REPA Model for Impact Assessment of Environmental Policies under Regional Economic Integration in East Asia

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Abstract

This paper introduces the REPA model, which stands for Regional Environmental Policy Assessment model. The REPA model is a multiregional computable general equilibrium model developed based on the GTAP-E model. The main objective of the REPA model is to assess potential impacts of implementing a set of environmental policy instruments (policy package) on economic, environmental and poverty indicators under regional economic integration in East Asia in terms of ASEAN Plus Three. This paper first sketches the basics of the GTAP model and GTAP-E model, the prototype of the REPA model, then explains the four modules, i.e. dynamic module, environmental module, policy cost module and poverty module, which are incorporated into the REPA model.

Keywords

Computable General Equilibrium Model, Policy Impact Assessment, Economic Integration, Trade and Environment

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1. Introduction

Along with the recent boom in climate change debate, the concept of sustainability has also become very popular. Many ordinary Japanese citizens are now willing either to accept the inconvenience of taking their own shopping bags or paying for plastic bags at their local supermarket, for the sake of avoiding "unsustainability" in terms of irreversible climate change. The high attention now paid to climate change issues reveals a general concern over the sustainability of the current quality of life in the rich world, and such public opinion is definitely driving international climate negotiation to a certain extent. However, if we revisit the Brundtland Report (WCED 1987), which made sustainable development a global policy goal, we soon realise that sustainability of the current livelihood of rich countries is not the goal of Brundtlandian sustainable development. Rather, the real goal is development that can eliminate the vicious cycle of poverty and environmental degradation which is rampant in many developing countries, and that can transform lifestyles and economic systems in developed countries consistent with the carrying capacity of the Earth (Choucri 1999, Kojima 2007). The difference between 'sustainability' and 'sustainable development' has real policy implications. For example, the conflicts between developed countries and developing countries in climate negotiations may reflect such a difference.

This paper presents an attempt to develop a policy-making support tool from the perspective of sustainable development, whilst taking into account international linkages. International linkages are important because sustainable development policies in general affect international competitiveness and consequently the performance of such policies is affected by global market conditions. This paper focuses on environmental policies under regional economic integration in East Asia to conduct sustainable development policy impact assessment using the developed tool. Since the financial crisis in 1998, East Asian countries have rapidly promoted economic integration through bilateral or multilateral free trade agreements (FTAs) or economic partnership agreements (EPAs), and formulation of appropriate environmental policies that can both mitigate the negative impacts and enhance the positive impacts of regional economic integration is an imperative to promote sustainable development in this region.

The policy-making support tool will assess the economic and social costs of implementing a set of environmental policies under regional economic integration. This requires analysis of the economic effects of regional economic integration considering the direct and indirect interactions between countries as well as between industrial sectors. An appropriate treatment of such complex economic interactions requires a general equilibrium approach. The REPA model, which stands for Regional Environmental Policy Assessment model, was developed as the main analytical tool satisfying this requirement.

This paper is organised as follows. Section 2 briefly introduces the GTAP model and the GTAP-E model, the prototype of the REPA model. Section 3 explains the development of the REPA model. Lastly, Section 4 concludes this paper with identifying the remaining tasks.

2. Prototype of the REPA Model - GTAP

2.1 Outline of the GTAP

The REPA model was developed based on the GTAP Data Base and the GTAP-E model, which is an energy-substitute-extended version of the GTAP model. The Global Trade Analysis Project (GTAP) is a global project aiming at facilitating high quality quantitative analysis of the global economic issues. GTAP is coordinated by the Center for Global Trade Analysis at the Perdue University in the United States, and many researchers and government officers worldwide have contributed to the project. The main products of the GTAP are the global database (the GTAP Data Base) and the global economic model (the standard GTAP model) to conduct policy simulations with the GTAP Data Base.[1]

Tha GTAP Data Base consists of individual countries' input-output data and bilateral trade, transportation and protection data that represent international linkages. The latest version of the GTAP Data Base disaggregates the world economy into 87 regions and 57 sectors.

The standard GTAP model is a comparative static multiregional computable general equilibrium model of the world economy written in the GEMPACK that was developed at the Centre of Policy Studies, Monash University.

