Analyzing Taiwan's Air Pollution: An Application of the CGE Model and the Concept of Green National Product

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Abstract

The purposes of this paper are to establish a link between the concept of green national product and that of CGE modeling, and demonstrate empirically the existence of significant differences between the value of conventional GNP and that of Green GNP. We first derive theoretically the framework of Green GNP under two different definitions, SEEA and ENRAP, taking into account pollution and pollution prevention activities. Then, we employ a 28-sector static CGE model for Taiwan to assess the effects of the policy of mandatory reduction in air pollution emission on Taiwan's macroeconomic variables as well as sectoral resource allocation. The social accounting matrix used by the CGE model is compiled on the basis of the 1997 national income data (aggregates) and 1996 input-output data (structure). The model is then supplemented by the pollution generation coefficients, the emission coefficients and the abatement costs, which are computed from the Trial Compilation of Green National Product prepared by the Directorate-General of Budgeting, Accounting, and Statistics (DGBAS). Three kinds of air pollutants are considered: Sulfur Oxides (SOx), Nitrogen Oxides (NOx), and Volatile Organic Compounds (VOC). Simulation results generated from the model are used to compute two measures of Green National Product, the EDPII under the United Nations' SEEA system, and an alternative measure, which is derivable from maximizing the present value of future consumption stream and is closer to the ENRAP system, in addition to the conventional GNP and other macroeconomic and sectoral variables. It is found that although a more stringent air pollution control policy will raise costs and thereby reduce the conventional GNP, the Green National Product, which reflects social welfare better than the conventional GNP does, will increase by either measure. Sectorally, industries with heavier air pollution generations tend to lose resources to the other sectors, as expected.

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1. Introduction

The concept of Green NDP differs from that of traditional NDP by accounting for the parts of depletion in natural resources and degradation of the environment, which are not included in the computation of the traditional NDP. As such, it is closer to the social welfare concept in economics than is traditional NDP. It is therefore a more preferable goal of policies. Since the publication of SEEA (1993) by the United Nations, many institutions and countries have involved in studying and implementing the construction of Green Domestic Product, including the United Nations, Japan, Korea, and so on.

The government of Taiwan has already devoted to the Trial Compilation of Green NDP since 2000 (DGBAS, 2000). Taiwan's construction is based on the method recommended by SEEA (1993). As such, it leaves at least two rooms for improvement. One is to take into account the effect suggested by Aaheim and Nyborg (1995). Aaheim and Nyborg point out that the SEEA framework subtracts the monetary degradation called "maintenance cost" associated with untreated pollution from the Traditional Net Domestic Product, as if the imputation of this monetary amount and the traditional NDP are independent of each other. In the real world, if government policies require large reduction in the untreated wastes, the private sector will change their behavior. So the traditional NDP would not be independent of the changing policy, and that is why Aaheim and Nyborg stressed the importance of taking the general equilibrium aspect into consideration when compiling Green NDP. The above is

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the first reason why we write this paper. Specifically, this paper uses a general equilibrium model to catch the inter-sectoral and macroeconomic effects of tighter air pollution control policies and then compute Green NDP based on the simulation results of the model.

The second reason for improvement, as Chu (2000) points out, is that maintenance cost as defined by SEEA (1993) is actually the “benefits” of environmental pollution. In a theoretically correct formulation of Green NDP, as developed by Chu (2000), such benefits should not be subtracted, where should be subtracted from Traditional NDP is the “cost” of “environmental pollution”.

The new draft handbook of Green National Product prepared by the London Group has taken this point into account. So they define a new measure of Green NDP, among many other options, which subtracts damages of pollution rather than the benefits of pollution from traditional NDP. And this is the second reason and contribution of our paper, because this paper will compute not only the SEEA (1993) Green NDP, but also an alternative Green NDP, which subtracts damages of air pollution from traditional NDP rather than the maintenance cost. We will call this new measure Revised Green NDP.

In what follows, we will review some related literature in section 2, explain the theoretical framework in section 3, and describe the modeling inputs in section 4. Section 5 gives the figures, and finally concluding remarks are given in section 6.

2. Review of literature

(1) Air pollution: CGE studies

Conrad and Schroder (1993) use a dynamic CGE model to assess the impact on economy of difference kinds of environmental policy tools, and it is found that the imposition of emission fee is the first best policy, while the second best policy be subsidizing the pollution abatement activities by the firms. Bergman (1990) uses a CGE model to assess the effects of nuclear power policies on GNP and the sectoral allocation of resources. Its model contains 45 sectors and covers the period of 1985 to 2000. It is found that if policies are undertaken to reduce the SOx and NOx emission from the 1980 base level, the Swedish GNP will be reduced substantially.

Xie (1996) uses a CGE model to assess the impact of a wastewater emission fee on the economy of China. He found that an increase in tax rate will result in a reduction of domestic product, an increase in price and unemployment, but a decrease in pollution emissions. Yang (2001) uses a 18-sector CGE model to assess the effects of trade liberalization on the emission of CO_2 in Taiwan, and found that trade liberalization will result in an increase in total CO_2 emission. In addition, resources will flow from low to high carbon content products.

Wiebelt (2001) uses an open economy CGE model to assess the effects of environmental tax on hazardous waste in South African mining industry. It is found that the imposition of tax will increase the production cost, lowering the international competitiveness of the mining products. In addition, the miners will be adversely affected. Abimanyu (2000) uses a CGE model called INDORANI to simulate the effects of reducing agriculture trade distortion and government subsidy on economic and environmental variables. It is found that although the effect on GDP is positive, the environment will be adversely affected.

Garbaccio, Ho, and Jorgenson (1999) construct a dynamic CGE model for China to assess the effects of carbon taxation. They found that under the neutral carbon taxation policy, China could achieve the "double dividend" effect. Morris, et al. (1999) use a CGE model called FEIM to assess the effects of air pollution tax on the economy of Hungary, but their results show that the double dividend effect would not be significant.

Lai and Wang (1997) use a 13-sector CGE model to assess the effects of tighter air pollution control policies on the petroleum chemical industry and some macroeconomic and sectoral variables. It is found that because the enterprises have to devote more resources to pollution control, the real GDP will be adversely affected. Chiang (1995) uses a CGE model to assess the effects of end-of-pipe air pollution control policies on Taiwan's macroeconomic and sectoral variables. He takes into account the operation as well as the air pollution control equipment investment expenditure and finds that the increase in operation and maintenance cost will result an increase in prices, resulting in a decrease in GDP and total output. On the other hand, the increase in air pollution control equipment investment will have much smaller effects.

All the above studies are very useful for the problems concerned with, and have all been able to catch the general equilibrium effects of policy changes. But so far there has not seen to be any CGE model that involves in the computation of Green NDP. So our paper will be CGE-based and involved in the computation of Green NDP at the same time.

(2) Green GDP Studies

Adjustments of conventional national product measures to reflect changes in the value of environmental assets, popularly known as green accounting, have gained considerable attention in recent years. In the U.S., intensive work on environmental accounting began in the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce in 1992. Shortly after the first publication of the U.S. Integrated Environmental and Economic Satellite Accounts (IEESA) in 1994, however, Congress directed the Commerce Department to suspend further work in this area and to obtain an external review of environmental accounting. A panel was then organized by the National Research Council and charged to do the work. The final report of the panel was recently released (Nordhaus and Kokkelenberg, 1999). There the panel concludes that "extending the U.S. national income and product accounts to include assets and production activities associated with natural resources and the environment is an important goal; and that developing a set of comprehensive non-market economic accounts is a high priority for the nation." The panel explicitly recommends that "Congress authorize and fund Bureau of Economic Affairs of the Department of Commerce to recommence its work on developing natural-resource and environmental accounts." Elsewhere the work continued without pause in many countries.[4]

3. Methodology

3.1 CGE Model

This paper uses a revised version of the DMR model, in which a total of 28 sectors are included. The entire equation system is shown in Table 1, it includes the price determination, production, income, consumption, saving, market clearing, environmental and air pollution equations. This section will only explain in more details the part of equations that are directly associated with air pollution, because the other specifications are pretty standard.

(1) Production function

$$
\begin{aligned}
X_i = (1 - (& SUABC_i \cdot (SPOSTC_i + SCC_i \cdot AA_{2,j} \\
& + SNGC_i \cdot (AA_{3,j} + 0.40291087 AA_{24,j}) + SGC_i \cdot 0.00072913267 AA_{9,j} \\
& + SDC_i \cdot 0.042436543 AA_{10,j} + SFOC_i \cdot AA_{11,j} \\
& + SLPG_i \cdot (AA_{12,j} + 0.597089127 AA_{24,j}) + SCPC_i \cdot AA_{13,j}) \cdot (1 - THETAS)) \\
& - (STUABC_i \cdot (STGC_i \cdot 0.9992786733 AA_{9,j} \\
& + STDC_i \cdot 0.957563456 AA_{10,j}) \cdot (1 - THETAS)) \\
& - (NUABC_i \cdot (NPOSTC_i + NCC_i \cdot AA_{2,j} \\
& + NNGC_i \cdot (AA_{3,j} + 0.40291087 AA_{24,j}) + NGC_i \cdot 0.00072913267 AA_{9,j} \\
& + NDC_i \cdot 0.042436543 AA_{10,j} + NFOC_i \cdot AA_{11,j} \\
& + NLPG_i \cdot (AA_{12,j} + 0.597089127 AA_{24,j}) + NCPC_i \cdot AA_{13,j}) \cdot (1 - THETAN)) \\
& - (NTUABC_i \cdot (NTGC_i \cdot 0.9992786733 AA_{9,j} \\
& + NTDC_i \cdot 0.957563456 AA_{10,j}) \cdot (1 - THETAN))) \\
& \cdot AX_i K_i^{1-\alpha_i} L_i^{\alpha_i}
\end{aligned}
\tag{1}
$$

Where,

Xi = sectoral domestic output

[4] See the survey in Peskin (1999). For recent efforts by Japan and Korea along the United Nation's System of Integrated Environmental and Economic Accounting or SEEA (CECE et. al, 1993, and UN, 1998) line, see Economic Planning Agency, Japan, 1998, and UNDP, 1998; and for efforts along the ENRAP (Environmental and Natural Resources Accounting Project as implemented in the Philippines) line, see IRG, 1996.

