exposure to PM_{10} increases the morbidity rate of all ages such as increasing chronic bronchitis, hospital admissions due to respiratory problems, restricted activity days, respiratory infections in children, and general respiratory symptoms. For mortality caused by short-term exposure to children under the age of 5 years, the following equation was used:

$$RR = exp[\beta(x - x_o)] \quad (11)$$

Whereas $0.0006 \leq \beta \leq 0.0010$ and x is the current annual mean concentration of PM_{10} (μg per cubic meter), and x_o is the baseline concentration of PM_{10} (μg per cubic meter).

Cardiopulmonary mortality due to long-term exposure of adults over the age of 30 years is estimated by the following equation:[28]

$$RR = [(x+1)/(x_o+1)]^{\beta} \quad (12)$$

Whereas $0.0562 \leq \beta \leq 0.2541$ and x is the current annual mean concentration of $PM_{2.5}$ (μg concentration of $PM_{2.5}$ (μg per cubic meter). For lung cancer mortality in adults over 30 years of age due to long-term exposure, the following equation was applied:[28]

$$RR=[(x+1)/(x_o+1)]^{\beta} \quad (13)$$

Whereas $0.08563 \leq \beta \leq 0.37873$ and x is the current annual mean concentration of $PM_{2.5}$ (μg per cubic meter), and x_o is the baseline concentration of $PM_{2.5}$ (μg per cubic meter).

Results and Discussion

Table 1 and Figure 1 show changes in emission levels, as a results of green tax policy. Accordingly, the release of all pollutants is always reduced. This decline is inappreciable in low tax scenarios, such as 1 and 5 percent: in the 1 percent green tax scenario, the highest emission reductions for SO_2 and CH_4 pollutants are about 1.4 percent and the lowest reduction for CO_2 is reduced by 1 percent. Increasing the tax from 10% to 15% has more significant effects on emissions reductions. In the tax scenario of 30%, the highest reductions are in NO_X, SO_3, and CH_4, and the lowest are N_2O and CO levels.

Table 1. Change in emission levels in response to different green tax scenarios (percentage)

pollutants	Green Tax Scenarios					
	1%	5%	10%	15%	20%	30%
NO_x	-1.32	-3.25	-5.28	-12.85	-17.5	-32.25
SO_2	-1.25	-3.05	-7.37	-11.45	-16.72	-24.55
SO_3	-1.43	-3.54	-8.56	-13.24	-18.25	-26.78
CO	-1.23	-3.03	-7.32	-10.8	-14.62	-21.45
SPM	-1.27	-3.12	-7.49	-11.62	-15.6	-21.83
CO_2	-1.05	-2.65	-6.4	-10.5	-15.23	-22.56
CH_4	-1.4	-3.44	-8.32	-12.92	-17.35	-24.85
N_2O	-1.12	-2.71	-6.55	-10.16	-13.56	-20.35

Source: Research findings

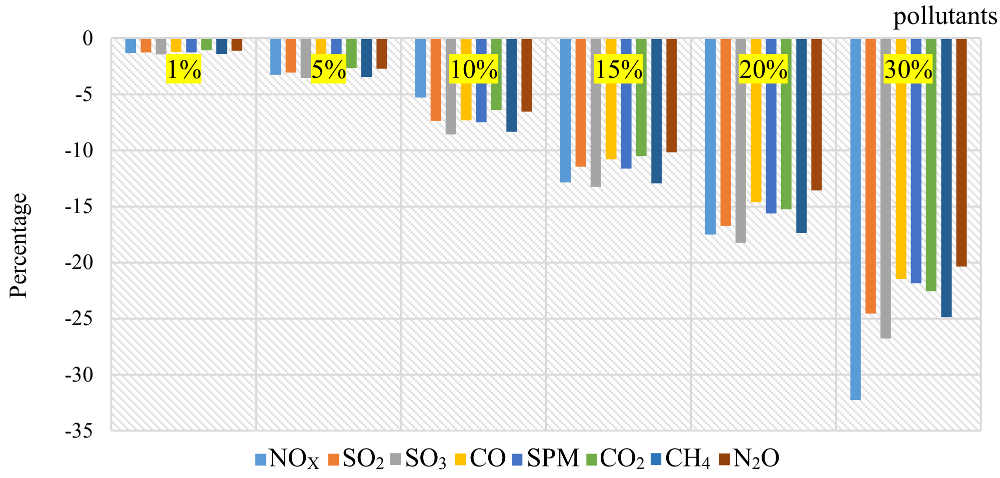

Fig. 1. Change in emission levels in response to different green tax scenarios

We evaluated the cost of damage caused by the reduction of air pollutants emissions due to the application of green tax, through Sarraf *et al.* and Mayeres & Van Regemorter approach.[29,13] These studies calculated the association of total air pollution damage with mortality, morbidity and non-health effects (e.g., reduced visibility and aesthetic value of landscapes). We investigated the health effects of suspended particulate matter (PM_{10}, $PM_{2.5}$) and SO_2, which have a significant impact on human health, separately. Also, the effects of other pollutants were integrated seamlessly. The results show that $PM_{2.5}$, PM_{10}, other pollutants and SO_2 have the highest share of health indicators with 55.2, 33.5, 10.4, and 0.9 percent, respectively.