2.2 Structure of the standard GTAP model

The standard GTAP model describes accounting relations and behavioural equations of households and firms in each region, as well as hypothetical global sectors introduced to complete the model.

The model assumes a regional household for each region, the behaviour of which is described by an aggregate utility function. The regional households earn factor income by providing factors (labour, capital, land and natural resources) to the firms and receive net taxes, and allocate the whole income to composite private consumption, composite government purchases or savings. Inclusion of savings in this static utility function is one unique feature of the model. This top level allocation of regional income is specified as a Stone-Geary utility function with zero subsistence budget shares, which is mathematically identical to a Cobb-Douglas utility function.

For the second level allocation, government demands across composite goods are specified as a Cobb-Douglas function, while private household demands are specified as a constant difference of elasticities (CDE) function. The lack of separate objective functions for private households and government makes it difficult to impose government budget constraints to policy simulations, which is a potential drawback of this model.[2]

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[1] For the details of the standard GTAP model, see Hertel (1996).

[2] Further, Kojima (2007) argued that "policy-relevant quantitative policy analysis requires a decentralised setting in which private and public decision making are distinguished" (p.17). Also see Arrow and Kurz (1970) for decentralised setting in studying public policy.

Company behaviour is governed by the zero profit condition that results from profit maximisation under the competitive market assumption. Production technologies are assumed to demonstrate constant returns to scale and separability, which can be described as a production tree with several levels of nesting. The top level nest is expressed as a Leontief function between the value added and each intermediate input. The value added is a composite of primary factors, i.e. unskilled and skilled labour and capital for non-agricultural sectors, while land is added for agricultural sectors. The substitution possibility among primary factors is described as the constant elasticity of substitution (CES) function. Similarly, the CES function is employed for substitution between domestic products and imported goods of each intermediate following Armington's approach (Armington 1969).

The model assumes two global sectors, i.e. the global transportation sector and the global banking sector. The global transportation sector provides the international transport service that accounts for the difference between the FOB (free-on-board) value and the CIF (cost, insurance and freight) value of traded commodities. Due to lack of information about the price of international transport services of particular commodities and routes provided by a particular region, the price of the global transport service is a blend of the prices all transport services provided by all the regions. The global banking sector intermediates between global savings and investment. This sector receives net investment from all the regions and offers composite investment at a common price to regional households corresponding to their savings demand. In other word, this global banking sector represents neoclassical macroeconomic closure in which global investment is allowed to adjust to maintain macroeconomic accounting identities at the global level.

One thing may be worth noting here. The standard GTAP model updates the value of capital stock in each region as a result of net investment in each region from the beginning-of-period capital stock to the end-of-period capital stock, but it is not theoretically correct to use this updated value of capital stock for dynamic setting. Static models represent the world that has reached steady-state equilibrium, not the world without time dimension, and comparative static experiments simulate transitions from one steady-state equilibrium to another steady-state equilibrium as a result of exogenous shocks after a transition period "long enough" to absorb the shocks. The rigorous application of steady-state equilibrium assumption ensures the equality between the beginning-of-period and the end-of-period values of capital stock, but the determination of savings in the standard GTAP model is not restricted by this steady-state condition. Therefore the updated value of capital stock due to macroeconomic updating shocks (such as growth in factor inputs or in population) is represented by the *ex post* beginning-of-period capital stock, not by the end-of-period capital stock.

2.3 GTAP-E model and the corresponding database

The GTAP-E model incorporates energy substitution, in terms of both inter-fuel and fuel-factor substitution, into the standard GTAP model.[3] This extension enables an

[3] See Burniaux and Truong (2002) for the details of the GTAP-E model.

estimate of sectoral energy consumptions by fuel type, which serves as the basis of estimation of carbon emissions from fuel combustion.

The GTAP-E model employed a top-down (economic) approach to model energy substitution. This approach can incorporate the behavioural response of producers to changes in market conditions, at a cost of capability to incorporate newly developed or future energy technologies into the analysis. The GTAP-E assumes that capital and energy composite are substitutable to a certain extent and form capital-energy composite, which is one of primary factor input in the production functions. Different types of energy are nested at several levels based on their substitutability, for example gas, oil and petroleum products form a non-coal composite, and this composite plus coal form non-electricity composite.