AXi = technology parameter (constant of production function)

Ki = sectoral capital stock

Li = sectoral labor demand

α_i (*alpha*) = *labor share*

AA_{ji} = *input-output coefficient*

$SPOSTC_i$ and $NPOSTC_i$:= *SOx and NOx process emission factor respectively*

SCC_i *(NCCi) = SOx (NOx) combustion emission factor associated with coal*

SNGCi (NNGCi) = SOx (NOx) combustion emission factor associated with natural gas

SGCi (NGCi) = SOx (NOx) combustion emission factor associated with gasoline

STGCi (NTGCi)= SOx(NOx) combustion emission factor associated with gasoline

SDCi (NDCi) = SOx(NOx) transportation emission factor associated with diesel

STDCi (NTDCi) =SOx(NOx) transportation emission factor associated with diesel

SFOCi (NFOCi) = SOx (NOx) combustion emission factor associated with fuel oil

SLPGCi (NLPGCi) = SOx (NOx) combustion emission factor associated with liquid petroleum gas

SCPCi (NCPCi) = SOx(NOx) combustion emission factor associated with coal products

SUABCi (NUABCi)= SOx (NOx) unit abatement cost

STUABCi (NTUABCi) = SOx (NOx) unit abatement cost of transportation pollution

THETAS (THETAN) = SOx (NOx) emission-reduced rate (air control policy)

According to many studies including Liu (1999), Gray and Shadbegian (1993), Barbera and McConnell (1990), and Conrad and Wastl (1995), tighter environmental control typically will result in higher cost. Although there have been examples of tighter pollution control result in higher productivity, such as Royston (1979), but evidence are spare and may involve some information asymmetry.

So in this paper we will still adopt the standard assumption, that is, tighter control will result in higher cost. Specifically, the pollution control activities are specified as having an effect on the technology parameter of the production function. So, when the sector is required by new policy to adopt tighter control, the technology parameter *AXi* would be multiply by

$(1-\frac{UABC(X^b \cdot POSTC)\cdot(1-THETA)}{X^b})$, where *UABC* is unit abatement cost, *POCTC* is process emission factor, X^b is sectoral domestic output in baseline, and *THETA* is emission-reduced rate associated with air control policy.

There are many kinds of air pollutants, but not all of them have sufficient data to justify the inclusion in the model. So in this paper we will only consider Sulfur Oxides (SOx) and Nitrogen Oxides (NOx). The parameter used in the study are POSTC, UABC, THETA, sectoral process emission, sectoral combustion emission, and etc. Combustion emission can be further divided into two parts, one is combustion associated with production, and the other is transportation emission.

To compute combustion emission, we first compute the different type of fuels used in the production and transportation process by the various sectors. These fuels include gasoline, diesel, fuel oil, natural gas, coal and coal products. All six types are used in production, but only gasoline and diesel are used in transportation.

(2) Environmental equations

(2.1) Sectoral process emission：

$$SOxMQU_i = X_i \cdot SPOSTC_i \cdot THETAS \tag{2}$$

$$NOxMQU_i = X_i \cdot NPOSTC_i \cdot THETAN \tag{3}$$

Where $SOxMQU_i$ *and* $NOxMQU_i$ are sectoral *SOx* and *NOx* process emission. The definition of the other variables is the same with production function.

(2.2) Sectoral combustion and transportation emission：

$$\begin{aligned} SOxF_i = X_i(&SCC_i \cdot AA_{2,j} + SNGC_i \cdot (AA_{3,j} + 0.402910872 AA_{24,j}) \\ &+ SGC_i \cdot 0.00072913267 AA_{9,j} + STGC_i \cdot 0.99927086733 AA_{9,j} \\ &+ SDC_i \cdot 0.042436543 AA_{10,j} + STDC_i \cdot 0.957563456 AA_{10,j} \\ &+ SFOC_i \cdot AA_{11,j} + SLPG_i \cdot (AA_{12,j} + 0.597089 AA_{24,j}) + SCPC_i \cdot AA_{13,j}) \cdot THETAS \end{aligned}$$

$$(4)$$

Where $SOxF_i$ is sectoral SOx combustion emission. The definition of the other variables is the same with production function.

From equation (4), we can see that when performing emission reduction simulations, sectoral emission parameter will reduce proportionally by (1-*THETAS*) · 100%. However, this does not mean that all the sectors will reduce the emissions by the same amount, because emission reduction will come not only from the reduction in the value of emission parameter, but also from the reduction in sectoral output.

(2.3) Air pollution control policy

$$AIRCTS = \sum_i SOxM + \sum_i SOxF \Big/ \sum_i SOxM0 + \sum_i SOxF0$$

$$AIRCTN = \sum_i NOxM + \sum_i NOxF \Big/ \sum_i NOxM0 + \sum_i NOxF0 \qquad (5)$$

where *AIRCTS* and *AIRCTN* are exogenous variables which define the rate of air pollution （*SOx, NOx*）reduced from baseline level when policy changes, *SOxM0* and *NOxM0* are total process emission in the base year, and *SOxF0* and *NOxF0* are total combustion and transportation emission in the base year.

(2.4) Green NDP

$$SGNDP = RGDP.L - TDEPR.L - \left[\begin{array}{l} \sum_i SUABC_i \cdot \begin{pmatrix} SO_xM.L_i + SO_xF.L_i \\ - X.L_i \cdot 0.99927\, AA_{9,i} \cdot STGC_i \cdot THETAS.L \\ - X.L_i \cdot 0.95756\, AA_{10,i} \cdot STDC_i \cdot THETAS.L \end{pmatrix} \\ + \sum_i STUABC_i \cdot \begin{pmatrix} X.L_i \cdot 0.99927\, AA_{9,i} \cdot STGC_i \cdot THETAS.L \\ + X.L_i \cdot 0.95756\, AA_{10,i} \cdot STDC_i \cdot THETAS.L \end{pmatrix} \end{array} \right]$$

$$- \left[\begin{array}{l} \sum_i NUABC_i \cdot \begin{pmatrix} NO_xM.L_i + NO_xF.L_i \\ - X.L_i \cdot 0.99927\, AA_{9,i} \cdot NTGC_i \cdot THETAN.L \\ - X.L_i \cdot 0.95756\, AA_{10,i} \cdot NTDC_i \cdot THETAN.L \end{pmatrix} \\ + \sum_i NTUABC_i \cdot \begin{pmatrix} X.L_i \cdot 0.99927\, AA_{9,i} \cdot NTGC_i \cdot THETAN.L \\ + X.L_i \cdot 0.95756\, AA_{10,i} \cdot NTDC_i \cdot THETAN.L \end{pmatrix} \end{array} \right]$$

（6）

$$RGNDP = RGDP.L - TDEPR.L - 18.2757 \cdot \left[0.0035 \cdot \sum_i (SO_xM.L_i + SO_xF.L_i) + 0.000172 \cdot \sum_i (NO_xM.L_i + NO_xF.L_i) \right]$$

（7）

Equations (6) and (7) described above are the SEEA (1993) Green NDP and an alternative, revised measure of damage based Green NDP. The last term of the RHS of equation (6) is total maintenance cost, and the last term of equation (7) is total damage cost.

(3) Assumptions

(3.1) Domestic products and imports are imperfect substitutes. The domestic composite goods supply (Q_i) is a CES function of domestic production (D_i) and Imports.

(3.2) Domestic products and Exports are perfect substitutes.

(3.3) Exchange rate is fixed.

(3.4) The current model is static, so sectoral capital stocks are exogenously given and fixed.

3.2 Green GDP Model

Given the growing importance of green accounting, there are unfortunately still clouds of doubts around it both theoretically and empirically. Here we attempt to clarify some of the concepts concerning the treatment of important variables including defensive spending, direct service of environment, and depreciation in the process of constructing the green national product. It will be done by comparing both the United Nations' SEEA (System of Integrated Environmental and Economic Accounting) and the Philippine ENRAP (Environmental and Natural Resources Accounting Project) framework (closely associated with Professor Henry Peskin[5]) with a theoretically ideal system of national product, which the paper will build as an extension of the Hamilton's (1994, 1996) analysis.[6]

In particular, Hamilton's Models 2 and 5 in his 1996 paper as well as some parts of Model 1 in his 1994 paper will be integrated into one model, which will subsequently be transformed and re-interpreted. The idea is to develop a formulation that is as simple as possible, but powerful enough to address the issues at hand. It will be clear that the model to be presented is enough for the purpose, and possible extensions of the model to include other aspects such as exhaustible resources would be intuitive.

(1) The Model

Mostly following Chu (2000), the following symbols are defined:

U = utility
C = consumption
K = capital stock (produced assets)
F = production
g = net natural growth of resource
d = dissipation rate of the stock of pollution
e = pollution emissions
a = abatement expenditure by producers
Φ = environmental benefits to households

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5 For an earlier work on the comparison between SEEA and ENRAP that is from ENRAP's viewpoints, see Peskin and delos Angeles, 1998.

6 Weitzman (1976) shows that the present value of future consumption would be maximized by maximizing in each period the "national product" as conventionally defined, if the economy is on the dynamically optimal path. Solow (1986) subsequently shows that national product can be conceived as the interest on total accumulated wealth, and is followed by Usher (1994) who shows the Hamiltonian in the dynamic optimization specification is the return to wealth, defined as the present value of future consumption. Hartwick (1990), Mäler (1991) both extends Weitzman's model to analyze different aspects of the problem, while Hamilton (1994, 1996) attempts to synthesize and integrate the analysis by presenting a series of models that touch upon almost all of the important aspects of concern.

L = available labor

The economy produces according to

$$F = F(L, K) \quad (8)$$

where $F_L > 0$ and $F_K > 0$. The economy's production is supplied to consumption, investment and abatement expenditure.

$$F = C + a + \dot{K} \quad (9)$$

And emission is given by

$$e = e(F, a) \quad (10)$$

where $e_F > 0$ and $e_a < 0$. Environmental benefits to households (consumers) is given by

$$\Phi = \Phi(e - e_0) \quad (11)$$

where e is emission, and e_0 is equal the rate of natural dissipation.

The dynamic optimization problem is then to maximize

$$\int_0^\infty U(C, \Phi) e^{-rt} dt \quad (12)$$

subject to $\dot{K} = F - C - a$.

It is clear from Hamilton (1994, 1996) that the relevant Hamiltonian in this problem is

$$H = U + \gamma_1 \dot{K} = U + \gamma_1 (F - C - a) \quad (13)$$

Linearizing U (and Φ) so that $U = U_C C + U_\Phi \Phi = U_C C + U_\Phi[\partial\Phi/\partial(e - e_0)](e - e_0)$, and dividing both sides of (13) by U_C gives

$$H/UC = C + \theta 1 \dot{K} + \theta 2 (e - e0) \quad (14)$$

where $\theta_1 = \gamma_1 / U_c$, $\theta_2 = (U_\Phi/U_C)[\partial \Phi/\partial(e - e_0)]$.

It can be shown that the first-order conditions yield $\gamma_1 = U_C$, which makes $\theta_1 = 1$, so (14) can be re-written as

$$MEW = F - a + \theta 2 (e - e0) \quad (15)$$

Equation (15) is similar to Hamilton's (1996) equation, where *MEW* is what Hartwick (1990) and Hamilton (1994, 1996) terms the "measure of economic welfare." (see also Nordhaus-Tobin, 1973)

Now define an economy that operates by a mode, according to which the environment is not "disturbed" and stays at its pristine state. In this economy, a* is spent so that e =

$(F^*, a^*) = d = e_0$.

