Environmental and economic effects of carbon tax based on computable general equilibrium model (CGE),

Hassan Moeen Neamati,ph.D.Economics,Faculty Members,
Islamic Azad University,North Tehran Branch,
Islamic Republic of Iran,
moeinnemati@saipacorp.com
Alternate e-mail: hassan_moeen@hotmail.com

Abstract

Our paper deals with environmental, welfare and employment effects of carbon tax. Carbon tax Means adding the external cost of air pollution to price of fuel .The aim of carbon tax is reducing energy consumption and reducing harmful emissions, but also at decreasing labor tax and labor cost thus providing incentives to create new jobs. The study is in the base of a computable general equilibrium model that is revenue neutral. otherwise in our model total government income is constant . our model is a non linear equation system . so for solving the model we use GAMS software that is designed for solving such models .To ensure consistency of the data an solving the model we construct a social accounting matrix(SAM) from IRAN input – output table. Model calibrated to base year and it has been shown that using carbon tax for reducing labor income taxes , can improve quality of environment and it can cause positive employment and welfare effects.

Key words : carbon tax , general equilibrium model , CES production function , social accounting matrix , two level production function, conditional demand for input and outputs , unit cost function .

1-Introduction:

for Environmental Protection, environmental tax is more desirable than other economic or non economic instruments. This subject was mentioned by Pigou at 1920.the amount of environmental tax must be equal to marginal cost of pollutants. carbon tax means adding the external cost of air pollution to price of fuel. usually by using carbon tax labor tax decreases and total government income remain constant .The study is in the base of a computable general equilibrium model(CGE) that is revenue neutral. Objective of the paper is determining impact of carbon tax on:

- demand of consumption goods , energy and labor.
- Level of production ,price and investment in various economic sectors .
- Air pollution.
- Welfare.
- Unemployment
- Inflation

hypothesis of the study is that in the condition of undesirable unemployment and total government income to be constant , carbon tax would increase welfare ,decrease unemployment and improve quality of environment.

In our model, *EH* denotes the use of energy in the Household sector. For simplification, we assume a representative household which demands energy *EH*, an aggregate consumption good C, leisure *F* and a free public good *G*. The utility associated with the consumption of these goods is indicated by the function $u(X, EH, F, G)$.

in the model markets are : public goods ,consumption goods , Energy, labor and capital. Production functions in the model are defined as :X=f(Q , E) ,Q=f(K,L),U=f(FF, AC) , and AC=f(X,E). which: E-energy , G-public goods,X- consumption goods, L-labor, K-capital, FF–leisure, AC-aggregate consumption good.

Source of data is IRAN,s input – output table .Data for elasticity of substitutions and some of the parameters is used from the results of other studies.

2-Extracting equations of the model

Applied general equilibrium models(CGE) consist three groups of equations :zero profit equations ,market clearance equations and income equations .to determine these equations , first of all we must select algebraic format for production functions.

Structure of general equilibrium model is based on competitive conditions and constant return to scales Production function . Production function for X and U is two level CES Production function with constant return to scales :

$$Y_X = \left[\theta_{VAX}^{1/\sigma_{QE}} Q^{(\sigma_{QE}-1)/\sigma_{QE}} + (1-Q_{VAX})^{1/\sigma_{QE}} Y_E^{(\sigma_{QE}-1)/\sigma_{QE}} \right]^{\sigma_{QE}/(\sigma_{QE}-1)} \qquad (1)$$

$$Q = \left[\theta_K^{1/\sigma_{KL}} K^{(\sigma_{KL}-1)/\sigma_{KL}} + (1-\theta_k)^{1/\sigma_{KL}} L^{(\sigma_{KL}-1)/\sigma_{KL}} \right]^{\sigma_{KL}/(\sigma_{KL}-1)} \qquad (2)$$

