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

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by

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Overview of the presentation

- Introduction
- The Taiwan CGE Model
- Theoretical Model of Green GNP
- Data and Environmental Cost
- Scenarios and Analysis
- Conclusions

Introduction

- 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).
- 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**. As such, it is closer to the social welfare concept in economics than is traditional NDP.

Purpose of the study

- Establish a link between the concept of Green national product and that of CGE modeling, **in order to catch the general equilibrium effects, which are ignored in the traditional computation of Green NDP.**
- To distinguish from the traditional CGE literature by taking into account the effects of policies on measures of Green National Product.

The Taiwan CGE Model

- Use a revised version of the DMR model, in which a total of **28 sectors** are included.
- **Production function**

  Assume tighter environmental control will result in **higher cost**, which is specified as having an effect on the technology parameter of production function. So, when the sector is required by new policy to adopt tighter control, the technology parameter *AXi* would be multiplied by $(1 - \frac{UABC\ (X^{b} \cdot POSTC\ ) \cdot (1 - THETA\ )}{X^{b}})$

The Taiwan CGE Model

- **Environmental equations**
  - Sectoral Process emission

$$SOxMQU_i = X_i \cdot SPOSTC_i \cdot THETAS$$

$$NOxMQU_i = X_i \cdot NPOSTC_i \cdot THETAN$$

  - Sectoral Combustion and transportation emission

$$\begin{aligned} SOxF_i = X_i (&SCC_i \cdot AA_{2,j} + SNGC_i \cdot (AA_{3,j} + 0.402910872\, AA_{24,j}) \\ &+ SGC_i \cdot 0.000729132667\, AA_{9,j} + STGC_i \cdot 0.999270867333\, AA_{9,j} \\ &+ SDC_i \cdot 0.042436543\, AA_{10,j} + STDC_i \cdot 0.957563456\, AA_{10,j} \\ &+ SFOC_i \cdot AA_{11,j} + SLPG_i \cdot (AA_{12,j} + 0.597089\, AA_{24,j}) + SCPC_i \cdot AA_{13,j}) \cdot THETAS \end{aligned}$$

The Taiwan CGE Model

- **Environmental equations**
  - Air pollution control policy

$$AIRCTS = \left(\sum_i SOxM + \sum_i SOxF \right) \Big/ \left(\sum_i SOxM\,0 + \sum_i SOxF\,0 \right)$$

  - Green NDP

SGNDP = RGDP-TDEPR-MAINCOST ;

RGNDP = RGDP-TDEPR-DAMAGECOST ;

Theoretical Model of Green GNP

- **Mostly following Chu (2000), our model ignored the depletion of natural resources and direct services of the environment.**
  - The economy produces according to $F = F(L,K)$
  - The emission is given by $e = e(F, a)$, where a is abatement expenditure by producers
  - Environmental benefits to consumers is given by $\Phi = \Phi (e - e_0)$, where e_0 is equal to the rate of natural dissipation

Theoretical Model of Green GNP

- The dynamic optimization problem is

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

Subject to $\square = F - C - a$

- The relevant Hamiltonian in this problem is

$$H = U + \gamma_1 K = U + \gamma_1 \ (F - C - a \ )$$

- Linearizing U (and Φ) and dividing both sides by U_C, so that $H/UC = C + \theta 1 \, K + \theta 2 \, (e - e_0)$

- In the first order condition, it can be re-written as

$$MEW = F - a + \theta 2 \, (e - e_0)$$

Theoretical Model of Green GNP

- **"Sustainable" mode**
  - $a = a^*$, $F = F^*$, $e = (F^*, a^*) = d = e_0$
  - Sustainable *Green NNP* is defined as