Variables at such a hypothetical state have been denoted by an asterisk. Now we define the "sustainable" green NNP as $gNNP^* = F^* - a^*$

"Regular" green NNP (called "*MEW*") can then be defined as *gNNP** plus deviations (called "V_i's") from that mode of activities:

$$MEW = gNNP = gNNP^* + \Sigma_{i=1,2} V_i \qquad (16)$$

V_1 is what the actual abatement expenditure falls short of a^*, the level at which the environment would not be "disturbed." So this means the money firms save when they use the environment as a dumping place beyond natural dissipation levels. It therefore measures the additional service of the environment to producers who dispose of their wastes in the environment in excess of the natural absorptive capacity. The term V_2 is the remaining cost borne by consumers due to the fall in environment even after taking defensive actions.

So the sum of terms V_1 and V_2 actually represent the "*net benefits*" to an economy when it *deviates* from the "clean" or "sustainable" mode of production, i.e., it is the "net benefits of deviation."

Turn now to the question of conventional NNP. Hamilton defines conventional NNP as total production, *F* (Hamilton, 1996, p. 22), and argues in his Model 2 that *a* should be deducted because it is actually an "intermediate consumption." We will here simply make the assumption that either *a* has been recorded as an intermediate consumption (and so is not part of conventional NNP), or that it has been otherwise imputed as such and deducted. By so doing, we will define conventional NNP as $F - a$. We will call conventional NNP so defined "*cNNP*."

Now let us give green NNP an alternative interpretation. Under the sustainable mode, $cNNP^* = F^* - a^* = gNNP^*$

It would be useful to examine the relationship among *cNNP**, *gNNP* and *cNNP*. Let us then re-write equation (16)

$$MEW = gNNP = gNNP^* + \Sigma_{i=1,2} V_i = cNNP^* + \Sigma_{i=1,2} V_i$$

$$= cNNP^* + (cNNP - cNNP^*) + \theta_2 (e - e_0) \qquad (17)$$

That is, when the environment is brought back into the picture, benefits V_1 (waste disposal) would have been recorded by the conventional NNP. But conventional NNP is obviously an unsatisfactory candidate to maximize, because the term V_2 is left out. And this is precisely why the green accounting exercise is valuable.

(2) The SEEA and Revised Approaches and the Green NDP

SEEA (Version IV.2 in 1993, 1998) defines *gNNP* as *cNNP* minus "depletion" and "degradation" of natural resources. The depletion is estimated at net rent cost, or at user-cost, while degradation is estimated at the hypothetical abatement cost of bringing down pollution from the existing (post-treatment) level to a level that does not harm the environment (called "maintenance cost").

ENRAP has the "factor cost" and the "expenditure" side of the accounts. On the former side, *gNNP* equals *cNNP* plus waste disposal services (a negative number, as it is seen as a "subsidy" from nature) plus "net environmental benefits" minus "depreciation of 'natural assets' such as minerals, forests and fishery."[7] On the latter side, *gNNP* equals *cNNP* minus environmental damages (workday loss and medical costs) plus direct services of the environment to consumers minus "depreciation of natural assets."

Imputed the SEEA (1993) *gNNP* and the Revised *gNNP*, our model ignored the depletion of natural resources and direct services of the environment.

4. Input Data

The model uses the 1997 National Income as the main input of data. Basically, all aggregate figures are taken from that publication, but sectoral distribution is based on the 1996 Input-Output Tables. The pollution-related variables including the emission factors and the abatement cost are based on various research reports from the Environmental Protection Agency. The estimation of air pollution damages is based on Liang (1993). The specific steps of compilation is explained as follows:

(1) The dose response function of respiratory disease resulting from SOx and NOx air pollution are as follows:

NOx : $9.03875 * 10^{-6}$ (per person per day/*PPb*)

SOx : $1.42133 * 10^{-4}$ (per person per day /*PPb*)

(2) Using the emission factors (Table 10) to compute the amount of air pollution resulting from various energy consumption.

(3) Linking the air pollution concentration indicators to total emissions. The method is based on Liang (1993), but the data have been updated. The results are shown in Table 12.

(4) Using the Shaw et al. (1992) results to assess the avoidance cost. Based on their study, the average person in Taiwan is willing to pay NT$450 per day for the avoidance of the disease in 1992. We multiply this figure by the consumer price index to get the 1997 amount of NT$520.10.

(5) Unit damage (private health cost per unit of air pollution emission) equals concentration ratio times probability of disease, times population, then times private health cost per instance of disease.

And this can be further specified according to different types of fuel use, as follows.

(1) The private health cost associated with SOx pollution per unit coal used:

$$= \left(\frac{0.003925958\,ppm}{33786.311 \quad 10^3\ ton}\right) * (\ 0.142133\ /\ ppm) * 21742815 \text{ persons} * 365 \text{ days} *$$

520.1031 NT$/per person, day

= 68170.71959 (NT$/per 10^3 ton)

(2) The private health cost associated with SOx pollution per unit coal products used:

$$= \left(\frac{0.000474447\,ppm}{4083.031 \quad 10^3\ ton}\right) * (\ 0.142133\ /\ ppm) * 21742815 \text{ persons} * 365 \text{ days}$$

*520.1031 NT$/per person, day

= 68170.71959 (NT$/per 10^3 ton)

(3) The private health cost associated with SOx pollution per unit gasoline used:

$$= \left(\frac{0.0000440868\,ppm}{8557.865 \quad 10^3\ KL}\right) * (\ 0.142133\ /\ ppm) * 21742815 \text{ persons} * 365 \text{ days}$$

*520.1031 NT$/per person, day

= 3015.24337 (NT$/per 10^3 KL)

(4) The private health cost associated with SOx pollution per unit diesel used:

$$= \left(\frac{0.00032277\,ppm}{5064.57 \quad 10^3\ KL}\right) * (\ 0.142133\ /\ ppm) * 21742815 \text{ persons} * 365 \text{ days}$$

*520.1031 NT$/per person, day

[7] Imputed household production is included in ENRAP but ignored here for simplicity.

$= 37389.01774$ (NT$/per 10^3 KL)

(5) The private health cost associated with *SOx* pollution per unit fuel oil used:

$$= \left(\frac{0.001221735\,ppm}{14200.863 \quad 10^3\,KL}\right) * (\,0.142133\,/\,ppm) * 21742815 \text{ persons} * 365 \text{ days}$$

*520.1031 NT$/per person, day

$= 50472.55200$ (NT$/per 10^3 KL)

(6) The private health cost associated with *SOx* pollution per unit LPG used:

$$= \left(\frac{0.0000104737\,ppm}{5124.298528 \quad 10^3\,KL}\right) * (0.142133/\,ppm) * 21742815 \text{ persons} * 365 \text{ days}$$

*520.1031 NT$/per person, day

$= 1199.10548$ (NT$/per 10^3 KL)

(7) The private health cost associated with *SOx* pollution per unit natural gas used:

$$= \left(\frac{0.000000529262\,ppm}{8881.792 \quad 10^6\,m^3}\right) * (\,0.142133\,/\,ppm) * 21742815 \text{ persons} * 365 \text{ days}$$

*520.1031 NT$/per person, day

$= 34.95934$ (NT$/per 10^6 m^3)

The private health cost associated with NOx pollution is computed by similar methods, and will not be repeated here. It is worth noting, however, that private health cost is not the only cost associated with air pollution. Typically, the deterioration in health will also incur a substantial amount of external cost. Liang (1993) computes the external cost and concludes the total social cost should be 18.2757 times the private health cost. Therefore, we use this multiplier to derive the total social cost of health damage associated with SOx and NOx pollution.

5. Scenarios and Analysis

(1) Scenarios

In addition to the baseline, our model computes the effects of three different scenarios as shown in the following table.

Scenarios	Definition
Scenario 1	Economy-wide SOx and NOx emissions are reduced by 10% from baseline. Unit abatement cost is unchanged. (See Table 9)
Scenario 2	Economy-wide SOx and NOx emissions are reduced by 20% from baseline. Unit abatement cost is unchanged. (See Table 9)
Scenario 3	Economy-wide SOx and NOx emissions are reduced by 20%, but unit abatement cost is 1.2 times the baseline level.

Scenario 3 is designed to reflect the possibility that as the mandatory reduction in air pollution becomes more stringent, firms have to pay higher abatement cost than before, according to the concept of an increase in abatement cost.

(2) Macroeconomic effects

Table 15 reports the macroeconomic effects of baseline and three scenarios. It shows that domestic total output will be reduced by 0.009%, 0.018% and 0.019% respectively under the three scenarios. GDP will be reduced by 0.007%, 0.013% and 0.015% respectively under the three scenarios, while total labor compensation will be decreased by 0.014%, 0.028% and 0.033% respectively under the three scenarios.

There will be deterioration in trade surplus as exports fall and imports rise under the three scenarios. These results are due mainly to the effects of domestic price rise as a result of tighter air pollution control policies.

(3) Sectoral effects

The sectoral net price determines the direction of movement of labor. In sectors where the net price rises employment will be higher and also will be their output, and vice versa for sectors suffering from lower net price. However, in our simulations, because part of labor input must be used to control air pollution, so sectoral real output does not have to rise as a result the increase in employment.

Sectoral effects can be found in Table 16, the column in the middle of Table 16 shows the effects of policy change on sectoral distribution of GDP. In the table, the ten sectors (with GDP exceeding ten thousand millions dollars in baseline solution) that suffer the largest decrease in GDP are shaded. They are in the order of the decrease in GDP: (1) Power Generation, (2) Glass And Ceramics, (3) Petrochemical, (4) Fuel Oil Production, (5) Paper And Printing Processing, (6) Textile Mill Products, (7) Other Mining, (8) Iron and Steel, (9) Gasoline Production, and (10) Other Manufacturing.

These results are not surprising as sectors that have either higher emission factors or abatement cost or both suffer the most from the tighter pressure. Unlike the traditional CGE model, the direction in which sectoral GDP changes needs not to be the same as employment. As the evident from Table 16, this is because under our assumptions, pollution abatement uses the same technology as regular production. So in order to respond to stringent pollution abatement, firms have to devote more labor resources to the purpose. As such, it is possible to see as in the case of power generation, an increase in employment will be associated with a decrease in sectoral GDP.

The direction of change in Green NDP is positive under all scenarios. Table 17 shows that the SEEA Green NDP will rise 0.02% and 0.024% under scenario 1 and 2 respectively. The effects on the damage-based revised Green NDP are even bigger. It rises 0.027% and 0.053% under two scenarios. Such changes are in sharp contrast with the reduction of GNP as shown in the first row of the Table for the scenario 3. Under scenario 3 the unit abatement cost becomes higher, so other things being equal, more resources have to be spend to achieve the same level of total reduction in air pollution. Not surprisingly, under scenario 3 the traditional GNP is reduced by larger amount than in scenarios 1 and 2. The SEEA Green

NDP or the Revised Green NDP both reveal smaller gains under scenario 3 than under scenario 2.