Which Q is value added, P_Q price index of value added, P_E price index energy , Y_E level of energy production , θ_{VAX} , θ_K share parameters, $\theta_{VAX} = \frac{VA0_X}{Y0_X}$ share parameter for Q,1-θ $_{VAX}$

share parameter for energy and σ is constant elasticity of substitution:

$$\sigma = \frac{d\ Ln(Q/Y_E)}{d\ Ln(P_Q/P_E)} = \frac{d\ (Q/Y_E)}{d\ (P_Q/P_E)} . \frac{P_Q/P_E}{Q/E}$$

$$if \Rightarrow \rho = \frac{1-\sigma}{\sigma} \Rightarrow \begin{cases} \frac{1}{\sigma} = \rho - 1 \\ \frac{\sigma-1}{\sigma} = -\rho \Rightarrow \\ \frac{\sigma}{\sigma-1} = -\frac{1}{\rho} \end{cases}$$

$$Y_X = \left[\theta_{VAX}^{\rho-1} Q^{-\rho} + (1-\theta_{VAX})^{\rho-1} Y_E^{-\rho} \right]^{-1/\rho} \qquad (3)$$

Production function for E and G is one level CES Production function .

2-1-Extracting zero profit condition equations

We use relative demand of factor production and unit cost functions for determining ziro profit equations:

min : $W_G L + R K$

s.t $\quad Y_E = \left[\theta_K^{\rho-1} K^{-\rho} + (1-\theta_K)^{\rho-1} L^{\rho} \right]^{-1/\rho} \Rightarrow$

$$L = K \left(\frac{R}{W}\right)^{1/(1-\rho)} \theta_K^{(\rho-1)/(1-\rho)} (1-\theta_k) \qquad (4)$$

$$\rho = \frac{\sigma-1}{\sigma} \Rightarrow L = K \left(\frac{R}{W}\right)^{\sigma} \frac{(1-\theta_k)}{\theta_k} \rightarrow \text{(relative demand for labor)} \qquad (5)$$

$$K = L \left(\frac{W}{R}\right)^{\sigma} \frac{\theta_k}{(1-\theta_k)} \qquad (6)$$

$$C_E = (W_G L + RK)/Y_E \qquad (7)$$

$$C_E = \left[\theta_K R^{(1-\sigma_{KL})} + (1-\theta_K) W_G^{(1-\sigma_{KL})}\right]^{1/(1-\sigma_{KL})} \Rightarrow \text{(unit cost function in energy sector)}$$

$$C_E = \left[\theta_K R^{(1-\sigma_{KL})} + (1-\theta_K) W_G^{(1-\sigma_{KL})}\right]^{1/(1-\sigma_{KL})} = P_E$$

2-2-Extracting market clearance equations

For determining market clearance condition we set supply of goods or factors of production equal to conditional demand of goods or factors:

3- Total equations of the model

We have 30 equations and 30 endugenous variables in the model.

3-1-ziro profit condition equations

1 - $\left[\theta_{VAX} P_Q^{(1-\sigma_{QE})} + (1-\theta_{VAX}) P_E^{(1-\sigma_{QE})}\right]^{1/(1-\sigma_{QE})} = P_X$

2- $\left[\theta_{k_E} R^{(1-\sigma_{k_E})} + \theta_{L_E} W_G^{(1-\sigma_{KL_E})}\right]^{1/(1-\sigma_{KL_E})} = P_E$

3 - $\left[\theta_{k_G} R^{(1-\sigma_{k_G})} + \theta_{L_G} W_G^{(1-\sigma_{KL_G})}\right]^{1/(1-\sigma_{KL_G})} = P_G$

4 - $\left[\theta_{k_x} R^{(1-\sigma_{KL_x})} + \theta_{L_x} W_G^{(1-\sigma_{KL_x})}\right]^{1/(1-\sigma_{KL_x})} = P_Q$

5 - $\left\{C_{TOTSHR} P_C^{(1-\sigma_{CF})} + F_{SHR}\left[W_G (1-T_W \tau_{TW})\right]^{(1-\sigma_{CF})}\right\}^{1/(1-\sigma_{CF})} = P_U$

6 - $\left\{\alpha_x (P_x)^{(1-\sigma_{XE})} + \alpha_E \left[P_E (1+T_{HE})\right]^{(1-\sigma_{XE})}\right\}^{1/(1-\sigma_{XE})} = P_C$