    $gNNP^* = F^* - a^* + \theta 2\,(e - e_0) = F^* - a^* = cNNP^*$

- **"Regular" green NNP (called MEW)**

  $MEW \equiv gNNP$

  $= gNNP^* + V1\,(a^* - a) + V2\,(e - e_0)$

  $= cNNP^* + (cNNP - cNNP^*) + \theta 2\,(e - e_0)$

SEEA and ENRAP GNNP

- **SEEA(1993) defines *GNNP* as**

$$SgNNP = cNNP^{*} + (cNNP - cNNP^{*}) + \theta_2 (e - e_0)$$

$$= cNNP - \text{Maintenance Cost}$$

- **ENRAP defines *GNNP* as**

$$EgNNP = cNNP^{*} + (cNNP - cNNP^{*}) + \theta 2 (e - e0)$$

$$= cNNP - Damage\ Cost$$

Data and Environmental Cost

- **Input data**
  - All aggregate figures are taken from the **1997 National Income**.
  - 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 and the Trial Compilation of Green NDP (DGBAS,2000)**.

Data and Environmental Cost

- **Environmental damage cost**
  - The estimation of air pollution damages is based on **Liang (1993).** The private health cost of per ton SOx and NOx emission are 3495.934 NT$/ton and 171.964 NT$/ton respectively.
  - Typically, the deterioration in health will also incur a substantial amount of external cost. Liang (1993) computes the external cost and concludes that the total social cost should be **18.2757 times** the private health cost.

Scenarios and Analysis

- **Scenarios**

Scenarios	Definition
Baseline	This Baseline scenario assumes no policy intervention to limit the rate of SOx and NOx emissions.
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.