6. Conclusions and Remarks

This paper uses a 1997 static 28-sector CGE model to assess the effects of tighter air pollution control on the macroeconomic and sectoral variables. It also computes the SEEA (1993) Green NDP and an alternative, revised measure of damage-based Green NDP. The motivations for this paper are two folds:

(1) To use a CGE model to compute Green NDP in order to catch the general equilibrium effects, which are ignored in the traditional computation of Green NDP.

(2) To distinguish from the traditional CGE literature by taking into account the effects of policies on measures of Green National Product.

The three scenarios considered are respectively, (1) economy-wide SOx and NOx emissions being reduced by 10% and 20% at existing unit abatement cost; (2) economy-wide SOx and NOx emissions being reduced by 20% at higher unit abatement cost. Under these three scenarios we compute the macroeconomic and sectoral effects as well as the Green National Product.

Two definitions of Green National Product are used in the model. The first is SEEA (1993) definition, under which Green Net Domestic Product is equal to traditional NDP minus maintenance cost associated with air pollution. Under the second definition, what we called the Revised Green Net Domestic Product is equal to traditional NDP minus the damage cost of air pollution, where damages are defined as the social cost of the adverse effect of air pollution on human health.

The main findings of this paper are as follows:

(1) Tighter air pollution control measures will result in the decrease in GDP, total wage payment, and household income. Total exports will fall while total imports will rise, as

result of the increase in prices of domestic products.

(2) Under tighter air pollution control policy, sectors with higher emission per unit of production, or unit abatement cost, or both will suffer the larger decrease in their output and GDP. These sectors have higher larger emission per unit of production either because (a) their emission factor in the process of production is higher; (b) they use more intensively those fuels that have higher emission factors; (c) they use intensively those fuels with higher emission factors in transportation.

(3) The direction of change in Green NDP is positive under all scenarios. However, the effects on the damage-based revised Green NDP are even bigger. Under scenario 3 the unit abatement cost becomes higher, so other things being equal, more resources have to be spend to achieve the same level of total reduction in air pollution. As such, under scenario 3 the traditional GNP is reduced by a larger amount than in scenarios 1 and 2. And the SEEA Green NDP or the Revised Green NDP both reveal smaller gains under scenario 3 than under scenario 2.

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Table 1 CGE Model Equations

Price Block Equations		No. of equations
Import price	$PM_i = PW_i ER(1+tm_i)$	28
Composite goods price	$P_i = (PD_i D_i + PM_i M_i)/Q_i$	28
Net price	$PN_i = PD_i(1-td_i) - \sum P_j AA_{ji}$	28
Capital price	$PK_j = \sum P_i KF_{ij}$	28
I. Price Index	$PP = NGDP/RGDP$	1
Quantity Block Equations		**No. of equations**
Sectoral production function	$X_i = (1-(SUABC_i \cdot (SPOSTC_i + SCC_i \cdot AA_{2,j} + SNGC_i \cdot (AA_{3,j} + 0.40291087\ AA_{24,j}) + SGC_i \cdot 0.0007291326\ 7 AA_{9,j} + SDC_i \cdot 0.042436543\ AA_{10,j} + SFOC_i \cdot AA_{11,j} + SLPG_i \cdot (AA_{12,j} + 0.597089127\ AA_{24,j}) + SCPC_i \cdot AA_{13,j}) \cdot (1-THETAS)) - (STUABC_i \cdot (STGC_i \cdot 0.9992786733\ AA_{9,j} + STDC_i \cdot 0.957563456\ AA_{10,j}) \cdot (1-THETAS)) - (NUABC_i \cdot (NPOSTC_i + NCC_i \cdot AA_{2,j} + NNGC_i \cdot (AA_{3,j} + 0.40291087\ AA_{24,j}) + NGC_i \cdot 0.0007291326\ 7 AA_{9,j} + NDC_i \cdot 0.042436543\ AA_{10,j} + NFOC_i \cdot AA_{11,j} + NLPG_i \cdot (AA_{12,j} + 0.597089127\ AA_{24,j}) + NCPC_i \cdot AA_{13,j}) \cdot (1-THETAN)) - (NTUABC_i \cdot (NTGC_i \cdot 0.9992786733\ AA_{9,j} + NTDC_i \cdot 0.957563456\ AA_{10,j}) \cdot (1-THETAN))) \cdot AX_i K_i^{1-\alpha_i} L_i^{\alpha_i}$	28
Composite goods supply	$Q_i = \overline{B}_i(\delta_i M_i^{-\rho_i} + (1-\delta_i)D_i^{-\rho_i})^{-1/\rho_i}$	28
Intermediate Demand	$INTD_i = \sum_j AA_{ij} X_j$	28
Labor demand	$\lambda_i WL_i = \alpha_i PN_i X_i$	28
Investment demand	$INV_i = invcoe_i(RINV + GINV)$	28
Export Demand	$LogE_i = Log(econst_i) + ecoep_i Log((PSTAR_i / PD_i)ER) + ecoetw_i Log(WTV)$	28
Income □ Expenditure Block Equations		**No. of equations**
II. Total labor income	$TWAGE = \sum_i \lambda_i WL_i + GW \cdot P("S28") + PP(ER \cdot ROWL - LROW)$	1
Total depreciation	$TDEPR = \sum_j PK_j K_j deprate_i + GDEPR \cdot PK("S28")$	1
Tariff revenue	$TARIFF = \sum_i tm_i PW_i M_i ER$	1
Total indirect tax	$TTD = \sum_i td_i X_i PD_i$	1

Table 1　CGE Model Equations - continued

Income □ Expenditure Block Equations		No. of equations
III. Capital income	$TPROF = \sum_i PN_i X_i - (TWAGE - GW \cdot P("S28")) - (TDEPR - GDEPR \cdot PKP("S28")) + PP(ER \cdot ROWK - LROW + ER \cdot ROWL)$	1
Household income	$HOUSEY = profcoeh \cdot TPROF + TWAGE + PP(TRGH + ER \cdot TRROWH)$	1
Household income tax	$TAXH = taxcoeh \cdot HOUSEY$	1
Household saving	$HOUSAV = savrath \cdot HOUSEY$	1
Household expenditure	$C_i P_i = concoeh_i (HOUSEY - HOUSAV - TAXH - PP \cdot ROWTRH)$	28
Government savings	$GOVSAV = TTD + TARIFF + (1 - procoeh) TPROF + TAXH - \sum_i P_i G_i - GDEPR \cdot PK("S28") - GW \cdot P("S28") - PP(TRGH + ROWTRG - ER \cdot TRROWG)$	1
Total Saving	$S = TDEPR + HOUSAV + GOVSAV$	1

Market Cleaning Equations		No. of equations
Composite goods demand	$Q_i = INTD_i + C_i + G_i + INV_i$	28
Labor market equilibrium	$\sum_i L_i = L^s$	1
IV. Loanable market	$(RINV + GINV) \cdot \sum_i invcoe_i P_i = S - INVABR$	1
Doemestic product market equilibrium	$X_i - E_i - D_i = 0$	27
Net investment abroad	$INVABR = \sum_i PD_i E_i + PP \cdot ER \cdot TRROWH - \sum_i PW_i M_i ER + PP(ER \cdot ROWL + ER \cdot ROWK + ER \cdot TRROWG - LROW - ROWTRH - ROWTRG)$	1
Import Demand	$M_i / D_i = (PD_i / PM_i)^{\sigma_i} \cdot (\delta_i / (1 - \delta_i))^{\sigma_i}$	28
MoverD	$MOVERD_i = M_i / D_i$	28

Environmental Equations		**No. of equations**
Process emission	$SOxMQU_i = X_i \cdot SPOSTC_i \cdot THETAS$ $NOxMQU_i = X_i \cdot NPOSTC_i \cdot THETAN$	56

Table 1 CGE Model Equations - continued

Environmental Equations		No. of equations
Combustion emission	$\begin{aligned} SOxFQU_i &= X_i(SCC_i \cdot AA_{2,j} + SNGC_i \cdot (AA_{3,j} + 0.402910872 AA_{24,j}) \\ &+ SGC_i \cdot 0.00072913267 AA_{9,j} + STGC_i \cdot 0.99927086733 AA_{9,j} \\ &+ SDC_i \cdot 0.042436543 AA_{10,j} + STDC_i * 0.957563456 AA_{10,j} \\ &+ SFOC_i \cdot AA_{11,j} + SLPG_i \cdot (AA_{12,j} + 0.597089 AA_{24,j}) + SCPC_i \cdot AA_{13,j}) \cdot THETAS \end{aligned}$ $\begin{aligned} NOxFQU_i &= X_i(NCC_i \cdot AA_{2,j} + NNGC_i \cdot (AA_{3,j} + 0.402910872 AA_{24,j}) \\ &+ NGC_i \cdot 0.00072913267 AA_{9,j} + NSTGC_i \cdot 0.99927086733 AA_{9,j} \\ &+ NDC_i \cdot 0.042436543 AA_{10,j} + NTDC_i \cdot 0.957563456 AA_{10,j} \\ &+ NFOC_i \cdot AA_{11,j} + NLPG_i \cdot (AA_{12,j} + 0.597089 AA_{24,j}) + NCPC_i \cdot AA_{13,j}) \cdot THETAN \end{aligned}$	56
SOx emission control	$AIRCTS = \dfrac{\sum_i SOxM + \sum_i SOxF}{\sum_i SOxM0 + \sum_i SOxF0}$	1
NOx emission control	$AIRCTN = \dfrac{\sum_i NOxM + \sum_i NOxF}{\sum_i NOxM0 + \sum_i NOxF0}$	1

Gross National Product Identities		No. of equations
Nominal GDP	$\begin{aligned} NGDP &= \sum_i (P_i(C_i + INV_i + G_i) + PD_i E_i - PW_i M_i ER) \\ &+ GDEPR \cdot PK("S26") + GW \cdot PK("S26") \end{aligned}$	1
Real GDP	$RGDP = \sum_i (1 - \sum_j AA_{ji}) X_i + GW + GDEPR + \sum_i tm_i M_i$	1
SEEA Green NDP	$\begin{aligned} SGNDP &= RGDP.L - TDEPR.L - \left[\sum_i SUABC_i \cdot \left(\begin{aligned} & SO_x M.L_i + SO_x F.L_i \\ & - X.L_i \cdot 0.99927 AA_{9,i} \cdot STGC_i \\ & - X.L_i \cdot 0.95756 AA_{10,i} \cdot STDC \end{aligned} \right. + \sum_i STUABC_i \cdot \left(\begin{aligned} & X.L_i \cdot 0.99927 AA_{9,i} \cdot STGC \\ & + X.L_i \cdot 0.95756 AA_{10,i} \cdot ST \end{aligned} \right. \right. \\ & - \left[\sum_i NUABC_i \cdot \left(\begin{aligned} & NO_x M.L_i + NO_x F.L_i \\ & - X.L_i \cdot 0.99927 AA_{9,i} \cdot NTGC_i \cdot THETAN.L \\ & - X.L_i \cdot 0.95756 AA_{10,i} \cdot NTDC_i \cdot THETAN.L \end{aligned} \right) + \sum_i NTUABC_i \cdot \left(\begin{aligned} & X.L_i \cdot 0.99927 AA_{9,i} \cdot NTGC_i \cdot THETAN.L \\ & + X.L_i \cdot 0.95756 AA_{10,i} \cdot NTDC_i \cdot THETAN.L \end{aligned} \right) \right] \end{aligned}$	1
Revised Green NDP	$RGNDP = RGDP.L - TDEPR.L - 18.2757 \cdot \left[\begin{aligned} & 0.0035 \cdot \sum_i (SO_x M.L_i + SO_x F.L_i) \\ & + 0.000172 \cdot \sum_i (NO_x M.L_i + NO_x F.L_i) \end{aligned} \right]$	1