3-2-market clearance equations

7 - market clearance for capital :

$$\sum_i KD_i KD0_i = \overline{K}$$

8 - $\theta_{K_x}(Q) VA0_x (P_Q / R)^{\sigma_{KL_x}} = KD_x KD0_x$

9 - $\theta_{K_E} Y_E (YO_E)(P_E / R)^{\sigma_{KL_E}} = KD_E KDO_E$

10 - $\theta_{K_G} Y_G YO_G (P_G / R)^{\sigma_{KL_G}} = KD_G KDO_G$

11 - market clearance for labor :

$$\sum_i LD_i LD0_i = \left[\bar{L} - (FF)(FF0)\right](1-UR)$$

Labor supply:

Total accessable time:

12 - $\theta_{L_x}(Q)VA0_x(P_Q/W_G)^{\sigma_{KL_x}} = LD_x LD0_x$

13 - $\theta_{L_E} Y_E YO_E (P_E/W_G)^{\sigma_{KL_E}} = LD_E LDO_E$

14 - $\theta_{L_G} Y_G YO_G (P_G/W_G)^{\sigma_{KL_G}} = LD_G LDO_G$

15 - leisure demand:

$$F_{SHR}(HH\_I\_F/P_U)\left[P_U/W_G(1-T_W\tau_{TW})\right]^{\sigma_{CF}} = FF(FF0)$$

16 - $Y_x Y0_x = CD_x C0_x$

17 - $Y_E Y0_E = CD_E C0_E + IDE(IDE0)$

18 - $Y_G(Y0_G)P_G = GOVT\_I$

19 - $(HH\_I\_D)/P_C = INC0(AC)$

20 - $HH\_I\_F/P_U = (FULINC0)(U)$

21 – final demand of commodities:

$$\alpha_x(HH\_I\_D/P_C)\left[P_C/P_x(1+T_{HE})\right]^{\sigma_{XE}} = CD_x C0_x$$

22 - $\alpha_E(HH\_I\_D/P_C)\left[P_C/P_E(1+T_{HE})\right]^{\sigma_{XE}} = CD_E C0_E$

23 - demand of value added:

$$\theta_{VAX} Y_x Y0_x (P_x/P_Q)^{\sigma_{QE}} = Q(VA0_x)$$

24 - $(1-\theta_{VAX})Y_x Y0_x\left[P_x/P_E(1+T_{YE})\right]^{\sigma_{QE}} = IDE(IDE0)$

3-3-income equations

25 -houshold full income:

$$(\bar{K})(R) + (W_G)(\bar{L})(1-T_W\tau_{TW}) - W_G\left[\bar{L} - (FF)(FF0)\right]UR(1-T_W\tau_{TW}) = HH\_I\_F$$

26 - $(\bar{K})(R) + W_G(1-T_W\tau_{TW})\sum_i LD_i LD0_i = HH\_I\_D$

27 - $T_W\tau_{TW} WG\sum_i LD_i LD0_i + T_{HE}P_E CD_E CO_E + T_{YE}P_E IDE(CO_E) = GOV\_I$

3-4-wage equation

28 - $LOG(W_G/P_C) = \delta_0 + \delta_1 LOG(UR) - LOG\,\rho$

3-5-net wage rate

net wage rate is function of endogenous tax rate on wage

29 - $\rho = 1 - T_W\tau_{TW}$

3-6-production of public good

we assume that the public good is provided at a constant quantity:

30 - $Y_G = G_{FIX}$

endogenous variables : R ، W_G ، P_Q ، P_X ، P_E ، P_G ، P_C ، P_U ، Y_X ، Y_E ، Y_G، KD_X ،TAU ،KD_G KD_E ، LD_X ، LD_E ، LD_G ، Q ، IDE ، CD_X ،CD_E ، FF ، U ، AC ، UR ، HH_I_F

exogenous variables ,parameters and data: LS_0 و $\bar{K}$ ELS,UR0 σ_{QE} , σ_{KL} $LD0_i$ $KD0_i$ $Y0_i$, $C0_i$ T_W IDE0,INC0 $VA0_i$ ،GO ، σ_{CF} ، α_I ، θ_{VAX} ، θ_L ، FF0, ، F_{SHR} C_{TOTSHR} , γ_1