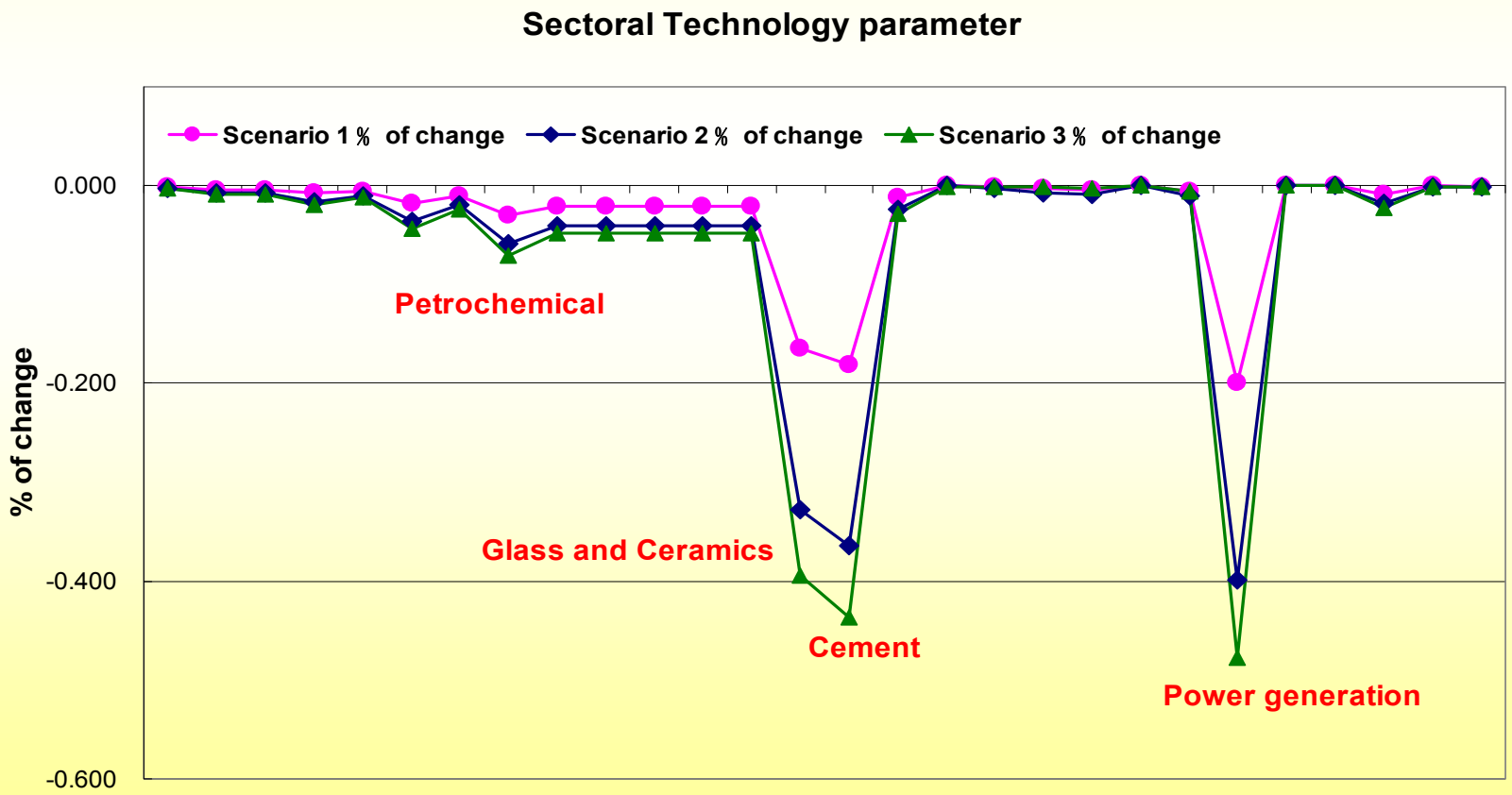
Scenarios and Analysis

Macroeconomic effects

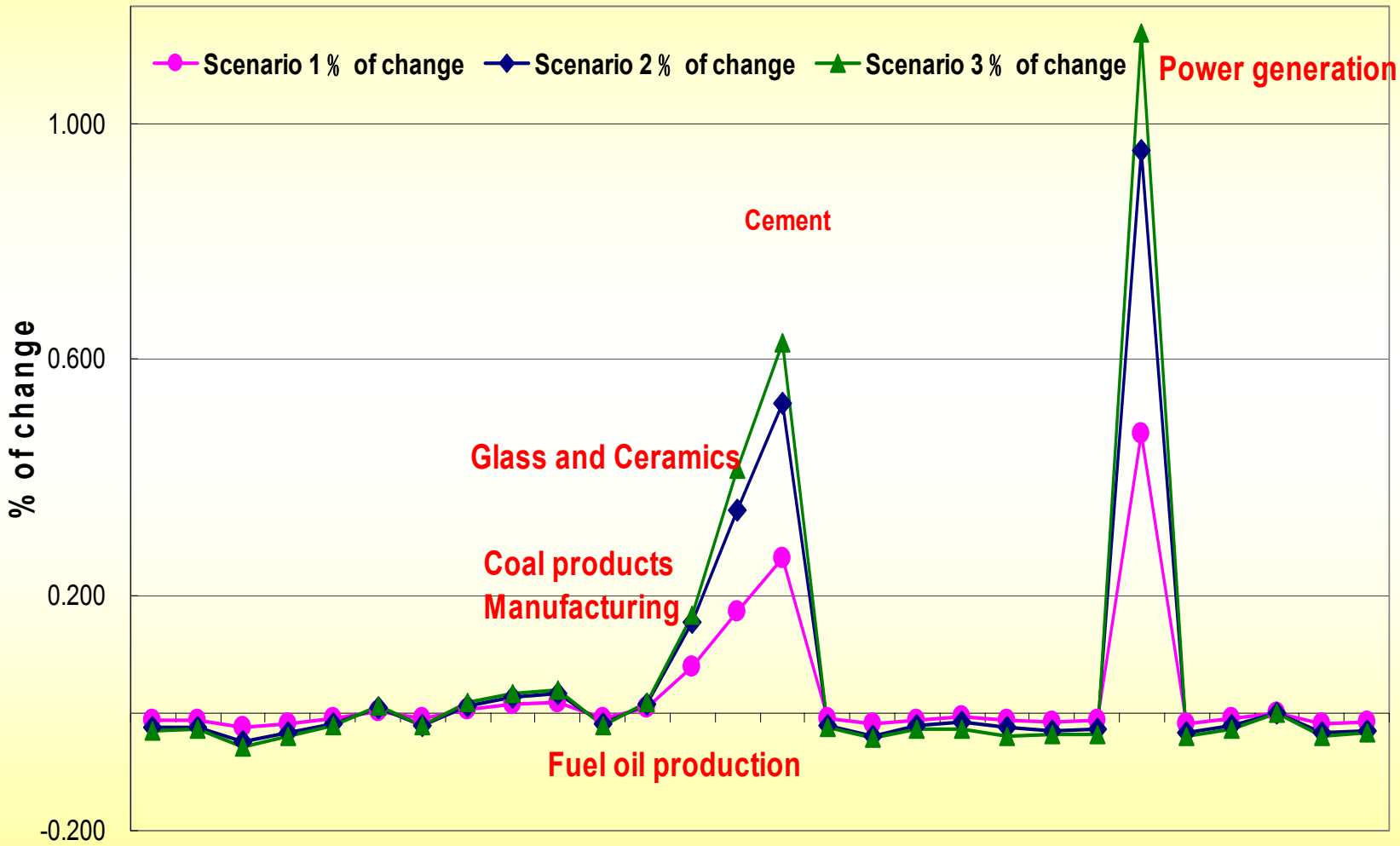
	Baseline result (MNT$)	Scenario 1 % of change	Scenario 2 % of change	Scenario 3 % of change
Gross Domestic Product	8131152.00	-0.00663	-0.01329	-0.01467
Domestic total output	15627050.27	-0.00878	-0.01760	-0.01901
Exports	4003495.22	-0.00326	-0.00653	-0.00671
Imports	3780185.31	0.00504	0.01014	0.00779
Indirect tax	573274.00	-0.00764	-0.01532	-0.01516
Tariff tax	158030.00	0.01088	0.02189	0.01949
Investment demand	1791300.49	0.01180	0.02369	0.02015
Total labor income	4260962.00	-0.01089	-0.02185	-0.02506
Wage rate	78.21	-0.01384	-0.02775	-0.03257
Total depreciation	771968.00	0.00317	0.00637	0.00718
Capital Income	2568527.00	-0.00284	-0.00568	-0.00483
Household income	6895596.00	-0.00767	-0.01537	-0.01708
Current account surplus	217225.00	-0.10809	-0.21770	-0.17516
Household savings	1062990.00	-0.00771	-0.01533	-0.01712
Government savings	173568.00	-0.02742	-0.05491	-0.05738