Parameter definition:

AA_{ji} : input-output coefficient

KF_{ji} : capital formation matrix

AX_i : constant of production function

α_i *(alpha)*: labor share on sector i

λ_i *(lamda)* : wage ratios on sector i

td_i : indirect tax on sector i

$deprate_i$: depreciation rate on sector i

$concoeh_i$: sectoral household comsumption ratio

taxcoeh : household income tax rate

savrath : household saving rate

$concoeg_i$: sectoral government consumption ratio

$invcoe_i$: investment coefficient on sector i

tm_i : tariff rate on sector i

$econst_i$: constant in export demand function on sector i

$ecoep_i$: exports price demand elasticity on sector i

$ecoetw_i$: exports world trade volume elasticity on sector i

σ_i *(sigma)* :trade aggregation substitute elasticity

δ_i (*delta*): Armington function share parameter

ρ_i *(rhoh)*: $\frac{1-\alpha_i}{\alpha_i}$

$\overline{B}_i$ (*BABR*): Armington function shift parameter

$SPOSTC_i$ and $NPOSTC_i$: *SOx* and *NOx* process emission factor respectively

SCC_i (NCC_i) : *SOx*(*NOx*) combustion emission factor associated with coal

$SNGC_i$ ($NNGC_i$) : *SOx*(*NOx*) combustion emission factor associated with natural gas

SGC_i (NGC_i) : *SOx*(*NOx*) combustion emission factor associated with gasoline

$STGC_i$ ($NTGC_i$) : *SOx*(*NOx*) combustion emission factor associated with gasoline

SDC_i (NDC_i) : *SOx*(*NOx*) transportation emission factor associated with diesel

$STDC_i$ ($NTDC_i$) : *SOx*(*NOx*) transportation emission factor associated with diesel

$SFOC_i$ ($NFOC_i$) : SOx (NOx) combustion emission factor associated with fuel oil

$SLPGC_i$ ($NLPGC_i$) : SOx (NOx) combustion emission factor associated with liquid petroleum gas

$SCPC_i$ ($NCPC_i$) : SOx (NOx) combustion emission factor associated with coal products

$SUABC_i$ ($NUABC_i$): SOx (NOx) unit abatement cost

$STUABC_i$ ($NTUABC_i$) : SOx (NOx) unit abatement cost of transportation pollution

THETAS (*THETAN*) : SOx (NOx) emission-reduced rate (air control policy)

Table 2 Sectoral process emission

Sector		Process emission (tons)	
		SOx	*NOx*
1	Agriculture, hunting, forestry and Fishing	0	0
2	Coal mining	3.77	0.07
3	Natural gas production	82.67	1.53
4	Other mining	833.56	15.40
5	Food	68	123
6	Textile mill products	11	16
7	Paper and printing processings	535	338
8	Petrochemical	2035	346
9	Gasoline production	0	0
10	Diesel production	0	0
11	Fuel oil production	0	0
12	Refinery gas	0	0
13	Coal products Manufacturing	0	0
14	Glass and ceramics	4100	4142
15	Cement	2385	32036
16	Iron and Steel Basic Industries	6079	1189
17	Metal Products Surface Treating	0	0
18	Computer and Other Computer Equipments	1497.05	2526.62
19	Semi-conductors	554.17	935.29
20	Photonics Materials and Components	70.47	118.93
21	Printed circuit board	0	0
22	Other manufacturing	7578.31	12790.16
23	Power generation	0	0
24	Gas supply	0	0
25	Construction	0	0
26	Transportation	9394.32	80084.01
27	Other basic construction	0	0
28	Services	493	466

Table 3 Sectoral combustion emission

Sector		Combustion emission (tons)	
		SOx	*NOx*
1	Agriculture, hunting, forestry and Fishing	0	0
2	Coal mining	0.25	0.37
3	Natural gas production	5.57	8.18
4	Other mining	56.17	82.45
5	Food	9130	5531
6	Textile mill products	21037	8249
7	Paper and printing processings	16532	12810
8	Petrochemical	31941	39031
9	Gasoline production	2792.84	3844.34
10	Diesel production	1778.29	2447.81
11	Fuel oil production	1700.36	2340.54
12	Refinery gas	217.27	299.08
13	Coal products Manufacturing	1310.56	1803.98
14	Glass and ceramics	3209	11926
15	Cement	835	248
16	Iron and Steel Basic Industries	21974	22405
17	Metal Products Surface Treating	0	0
18	Computer and Other Computer Equipments	64.40	78.69
19	Semi-conductors	36.37	121.91
20	Photonics Materials and Components	22.16	34.48
21	Printed circuit board	0	0
22	Other manufacturing	19918.76	18444.18
23	Power generation	190841	85862
24	Gas supply	0	0
25	Construction	0	0
26	Transportation	0	0
27	Other basic construction	0	0
28	Services	11311	3738

Table 4 Sectoral Process Emission Factor

Sector	Sectoral Domestic output (MNT$)	Emission factor (ton /MNT$)	
		V. SOx	*NOx*
Agriculture, hunting, forestry and	466418.79	0.0000	0.0000
Coal mining	267.00	0.0141	0.0003
Natural gas production	5861.99	0.0141	0.0003
Other mining	59105.01	0.0141	0.0003
Food	414220.55	0.0002	0.0003
Textile mill products	376703.28	0.0000	0.0000
Paper and printing processings	248476.02	0.0022	0.0014
Petrochemical	167959.74	0.0121	0.0021
Gasoline production	96896.37	0.0000	0.0000
Diesel production	61696.94	0.0000	0.0000
Fuel oil production	58993.11	0.0000	0.0000
Refinery gas	7538.21	0.0000	0.0000
Coal products Manufacturing	45469.20	0.0000	0.0000
Glass and ceramics	74533.13	0.0550	0.0556
Cement	102291.38	0.0233	0.3132
Iron and Steel Basic Industries	519472.99	0.0117	0.0023
Metal Products Surface Treating	30764.87	0.0000	0.0000
Computer and Other Computer	734025.78	0.0020	0.0034
Semi-conductors	271718.16	0.0020	0.0034
Photonics Materials and Components	34551.43	0.0020	0.0034
Printed circuit board	176933.28	0.0000	0.0000
Other manufacturing	3715758.66	0.0020	0.0034
Power generation	259108.02	0.0000	0.0000
Gas supply	31072.00	0.0000	0.0000
Construction	949183.00	0.0000	0.0000
Transportation	579802.00	0.0162	0.1381
Other basic construction	335370.86	0.0000	0.0000
Services	6135252.21	0.0001	0.0001

Table 5 Transportation Emission factor（ton /MNT$）

	SOx	SOx	NOx	NOx
	Emission factor of gasoline	Emission factor of diesel	Emission factor of gasoline	Emission factor of diesel
The rest of sectors	0.0213	0.1296	0.3678	1.2500
Natural gas production	0.0000	0.1296	0.0000	1.2500
Gas supply	0.0213	0.0000	0.3678	0.0000
Transportation	0.0000	0.0000	0.0000	0.0000

Table 6 SOx combustion emission factor associated with each type of fuels （ton/MNT$）

Sector	Coal	Natural gas	Gasoline	Diesel	Fuel oil	Refinery gas	Coal products
Agriculture, hunting, forestry and Fishing	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Coal mining	0.2683	0.0000	0.0016	0.0237	0.0000	0.0000	0.0000
Natural gas production	0.0000	0.0000	0.0000	0.0143	0.0378	0.0000	0.0000
Other mining	0.1489	0.0000	0.0009	0.0132	0.0349	0.0007	0.0195
Food	31.8983	0.0049	0.1905	2.8226	7.4852	0.1471	4.1803
Textile mill products	52.1618	0.0079	0.3116	4.6157	12.2403	0.2405	6.8359
Paper and printing processings	23.6668	0.0036	0.1414	2.0942	5.5536	0.1091	3.1016
Petrochemical	0.0000	0.0064	0.2507	3.7134	9.8476	0.1935	5.4996
Gasoline production	0.0000	0.0019	0.0754	1.1166	2.9612	0.0582	1.6537
Diesel production	0.0000	0.0019	0.0754	1.1167	2.9613	0.0582	1.6538
Fuel oil production	0.0000	0.0019	0.0754	1.1166	2.9612	0.0582	1.6537
Refinery gas	0.0000	0.0019	0.0732	1.0844	2.8757	0.0565	1.6060
Coal products Manufacturing	0.1140	0.0000	0.0007	0.0101	0.0267	0.0000	0.0149
Glass and ceramics	4.9891	0.0008	0.0298	0.4415	1.1707	0.0230	0.6538
Cement	0.2001	0.0000	0.0012	0.0177	0.0470	0.0009	0.0262
Iron and Steel Basic Industries	8.6080	0.0013	0.0514	0.7617	2.0200	0.0397	1.1281
Metal Products Surface Treating	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Computer and Other Computer Equipments	4.1170	0.0006	0.0246	0.3643	0.9661	0.0190	0.5395
Semi-conductors	4.1170	0.0006	0.0246	0.3643	0.9661	0.0190	0.5395
Photonics Materials and Components	4.1170	0.0006	0.0246	0.3643	0.9661	0.0190	0.5395
Printed circuit board	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Other manufacturing	4.1170	0.0006	0.0246	0.3643	0.9661	0.0190	0.5395
Power generation	9.1387	0.0014	0.0546	0.8087	2.1445	0.0421	1.1976
Gas supply	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Construction	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Transportation	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Other basic construction	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Services	0.0000	0.0103	0.4038	5.9817	15.8627	0.3116	8.8590

Table 7 NOx combustion emission factor associated with each type of fuels （ton/MNT$）