1-social accounting matrix for Iran(SAM)-1999.

sectors / markets	(X)	(E)	(G)	(H)	(GOV)
(X)	+629494486			-629494486	
(E)	−14169586	+87832945		-73663359	
(G)			+47018486		−47018486
(L)	−82415952	−2828381	−28386213	+113630546	
(K)	−532908948	−85004564	−18632273	+636545785	

Source :Iran input-output table for 1999

5- initial solution(benchmark equilibrium)

for solving the model we use GAMS software . part of initial solution is:

	LOWER	LEVEL	UPPER	MARGINAL
---- VAR R	1.000	1.000	1.000	EPS
---- VAR WG	.	1.000	+INF	.
---- VAR PQ	.	1.000	+INF	.

R Interest rate , WG Gross wage rate (incl. income taxes) , PQ Value added composite price in X production

---- VAR P Producer prices

	LOWER	LEVEL	UPPER	MARGINAL
x	.	1.000	+INF	.
E	.	1.000	+INF	.
G	.	1.000	+INF	.

	LOWER	LEVEL	UPPER	MARGINAL
---- VAR PC	.	1.000	+INF	.
---- VAR PU	.	1.000	+INF	.

PC Consumption composite price index , PU Utility price index

---- VAR Y Production level

	LOWER	LEVEL	UPPER	MARGINAL
x	.	1.000	+INF	.
E	.	1.000	+INF	.
G	.	1.000	+INF	.

---- VAR KD Capital demand

	LOWER	LEVEL	UPPER	MARGINAL
x	.	1.000	+INF	.
E	.	1.000	+INF	.
G	.	1.000	+INF	.

---- VAR LD Labor demand

	LOWER	LEVEL	UPPER	MARGINAL
x	.	1.000	+INF	.
E	.	1.000	+INF	.
G	.	1.000	+INF	.

	LOWER	LEVEL	UPPER	MARGINAL
---- VAR Q	.	1.000	+INF	.
---- VAR IDE	.	1.000	+INF	.

Q Value added , IDE Intermediate demand of energy

---- VAR CD Final consumption demand of E and X

	LOWER	LEVEL	UPPER	MARGINAL
x	.	1.000	+INF	.
E	.	1.000	+INF	.

	LOWER	LEVEL	UPPER	MARGINAL
---- VAR FF	.	1.000	+INF	.
---- VAR U	.	1.000	+INF	.
---- VAR AC	.	1.000	+INF	.
---- VAR HH_I_F	.	7.6125E+8	+INF	.
---- VAR HH_I_D	.	7.0316E+8	+INF	.
---- VAR GOVT_I	.	4.7018E+7	+INF	.
---- VAR UR	.	0.140	+INF	.
---- VAR RHO	.	0.586	+INF	.

FF Leisure demand, U Utility, AC Aggregate consumption , UR Unemployment rate

HH_I_F Household full income (including leisure), HH_I_DHousehold disposable income

GOVT_I Government income , RHO Endogenous tax wedge variable in initial solution price and quantities is equal to one.

6-counterfactual solution of the model and results

in second or counterfactual solution of the model we set carbon tax rate equal to 30 percent and deviation of endogenous variables (price and quantities) from one can show empacts of carbon tax.

2- Result of counterfactual solution

counterfactual solution results	variables	counterfactual solution results	variables
0.100	Unemployment rate (UR)	1.020	Price index of ggregate consumption good(PC)
0.944	Leisure demand (FF)	1.041	Production of consumption good (X)
1.005	welfare (U)	1.041	Production of consumption good (X)
1.000	Interest rate (R)	1.000	Production of public good (G)
0.864	Intermediate energy consumption(IDE)	1.036	Capital demand in consumption good sector(KD_X)
0.777	Final energy consumption(E)	1.116	labor demand in consumption good sector(LD_X)

Result of counterfactual solution is shown that using carbon tax to reducing labor income taxes , can improve quality of environment and it can cause positive employment and welfare effects .