Table 2 shows the results of pollution effects on health indicators . Accordingly, the distribution of health indicators as well as the financial evaluation of these effects, including mortality, morbidity, and non-health effects of air pollution, are 62%, 26.4%, and 11.6%, respectively.

It should be noted, to calculate monetary value based on Iran's minimum wage in 2016.

Table 3 shows the variation in average annual health costs, including mortality, morbidity and non-health effects, caused by applying different green tax scenarios. Accordingly, there is always a positive correlation between the increase in green tax and the reduction in health costs.

Table 2. Estimating health effects based on monetary evaluation

Annual health effect	Total DALYs	Value (Million Rials)
Mortality	118376	32047
Morbidity	50498	13671
Non health effects	22126	5990
Total mortality, morbidity and non-health effects	191000	51708

Source: Research findings

Table 3. Estimating the impact of annual health costs caused by the application of different green tax scenarios

Annual health effect	Green Tax Scenarios					
	1%	5%	10%	15%	20%	30%
Health costs (mortality, morbidity and non-health effects)	-1.26	-3.10	-7.16	-11.70	-16.10	-24.33

Source: Research findings

The results of the simulation of green taxation scenarios show a decline in production in most of the study sectors, and in all tax scenarios, health costs (mortality, morbidity and non-health effects) will be significantly reduced. For instance, by levying a 30% tax rate, NOx and SO_3 pollutants have the highest reductions equal to 32.25% and 26.78%, respectively. Moreover, CH_4 and SO_2 would be reduced by about 25%. The rest of pollutants will also be decreased by about 21%. At this green tax rate, the health costs i.e., mortality, morbidity, and non-health effects, would be reduced 24.33%. Obviously, income from environmental taxes could be used to finance the reduction of existing taxes. This process of recycling funds significantly reduces the welfare costs associated with the general plan of taxation compared with the case where environmental revenues are fixed.

Our findings agree with the following studies. Farajzadeh and Bakhshoodeh also showed that rising energy product prices led to reduced pollutions.[15] We also confirmed the findings of Ghorani-Azam *et al*. study.[11] We got a similar outcome regarding the effects of reducing pollutions on heath indices. Keshavarz *et al.* showed that eliminating subsidies would have a negative effect on the health sector and household costs, and would increase the health prices index.[10] This result was also in line with our results. In the same framework, O'Ryan *et al.* also showed that pollution tax led to a better environmental situation, which again is aligned with our outcomes.[18]

These results appear to be rational. Pollutant industries simply care for revenues and incomes, and not for the environment. However, given the direct penalties for pollutant industries imposed by a green tax policy, it definitely can be an incentive to reduce pollution. In other words, taxes on pollution provide clear incentives to polluters to reduce emissions and seek out cleaner and sustainable alternatives. Green tax is common in developed countries. Many European countries have imposed green tax on carbon dioxide, sulfur dioxide, and nitrogen oxides. Australia also introduced a carbon tax in July 2012, which is an excise levy on the carbon-based content of fossil fuels, as a means of reducing greenhouse gas emissions, which contribute to global warming and climate change. Even in developing countries like India, "green tax" was implemented to fight pollution in August 2010. However, at the moment, green tax is still at an early stage in Iran and only covers a fraction of large firms. Article 38 of the Value Added Tax (VAT) act, related to pollutants, specifies that, in addition to VAT, large polluting industries should also pay one percent of their income as green taxes. However, this tax is subject to a range of financial structure reforms that can be called "environmental reform of the financial system." In addition, 6% of GDP and 5 to 10% of governmental expenditures of developing countries are allocated to the healthcare system.[30] Therefore, it is possible to improve the quality of the environment and reduce health costs by excluding taxes on the sale of eco-friendly products, tax on wage and business income of jobs that operate in any way to preserve the environment, and also taxes on buildings that are designed to protect the environment. Instead, the tax on fossil fuels, mining taxes and also the tariff on imports of high energy products should be increased.

Conclusion

The main objective of the present study was to examine the effects of green tax on pollution reduction and health indicators such as mortality and morbidity costs in Iran. In this regard, the present study used by a CGE model and calibrated by Iran's Social Accounting Matrix in 2011. Based on the findings of the present study, green taxes reduced all kinds of environmental pollutions. Furthermore, $PM_{2.5}$, PM_{10}, other pollutants and SO_2 have the highest effects on health indicators with 55.2, 33.5, 10.4, and 0.9 percent, respectively. Finally 62% of health costs was spent on mortality, 26.4% on morbidity, and 11.6% on non-health effects.

Conflict of Interests

Authors have no conflict of interests.

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