Sector	Coal	Natural gas	Gasoline	Diesel	Fuel oil	Refinery gas	Coal products
Agriculture, hunting, forestry and Fishing	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Coal mining	0.3947	0.0000	0.0988	0.0107	0.0000	0.0000	0.0000
Natural gas production	0.0000	0.0092	0.0000	0.0009	0.0057	0.0000	0.0000
Other mining	0.1737	0.0504	0.0435	0.0047	0.0309	0.0106	0.0344
Food	21.4777	6.2269	5.3749	0.5800	3.8254	1.3168	4.2566
Textile mill products	25.8305	7.4888	6.4642	0.6975	4.6007	1.5837	5.1192
Paper and printing processings	21.0693	6.1084	5.2727	0.5689	3.7527	1.2917	4.1756
Petrochemical	0.0000	8.1684	7.0508	0.7608	5.0182	1.7274	5.5838
Gasoline production	0.0000	3.8169	3.2947	0.3555	2.3449	0.8072	2.6092
Diesel production	0.0000	3.8170	3.2948	0.3555	2.3450	0.8072	2.6093
Fuel oil production	0.0000	3.8169	3.2947	0.3555	2.3449	0.8072	2.6092
Refinery gas	0.0000	3.7067	3.1996	0.3452	2.2772	0.7839	2.5339
Coal products Manufacturing	0.1556	0.0000	0.0389	0.0042	0.0277	0.0000	0.0308
Glass and ceramics	9.0265	2.6170	2.2589	0.2437	1.6077	0.5534	1.7889
Cement	0.0597	0.0173	0.0149	0.0016	0.0106	0.0037	0.0118
Iron and Steel Basic Industries	6.9269	2.0083	1.7335	0.1870	1.2338	0.4247	1.3728
Metal Products Surface Treating	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Computer and Other Computer	3.6558	1.0599	0.9149	0.0987	0.6511	0.2241	0.7245
Semi-conductors	3.6558	1.0599	0.9149	0.0987	0.6511	0.2241	0.7245
Photonics Materials and Components	3.6558	1.0599	0.9149	0.0987	0.6511	0.2241	0.7245
Printed circuit board	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Other manufacturing	3.6558	1.0599	0.9149	0.0987	0.6511	0.2241	0.7245
Power generation	3.8707	1.1222	0.9687	0.1045	0.6894	0.2373	0.7671
Gas supply	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Construction	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Transportation	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Other basic construction	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Services	0.0000	0.3437	1.6317	0.1761	1.1613	0.2898	1.2922

Table 8 Average Abatement Cost of Air Pollutants for US Industries, 1979~1985

Unit: NT$1997/ton

ISIC	Sector	PM	SOx	NOx,CO2	HC
3110	Food	2966.45	17971.14	7899.03	5587.96
3130	Beverages	5381.00	9347.75	411094.24	411094.24
3140	Tobacco	9244.27	5760.42	5760.42	414957.51
3210	Textiles	13659.45	13659.45	47566.62	47566.62
3211	Spinning	9382.25	18454.05	49360.28	6484.79
3220	Apparel	15349.63	2104.11	2104.11	2104.11
3230	Leather	4553.15	13004.07	290780.70	21834.42
3240	Footwear	18626.52	7140.17	34252.10	53740.96
3310	Wood	1621.20	1310.76	1310.76	1310.76
3320	Furniture	1483.22	862.34	862.34	862.34
3410	Paper Products	3000.94	12555.66	16280.96	16280.96
3411	Pulp, Paper	1483.22	5346.50	689.87	689.87
3420	Printing	14625.27	4035.75	10658.51	10589.52
3511	Industrial Chemicals	1586.70	2587.02	10486.04	7347.13
3512	Agricultural Chemicals	4380.68	17902.16	30664.77	11762.30
3513	Resins	2828.47	19385.38	7140.17	4242.71
3520	Chemical Products	7312.63	23490.11	1655.69	5415.49
3522	Drugs	9278.77	36045.77	15556.60	5967.39
3530	Refineries	11313.89	5691.44	2035.12	4173.72
3540	Petroleum, Coal	2035.12	67020.99	2656.00	2656.00
3550	Rubber	7554.09	38184.37	11831.29	11831.29
3560	Plastic	7554.09	83301.94	8105.99	8105.99
3610	Pottery	6381.31	3656.32	130799.58	130799.58
3620	Glass	6415.80	18971.46	11693.32	11693.32
3690	Non-Metal Products	689.87	7347.13	56810.89	57190.32
3710	Iron, Steel	6277.83	18212.60	3966.76	41495.75
3720	Non-Ferrous Metals	11727.81	5243.02	1690.18	22834.74
3810	Metal Products	11831.29	53913.43	15901.53	13762.93
3820	Other Machinery	8761.36	29491.99	17764.18	17764.18
3825	Office, Computing Machinery	8450.92	8450.92	29802.44	32320.46
3830	Other Electrical Machinery	12866.10	16660.39	53775.46	7416.12
3832	Radio, TV	13590.46	63951.06	31182.18	37804.94
3840	Transport Equipment	21903.41	43668.85	16142.99	34700.52
3841	Shipbuilding	4311.69	28698.64	76886.14	76886.14
3843	Motor Vehicles	12072.75	52533.69	39840.06	84198.78
3850	Professional Goods	41668.22	105067.38	30078.38	47463.14
3900	Other Industries	1310.76	896.83	3794.29	3794.29

Table 9 Sectoral unit abatement cost

Sector	*SOx*	*NOx*
Sector 1 to 4 (Agriculture, , hunting, forestry and Fishing, Coal mining, Natural gas production, Other mining)	23552.00	7697.00
Food	17971.14	7899.03
Textile mill products	13659.45	47566.62
Paper and printing processings	7312.63	9209.78
Petrochemical	2587.02	10486.04
Gasoline production	67020.99	2656.00
Diesel production	67020.99	2656.00
Fuel oil production	67020.99	2656.00
Refinery gas	67020.99	2656.00
Coal products Manufacturing	67020.99	2656.00
Glass and ceramics	11313.89	71246.45
Cement	7347.13	56810.89
Iron and Steel Basic Industries	18212.60	3966.76
Metal Products Surface Treating	53913.43	15901.53
Computer and Other Computer Equipments	8450.92	29802.43
Semi-conductors	105067.38	30078.38
Photonics Materials and Components	105067.38	30078.38
Printed circuit board	105067.38	30078.38
Other manufacturing	33700.21	34197.90
The rest sector (from sector 23 to 28)	23552.00	7697.00

Table 10 Emission factors of different types of fuel

Untreated emission factors	Coal (10^3 ton)	Coal products (10^3 ton)	Gasoline (10^3 KL)	Diesel (10^3 KL)	Fuel oil (10^3 KL)	LPG (10^3 KL)	Natural gas (10^6 M^3)
SOx	19.5*(1)	19.5*(1)	17.25*(0.05)	17.25*(0.62)	19.25*(0.75)	0.343	0.01
NOx	9.1	9.1	2.8	2.8	7.5	2.24	2.24

Table 11 Energy Consumption and Pollution Emissions in Taiwan, 1997

Types of fuel	Final Energy Consumption	Transformation Input	Final Energy Consumption and Transformation Input	Untreated Emission （ton）	
				SOx	NOx
Coal (10^3 ton)	5,896.828	27,889.483	33,786.311	658,833.06	307,455
Coal products (10^3 ton)	4,083.031	0.000	4,083.031	79,619	37,156
Gasoline (10^3 KL)	8,552.043	25.822	8,577.865	7,398	24,018
Diesel (10^3 KL)	4,902.130	162.440	5,064.570	54,166	14,181
Fuel oil (10^3 KL)	7,451.519	6,749.344	14,200.863	205,025	106,506
LPG (10^3 KL)	5,103.400	20.899	5,124.299	1,758	11,478
Natural gas (10^6 M^3)	2,687.385	6,194.407	8,881.792	89	19,895
Total	38,676	41,042	79,719	1,006,888	520,690

12 Contribution of Energy Combustion on The Intensity of Air Pollution in Taiwan

Average Intensity / **Types of Fuel**	SOx (*ppm*)	*Ratio*	NOx (*ppm*)	*Ratio*
Coal (10^3 ton)	0.0039	65.43%	0.0142	59.05%
Coal products (10^3 ton)	0.0005	7.91%	0.0017	7.14%
Gasoline (10^3 KL)	4.4E-05	0.73%	0.0011	4.61%
Diesel (10^3 KL)	0.0003	5.38%	0.0007	2.72%
Fuel oil (10^3 KL)	0.0012	20.36%	0.0049	20.45%
LPG (10^3 KL)	1.0E-05	0.17%	0.0005	2.20%
Natural gas (10^6 M^3)	5.3E-07	0.01%	0.0009	3.82%
Total	0.006	100%	0.024	100.00%

Table 13 **The private health cost associated with *SOx* pollution from each fuel use**

	[illegible] SOx [illegible] a	[illegible] b	[illegible] SOx [illegible] c = a / b	SOx [illegible] d	Population in 1997 e	Days in a year f	private health cost per unit of air pollution emission g	The private health cost associated with SOx pollution from per unit fuel use $h = c*d*e*f*g / 1000$	[illegible] 1 [illegible] SOx [illegible] $i = h$ / emission factor	[illegible] 1 [illegible] SOx [illegible] $j = i * 1000$
Fuel (unit)	ppm	10^3 KL/ 10^3 ton	ppm/10^3 KL	ppm	person	day	NT$/ person, per day	NT$/ KL	NT$/Kg	NT$/ton
Coal (10^3 ton)	0.0039	33786.311	1.162E-07	0.142133	21742815	365	520.1031	68.171	3.496	3495.934
Coal products (10^3 ton)	0.0005	4083.031	1.162E-07	0.142133	21742815	365	520.1031	68.171	3.496	3495.934
Gasoline (10^3 KL)	4.4E-05	8577.865	5.140E-09	0.142133	21742815	365	520.1031	3.015	3.496	3495.934
Diesel (10^3 KL)	0.0003	5064.57	6.373E-08	0.142133	21742815	365	520.1031	37.389	3.496	3495.934
Fuel oil (10^3 KL)	0.0012	14200.863	8.603E-08	0.142133	21742815	365	520.1031	50.473	3.496	3495.934
LPG (10^3 KL)	1.0E-05	5124.298528	2.044E-09	0.142133	21742815	365	520.1031	1.199	3.496	3495.934
Natural gas (10^6 M^3)	5.3E-07	8881.792	5.959E-11	0.142133	21742815	365	520.1031	0.035	3.496	3495.934

Table 14 The private health cost associated with *NOx* pollution from each fuel use

	[illegible] NOx [illegible] a	[illegible] b	[illegible] NOx [illegible] c = a / b	NOx [illegible] d	Population in 1997 e	Days in a year f	private health cost per unit of air pollution emission g	The private health cost associated with NOx pollution from per unit fuel use h = c*d*e*f*g /1000	The private health cost of per kilogram NOx emission i = h / emission factor	The private health cost of per ton NOx emission j = i *1000
Fuel (unit)	ppm	10^3 KL/ 10^3 ton	ppm/10^3 KL	ppm	person	day	NT$/ person, per day	NT$/ KL	NT$/Kg	NT$/ton
Coal (10^3 ton)	0.0142	33786.311	4.194E-07	0.000903875	21742815	365	520.1031	1.565	0.172	171.964
Coal products (10^3 ton)	0.0017	4083.031	4.194E-07	0.000903875	21742815	365	520.1031	1.565	0.172	171.964
Gasoline (10^3 KL)	0.0011	8577.865	1.291E-07	0.000903875	21742815	365	520.1031	0.482	0.172	171.964
Diesel (10^3 KL)	0.0007	5064.57	1.291E-07	0.000903875	21742815	365	520.1031	0.482	0.172	171.964
Fuel oil (10^3 KL)	0.0049	14200.863	3.457E-07	0.000903875	21742815	365	520.1031	1.290	0.172	171.964
LPG (10^3 KL)	0.0005	5124.298528	1.032E-07	0.000903875	21742815	365	520.1031	0.385	0.172	171.964
Natural gas (10^6 M^3)	0.0009	8881.792	1.032E-07	0.000903875	21742815	365	520.1031	0.385	0.172	171.964