In addition to energy substitution modules, the GTAP-E also introduced modules for estimating carbon emission from fuel combustion and simulating carbon tax and carbon emission trading.

The GTAP-E data base requires energy volume data (energy volume in domestic products, imports, and exports), carbon emission data and substitution parameters in addition to the GTAP Data Base.

3. Model Development

3.1 Outline of the REPA model

The REPA model employed a 12-region (i.e. 10 regions/countries for the ASEAN+3, the rest of OECD and the rest of the world), 33-sector aggregation of the GTAP database. The employed regional and sectoral aggregation schemes are shown in Tables 3.1 and 3.2, respectively.

Table 3.1 Regional aggregation

Code	Description
CHN	P.R. China (main land only)
JPN	Japan
KOR	Republic of Korea
IDN	Indonesia
MYS	Malaysia
PHL	Philippines
SGP	Singapore
THA	Thailand
VNM	Viet Nam
XSE	Other ASEAN members
XOE	Other OECD members
ROW	Rest of the world

Table 3.2 Sectoral aggregation

No.	Sector classification	No.	Sector classification
1	Paddy rice	17	Wood products
2	Other grains	18	Paper products, publishing
3	Vegetables, fruit, nuts	19	Petroleum, coal products
4	Oil seeds	20	Chemical, rubber, plastic products
5	Sugar cane, sugar beet	21	Ferrous metals
6	Livestock and dairy	22	Metals nec
7	Other agriculture	23	Motor vehicles and parts
8	Forestry	24	Electronic equipment
9	Fishing	25	Manufactures nec
10	Coal	26	Electricity
11	Oil	27	Gas manufacture, distribution
12	Gas	28	Construction
13	Minerals nec	29	Transport nec
14	Processed rice	30	Air transport
15	Food products	31	Dwellings
16	Textiles, apparel and leather	32	Other services

Note: “nec” stands for “not elsewhere classified.”

REPA model builds the following four modules into the latest published version of the GTAP-E model programme code (GTAP Version 6.2 rc 7):

– Dynamic module
– Environmental module
– Policy cost module
– Poverty module

For the parameter values, the REPA model basically employs the default setting of the standard GTAP model. However, parameters representing factor substitution elasticities are replaced with the parameter values used in the SALTER model (Jomini et al. 1994), based on which the GTAP model was developed. The standard GTAP setting assumed very low labour-capital substitutability in agricultural sectors and the highest substitutability in service sectors for the whole world, while it is argued that the historical pattern of structural change from primary sectors to service sectors is explained by lower labour-capital substitutability in service sectors. In this regard, the SALTER parameter setting, in which sectoral differentiation of factor substitution parameters is much less drastic than the GTAP setting, seems more relevant at least for this research that focuses on developing the East Asia region for the mid-term until 2020.

3.2 Dynamic module

The REPA model incorporates dynamics towards 2020 by solving a series of static equilibria connected by exogenous evolution of macroeconomic drivers. The employed time steps are 2001-2010, 2010-2015, and 2015-2020. For each time step, the following macroeconomic drivers were exogenously shocked to update the data sets:

- Population
- Capital stock
- Skilled and unskilled labour
- Economy-wide total factor productivity (TFP)

Growth rates of economy-wide TFP were obtained by calibration against the projected GDP growth, while those of other drivers and GDP were estimated based on the unpublished macroeconomic projections of the Center for Global Trade Analysis at Purdue University. The employed annual growth rates in all macroeconomic drivers and GDP are shown in Tables 3.3-3.8.

Table 3.3 Projection of annual growth rates in population

(Unit: %)

	2001-2010	2010-2015	2015-2020
China	0.65	0.60	0.59
Japan	-0.04	-0.30	-0.33
Republic of Korea	0.49	0.26	0.23
Indonesia	1.28	1.05	1.01
Malaysia	1.73	1.31	1.24
Philippines	1.78	1.40	1.33
Singapore	1.40	0.71	0.66
Thailand	0.62	0.51	0.48
Viet Nam	1.08	1.09	1.10
Other ASEAN	1.09	0.96	0.94
Other OECD	0.58	0.43	0.43
Rest of the world	1.45	1.28	1.25

Source: GTAP Center, unpublished data

Table 3.4 Projection of annual growth rates in capital accumulation

(Unit: %)