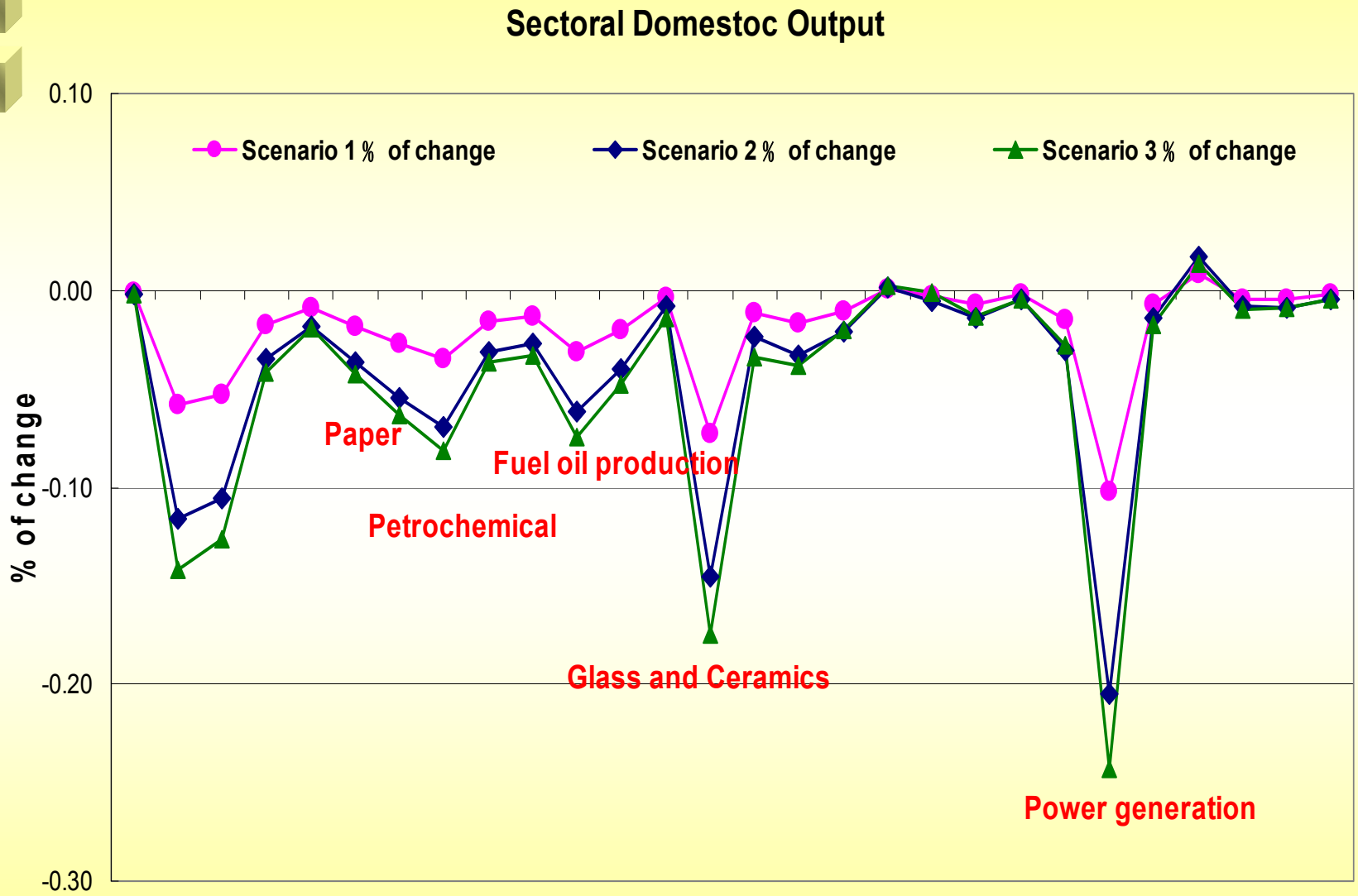
Scenarios and Analysis

Sectoral effects



Sectoral Net Price




Sectoral Domestoc Output
0.10
0.00
-0.10
-0.20
-0.30
% of change
Scenario 1 % of change
Scenario 2 % of change
Scenario 3 % of change
Paper
Fuel oil production
Petrochemical
Glass and Ceramics
Power generation

Scenarios and Analysis

Green NDP

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.
- 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.

Table Green Domestic Product

	Baseline result (MNT$)	Scenario **1** % of change	Scenario **2** % of change	Scenario **3** % of change
Gross Domestic Product	8131152.00	-0.006629	-0.013295	-0.014672
SOx maintenance cost	8079.73	-10.001278	-20.002271	-7.704510
NOx maintenance cost	6263.47	-9.998754	-19.997782	-17.990931
Total maintenance cost	14343.20	-10.000209	-20.000349	-12.196442
SOx damage cost	23916.24	-9.999983	-20.000008	-20.000008
NOx damage cost	1251.41	-10.000000	-20.000000	-20.000000
Total damage cost	25167.65	-10.000020	-20.000000	-20.000000
SEEA GREEN GDP	**8116809.00**	**0.011027**	**0.022028**	**0.006862**
Revised GREEN GDP	**8105984.00**	**0.024402**	**0.048766**	**0.047385**
Total Depreciation	771968.00	0.003174	0.006373	0.007176
SEEA GREEN NDP	**7344841.00**	**0.011845**	**0.023676**	**0.006821**
Revised GREEN NDP	**7334016.00**	**0.026629**	**0.053231**	**0.051622**

Conclusions

- 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 a result of the increase in prices of domestic products.
- 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.

Conclusions

- 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 spent 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.**