Table 15 Macroeconomic effects

	Baseline result (MNT$)	Scenario 1 (MNT$)	% of change	Scenario 2 (MNT$)	% of change	Scenario 3 (MNT$)	% of change
Gross Domestic Product	8131152.00	8130613.00	-0.00663	8130071.00	-0.01329	8129959.00	-0.01467
Domestic total output	15627050.27	15625677.62	-0.00878	15624300.59	-0.01760	15624078.80	-0.01901
Exports	4003495.22	4003364.56	-0.00326	4003233.61	-0.00653	4003226.71	-0.00671
Imports	3780185.31	3780375.99	0.00504	3780568.68	0.01014	3780479.91	0.00779
Indirect tax	573274.00	573230.20	-0.00764	573186.20	-0.01532	573187.10	-0.01516
Tariff tax	158030.00	158047.20	0.01088	158064.60	0.02189	158060.80	0.01949
Investment demand	1791300.49	1791511.90	0.01180	1791724.80	0.02369	1791661.40	0.02015
Total labor income	4260962.00	4260498.00	-0.01089	4260031.00	-0.02185	4259894.00	-0.02506
Wage rate	78.21	78.20	-0.01384	78.19	-0.02775	78.19	-0.03257
Total depreciation	771968.00	771992.50	0.00317	772017.20	0.00637	772023.40	0.00718
Capital Income	2568527.00	2568454.00	-0.00284	2568381.00	-0.00568	2568403.00	-0.00483
Household income	6895596.00	6895067.00	-0.00767	6894536.00	-0.01537	6894418.00	-0.01708
Current account surplus	217225.00	216990.20	-0.10809	216752.10	-0.21770	216844.50	-0.17516
Household savings	1062990.00	1062908.00	-0.00771	1062827.00	-0.01533	1062808.00	-0.01712
Government savings	173568.00	173520.40	-0.02742	173472.70	-0.05491	173468.40	-0.05738
SO_x emission-reduced rate [8]	1.00000	0.90056	-9.94377	0.80100	-19.89985	0.80118	-19.88182
NO_x emission-reduced rate	1.00000	0.90033	-9.96733	0.80058	-19.94182	0.80069	-19.93124

Table 16 Sectoral Effects（% of change）

Sector	Total air pollution				X (Domestic output , MNT$)				L (Labor, thousand)			
	Baseline Result	Scenario **1**	Scenario **2**	Scenario **3**	Baseline Result	Scenario **1**	Scenario **2**	Scenario **3**	Baseline Result	Scenario **1**	Scenario **2**	Scenario **3**
1	**8963.201****	-9.966	-19.940	-19.929	466418.800	-0.0011	-0.0021	-0.0024	878.000	0.00006	0.00009	0.00052
2	6.073	-10.003	-20.006	-20.011	267.000	-0.0579	-0.1160	-0.1421	0.065	-0.056	-0.113	-0.139
3	104.309	-9.995	-19.991	-19.990	5861.990	-0.0529	-0.1060	-0.1260	2.104	-0.063	-0.127	-0.151
4	5461.183	-9.977	-19.959	-19.953	59105.010	-0.0172	-0.0344	-0.0414	10.831	-0.021	-0.041	-0.050
5	15163.140	-9.961	-19.931	-19.917	414220.600	-0.0090	-0.0180	-0.0193	107.004	-0.005	-0.010	-0.009
6	29519.720	-9.967	-19.941	-19.930	376703.300	-0.0182	-0.0364	-0.0425	167.311	0.000	-0.001	0.001
7	30518.630	-9.979	-19.962	-19.954	248476.000	-0.0271	-0.0544	-0.0632	133.128	-0.023	-0.047	-0.054
8	73431.340	-9.988	-19.978	-19.974	167959.700	-0.0345	-0.0692	-0.0814	19.360	-0.014	-0.029	-0.030
9	6815.405	-9.972	-19.949	-19.940	96896.370	-0.0155	-0.0310	-0.0368	6.109	0.012	0.024	0.030
10	4339.577	-9.970	-19.946	-19.937	61696.940	-0.0135	-0.0270	-0.0328	3.890	0.017	0.034	0.040
11	4149.401	-9.985	-19.974	-19.971	58993.110	-0.0309	-0.0619	-0.0745	3.719	-0.026	-0.053	-0.064
12	530.628	-9.976	-19.957	-19.949	7538.215	-0.0199	-0.0399	-0.0480	0.434	0.001	0.002	0.002
13	3130.726	-9.961	-19.931	-19.922	45469.200	-0.0041	-0.0080	-0.0140	1.501	0.087	0.174	0.185
14	23488.960	-10.026	-20.045	-20.056	74533.130	-0.0728	-0.1458	-0.1749	36.214	0.113	0.225	0.270
15	37005.140	-9.976	-19.957	-19.954	102291.400	-0.0116	-0.0233	-0.0338	49.994	0.264	0.529	0.626
16	52513.770	-9.969	-19.946	-19.935	519473.000	-0.0164	-0.0329	-0.0383	91.605	-0.013	-0.027	-0.029
17	**148.418****	-9.975	-19.955	-19.943	30764.870	-0.0105	-0.0209	-0.0199	19.646	-0.016	-0.032	-0.030
18	4364.720	-9.958	-19.925	-19.912	734025.800	0.0007	0.0015	0.0020	225.803	0.003	0.007	0.007
19	1799.425	-9.962	-19.932	-19.915	271718.200	-0.0025	-0.0050	-0.0009	79.587	0.004	0.008	0.004
20	257.757	-9.965	-19.938	-19.924	34551.430	-0.0071	-0.0142	-0.0136	10.575	-0.005	-0.011	-0.021
21	**164.400****	-9.967	-19.942	-19.931	176933.300	-0.0021	-0.0042	-0.0048	53.914	-0.004	-0.008	-0.009
22	64005.070	-9.971	-19.948	-19.932	3715759.000	-0.0151	-0.0303	-0.0279	1560.206	-0.015	-0.029	-0.033
23	283155.700	-10.044	-20.078	-20.092	259108.000	-0.1023	-0.2049	-0.2429	29.491	0.386	0.775	0.941
24	**39.565****	-9.972	-19.951	-19.942	31072.000	-0.0072	-0.0144	-0.0171	2.394	-0.011	-0.021	-0.025
25	**3427.786****	-9.958	-19.925	-19.916	949183.000	0.0084	0.0170	0.0139	885.000	0.011	0.023	0.019
26	89478.340	-9.969	-19.944	-19.934	579802.000	-0.0041	-0.0082	-0.0096	289.167	0.010	0.019	0.023
27	**1980.864****	-9.969	-19.945	-19.934	335370.900	-0.0045	-0.0091	-0.0090	178.949	-0.008	-0.016	-0.016
28	28548.110	-9.959	-19.927	-19.913	5802858.000	-0.0022	-0.0044	-0.0049	4007.000	-0.003	-0.006	-0.007

Table 16 Sectoral Effects（% of change）-continued

Sector	M （Imports, MNT$）				E （Exports, MNT$）				D （Domestic Demand, MNT$）			
	Baseline Result	Scenario 1	Scenario 2	Scenario 3	Baseline Result	Scenario 1	Scenario 2	Scenario 3	Baseline Result	Scenario 1	Scenario 2	Scenario 3
1	130985.200	-0.018	-0.036	-0.039	39037.870	0.003	0.005	0.006	427380.900	-0.0014	-0.0028	-0.0031
2	45526.880	-0.038	-0.076	-0.093	8.861	-0.021	-0.041	-0.051	258.139	-0.0592	-0.1186	-0.1452
3	15720.520	-0.050	-0.100	-0.118	1.108	-0.003	-0.006	-0.008	5860.883	-0.0529	-0.1061	-0.1261
4	179677.300	-0.015	-0.030	-0.036	1529.572	-0.002	-0.005	-0.006	57575.440	-0.0176	-0.0352	-0.0424
5	99116.070	-0.014	-0.027	-0.027	78388.080	0.001	0.001	0.001	335832.500	-0.0112	-0.0224	-0.0239
6	55712.650	-0.001	-0.003	0.005	268537.900	-0.013	-0.025	-0.031	108165.300	-0.0322	-0.0644	-0.0713
7	76638.230	0.013	0.026	0.036	31969.280	-0.018	-0.036	-0.045	216506.700	-0.0285	-0.0571	-0.0660
8	156916.700	0.005	0.011	0.019	22820.640	-0.017	-0.034	-0.043	145139.100	-0.0373	-0.0747	-0.0876
9	10637.940	0.012	0.025	0.031	230.377	-0.012	-0.024	-0.030	96666.000	-0.0155	-0.0310	-0.0368
10	4517.087	0.016	0.032	0.038	7714.316	-0.013	-0.026	-0.031	53982.630	-0.0136	-0.0272	-0.0331
11	17876.030	-0.021	-0.041	-0.049	9446.575	-0.006	-0.013	-0.016	49546.530	-0.0356	-0.0712	-0.0857
12	5453.473	0.004	0.009	0.011	5.538	-0.011	-0.021	-0.026	7532.677	-0.0199	-0.0399	-0.0480
13	921.504	0.102	0.205	0.219	53.164	-0.046	-0.092	-0.101	45416.030	-0.0040	-0.0079	-0.0138
14	20212.420	0.107	0.215	0.260	23267.000	-0.077	-0.155	-0.187	51266.140	-0.0707	-0.1416	-0.1696
15	5575.958	0.221	0.443	0.525	2438.898	-0.100	-0.200	-0.240	99852.480	-0.0095	-0.0189	-0.0287
16	163321.400	0.007	0.015	0.023	73648.730	-0.010	-0.020	-0.025	445824.300	-0.0175	-0.0350	-0.0405
17	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	30764.870	-0.0105	-0.0209	-0.0199
18	120242.000	0.000	-0.001	-0.002	579146.300	0.001	0.002	0.002	154879.500	0.0003	0.0006	0.0004
19	321902.600	-0.001	-0.003	-0.002	253156.900	-0.002	-0.005	-0.001	18561.240	-0.0039	-0.0078	-0.0028
20	47958.280	0.000	0.000	0.000	20457.060	-0.007	-0.014	-0.014	14094.370	-0.0070	-0.0141	-0.0133
21	36886.490	-0.005	-0.009	-0.008	143984.700	-0.001	-0.002	-0.003	32948.590	-0.0059	-0.0119	-0.0112
22	1680818.000	0.016	0.032	0.026	1745139.000	-0.003	-0.006	-0.006	1970620.000	-0.0257	-0.0516	-0.0478
23	1089.779	0.000	0.001	0.006	567.083	0.000	0.000	0.000	258540.900	-0.1025	-0.2053	-0.2434
24	121.341	-0.008	-0.015	-0.018	187.182	0.000	0.000	0.000	30884.820	-0.0072	-0.0144	-0.0173
25	8259.195	0.011	0.022	0.020	3931.920	0.000	0.000	0.000	945251.100	0.0085	0.0171	0.0140
26	104486.000	-0.006	-0.012	-0.013	243556.400	0.000	0.000	0.000	336245.600	-0.0071	-0.0142	-0.0166
27	18327.060	-0.013	-0.025	-0.026	63781.270	0.000	0.000	0.000	271589.600	-0.0056	-0.0112	-0.0111
28	451285.200	-0.008	-0.017	-0.019	390489.500	0.000	0.000	0.000	5412369.000	-0.0024	-0.0047	-0.0053

Table 16 Sectoral Effects（% of change）-continued

Sector	Q (Composite goods, MNT$)				INTD（Intermediate goods, MNT$）			
	Baseline Result	Scenario **1**	Scenario **2**	Scenario **3**	Baseline Result	Scenario **1**	Scenario **2**	Scenario **3**
1	564467.600	-0.0054	-0.0107	-0.0119	309369.400	-0.007	-0.015	-0.016
2	46001.390	-0.0380	-0.0760	-0.0930	35712.800	-0.052	-0.105	-0.126
3	22405.920	-0.0508	-0.1017	-0.1198	23240.740	-0.048	-0.097	-0.115
4	241666.300	-0.0156	-0.0312	-0.0374	237752.600	-0.016	-0.032	-0.038
5	447108.400	-0.0118	-0.0236	-0.0247	164612.100	-0.006	-0.012	-0.012
6	166335.800	-0.0214	-0.0429	-0.0447	191772.700	-0.016	-0.033	-0.035
7	295166.900	-0.0174	-0.0350	-0.0387	277260.700	-0.012	-0.025	-0.028
8	303680.700	-0.0151	-0.0302	-0.0321	254861.900	-0.020	-0.040	-0.042
9	122833.300	-0.0096	-0.0192	-0.0223	63118.120	-0.005	-0.009	-0.011
10	58499.710	-0.0113	-0.0226	-0.0276	51035.330	-0.014	-0.029	-0.034
11	68325.870	-0.0315	-0.0631	-0.0757	51838.860	-0.045	-0.091	-0.106
12	13624.760	-0.0091	-0.0182	-0.0216	12621.900	-0.011	-0.021	-0.025
13	46352.240	-0.0019	-0.0036	-0.0091	20310.890	-0.019	-0.039	-0.047
14	72561.470	-0.0184	-0.0369	-0.0436	69746.970	-0.009	-0.017	-0.021
15	106249.800	0.0043	0.0088	0.0045	111288.200	0.005	0.010	0.006
16	614535.000	-0.0106	-0.0213	-0.0232	573410.700	-0.012	-0.024	-0.026
17	30764.870	-0.0105	-0.0209	-0.0199	25967.820	-0.015	-0.029	-0.027
18	278483.600	0.0000	-0.0001	-0.0007	166417.200	-0.003	-0.006	-0.005
19	341778.800	-0.0016	-0.0032	-0.0020	300257.700	-0.003	-0.006	-0.004
20	62165.030	-0.0015	-0.0031	-0.0026	56472.880	-0.003	-0.006	-0.005
21	70641.750	-0.0053	-0.0106	-0.0094	78441.760	-0.004	-0.007	-0.006
22	3749634.000	-0.0059	-0.0119	-0.0128	2127307.000	-0.010	-0.020	-0.020
23	259630.700	-0.1021	-0.2045	-0.2424	233111.800	-0.023	-0.047	-0.053
24	31006.160	-0.0072	-0.0144	-0.0173	11815.330	-0.013	-0.025	-0.030
25	953510.300	0.0085	0.0171	0.0140	195110.500	-0.004	-0.008	-0.009
26	440731.600	-0.0068	-0.0136	-0.0158	202033.000	-0.007	-0.013	-0.015
27	289916.600	-0.0060	-0.0121	-0.0121	230121.700	-0.005	-0.010	-0.011
28	5863692.000	-0.0028	-0.0057	-0.0064	2424718.000	-0.007	-0.013	-0.014

Table 16 Sectoral Effects（% of change）-continued

Sector	PN （Net price）				PD （Domestic products price）				P （Composite goods price）			
	Baseline Result	Scenario 1	Scenario 2	Scenario 3	Baseline Result	Scenario 1	Scenario 2	Scenario 3	Baseline Result	Scenario 1	Scenario 2	Scenario 3
1	0.406	-0.013	-0.026	-0.030	1.0000	-0.0041	-0.0082	-0.0091	1.00000	-0.00309	-0.00619	-0.00687
2	0.615	-0.012	-0.025	-0.029	1.0000	0.0142	0.0286	0.0351	1.00000	0.00008	0.00016	0.00020
3	0.419	-0.024	-0.049	-0.057	1.0000	0.0019	0.0039	0.0056	1.00000	0.00050	0.00102	0.00147
4	0.535	-0.017	-0.035	-0.041	1.0000	0.0017	0.0035	0.0044	1.00000	0.00041	0.00082	0.00104
5	0.188	-0.010	-0.020	-0.022	1.0000	-0.0007	-0.0014	-0.0009	1.00000	-0.00052	-0.00103	-0.00065
6	0.350	0.004	0.008	0.011	1.0000	0.0119	0.0239	0.0294	1.00000	0.00776	0.01554	0.01914
7	0.268	-0.010	-0.020	-0.023	1.0000	0.0180	0.0361	0.0445	1.00000	0.01319	0.02648	0.03264
8	0.268	0.006	0.013	0.019	1.0000	0.0163	0.0327	0.0407	1.00000	0.00780	0.01562	0.01945
9	0.239	0.014	0.028	0.034	1.0000	0.0121	0.0242	0.0295	1.00000	0.00949	0.01902	0.02323
10	0.239	0.017	0.034	0.040	1.0000	0.0128	0.0256	0.0310	1.00000	0.01180	0.02366	0.02857
11	0.239	-0.009	-0.019	-0.022	1.0000	0.0064	0.0129	0.0158	1.00000	0.00468	0.00939	0.01146
12	0.218	0.007	0.014	0.018	1.0000	0.0105	0.0211	0.0257	1.00000	0.00583	0.01168	0.01419
13	0.507	0.077	0.154	0.167	1.0000	0.0460	0.0924	0.1014	1.00000	0.04510	0.09050	0.09933
14	0.351	0.172	0.344	0.413	1.0000	0.0775	0.1553	0.1869	1.00000	0.05471	0.10964	0.13196
15	0.236	0.262	0.525	0.628	1.0000	0.1000	0.2005	0.2404	1.00000	0.09395	0.18842	0.22590
16	0.247	-0.011	-0.022	-0.023	1.0000	0.0095	0.0191	0.0241	1.00000	0.00691	0.01387	0.01751
17	0.479	-0.019	-0.038	-0.043	1.0000	0.0025	0.0050	0.0080	1.00000	0.00249	0.00504	0.00801
18	0.186	-0.011	-0.022	-0.028	1.0000	-0.0006	-0.0011	-0.0016	1.00000	-0.00031	-0.00063	-0.00091
19	0.355	-0.007	-0.015	-0.027	1.0000	0.0016	0.0032	0.0005	1.00000	0.00009	0.00017	0.00003
20	0.214	-0.012	-0.024	-0.040	1.0000	0.0047	0.0095	0.0092	1.00000	0.00107	0.00215	0.00208
21	0.266	-0.016	-0.032	-0.037	1.0000	0.0008	0.0016	0.0022	1.00000	0.00038	0.00076	0.00104
22	0.272	-0.013	-0.027	-0.038	1.0000	0.0024	0.0047	0.0042	1.00000	0.00124	0.00249	0.00219
23	0.580	0.475	0.954	1.154	1.0000	0.3128	0.6280	0.7599	1.00000	0.31145	0.62535	0.75673
24	0.169	-0.017	-0.034	-0.041	1.0000	-0.0016	-0.0031	-0.0033	1.00000	-0.00157	-0.00313	-0.00330
25	0.349	-0.011	-0.022	-0.027	1.0000	0.0078	0.0156	0.0183	1.00000	0.00771	0.01548	0.01810
26	0.500	0.000	0.000	0.000	1.0000	0.0014	0.0027	0.0039	1.00000	0.00104	0.00207	0.00299
27	0.685	-0.018	-0.035	-0.040	1.0000	-0.0087	-0.0174	-0.0188	1.00000	-0.00815	-0.01634	-0.01762
28	0.592	-0.015	-0.030	-0.034	1.0000	-0.0067	-0.0134	-0.0152	1.00000	-0.00620	-0.01240	-0.01401

Table 17 Green Domestic Product

	Baseline result (MNT$)	Scenario **1** (MNT$)	% of change	Scenario **2** (MNT$)	% of change	Scenario **3** (MNT$)	% of change
Gross Domestic Product	8131152.00	8130613.00	-0.006629	8130071.00	-0.013295	8129959.00	-0.014672
SOx maintenance cost	8079.73	7271.65	-10.001278	6463.60	-20.002271	7457.22	-7.704510
NOx maintenance cost	6263.47	5637.20	-9.998754	5010.92	-19.997782	5136.61	-17.990931
Total maintenance cost	14343.20	12908.85	-10.000209	11474.51	-20.000349	12593.84	-12.196442
SOx damage cost	23916.24	21524.62	-9.999983	19132.99	-20.000008	19132.99	-20.000008
NOx damage cost	1251.41	1126.27	-10.000000	1001.13	-20.000000	1001.13	-20.000000
Total damage cost	25167.65	22650.88	-10.000020	20134.12	-20.000000	20134.12	-20.000000
SEEA GREEN GDP	8116809.00	8117704.00	0.011027	8118597.00	0.022028	8117366.00	0.006862
Revised GREEN GDP	8105984.00	8107962.00	0.024402	8109937.00	0.048766	8109825.00	0.047385
Total Depreciation	771968.00	771992.50	0.003174	772017.20	0.006373	772023.40	0.007176
SEEA GREEN NDP	7344841.00	7345711.00	0.011845	7346580.00	0.023676	7345342.00	0.006821
ENRAP GREEN NDP	7334016.00	7335969.00	0.026629	7337920.00	0.053231	7337802.00	0.051622
SOx emission-reduced rate from baseline level	1.00	0.90	-10.00	0.80	-20.00	0.80	-20.00
NOx emission-reduced rate from baseline level	1.00	0.90	-10.00	0.80	-20.00	0.80	-20.00