	2001-2010	2010-2015	2015-2020
China	10.43	8.24	7.48
Japan	2.84	2.45	2.21
Republic of Korea	5.07	4.92	4.83
Indonesia	4.35	4.72	4.84
Malaysia	5.87	5.82	5.71
Philippines	3.22	3.49	3.43
Singapore	5.54	5.27	5.13
Thailand	3.30	3.97	4.15
Viet Nam	6.60	5.92	5.81
Other ASEAN	3.95	3.60	3.44
Other OECD	3.53	3.27	3.15
Rest of the world	3.82	3.92	3.89

Source: GTAP Center, unpublished data

Table 3.5 Projection of annual growth rates in skilled labour

(Unit: %)

	2001-2010	2010-2015	2015-2020
China	3.59	4.56	7.48
Japan	-0.55	-0.96	2.21
Republic of Korea	4.36	6.58	4.83
Indonesia	8.44	6.92	4.84
Malaysia	7.11	3.65	5.71
Philippines	4.98	4.80	3.43
Singapore	1.66	1.24	5.13
Thailand	4.02	3.68	4.15
Viet Nam	2.08	2.05	5.81
Other ASEAN	4.12	3.90	3.44
Other OECD	0.93	0.61	3.15
Rest of the world	3.79	3.45	3.89

Source: GTAP Center, unpublished data

Table 3.6 Projection of annual growth rates in unskilled labour

(Unit: %)

	2001-2010	2010-2015	2015-2020
China	0.89	0.73	0.75
Japan	0.20	0.33	-0.09
Republic of Korea	-0.34	2.06	2.58
Indonesia	2.98	2.47	2.61
Malaysia	0.42	-2.21	-2.16
Philippines	1.45	1.78	1.99
Singapore	1.03	0.54	0.59
Thailand	-0.18	0.03	0.29
Viet Nam	1.45	1.35	1.43
Other ASEAN	1.36	1.26	1.35
Other OECD	0.99	1.14	1.28
Rest of the world	1.76	1.62	1.70

Source: GTAP Center, unpublished data

Table 3.7 Projection of annual growth rates in GDP

(Unit: %)

	2001-2010	2010-2015	2015-2020
China	7.57	6.53	6.52
Japan	1.95	1.60	1.56
Republic of Korea	4.89	4.67	4.64
Indonesia	4.93	5.09	5.05
Malaysia	5.75	5.56	5.49
Philippines	4.43	3.32	3.26
Singapore	4.61	4.94	4.88
Thailand	5.45	4.53	4.50
Viet Nam	5.19	5.64	5.65
Other ASEAN	3.04	3.07	3.12
Other OECD	2.77	2.88	2.88
Rest of the world	4.04	3.81	3.84

Source: GTAP Center, unpublished data

Table 3.8 Projection of annual growth rates in TFP

(Unit: %)

	2001-2010	2010-2015	2015-2020
China	3.28	3.31	3.85
Japan	1.72	1.65	1.82
Republic of Korea	2.59	1.30	1.34
Indonesia	1.33	1.61	1.70
Malaysia	2.44	3.87	4.12
Philippines	1.98	0.75	0.82
Singapore	1.80	2.57	2.72
Thailand	3.32	2.00	1.98
Viet Nam	1.84	2.95	3.21
Other ASEAN	0.32	0.66	0.93
Other OECD	1.50	1.80	1.89
Rest of the world	1.65	1.54	1.73

Source: Author's GTAP simulations

It might be worth noting that the employed methodology does not use equations of motion of physical capital to update the stock of physical capital. The employed methodology assumes that the evolution of the economy during each time step is represented as the shift of steady-state equilibrium caused by exogenous shocks. In case of the physical capital stock, this is represented as the shift from *ex ante* beginning-of-period capital stock (KB_0) to *ex post* beginning-of-period capital stock (KB_1). This method is consistent with the steady-state equilibrium assumption underpinning static general equilibrium theory.[4]

[4] In practice, the standard GTAP database does not satisfy this assumption (Walmsley 1998).

3.3 Environmental module

(1) Outline

The environmental module of the REPA model assesses environmental impacts, in terms of changes in emissions of pollutants from economic activities, associated with regional economic integration scenarios as well as environmental policies. The coverage of pollutants, or environmental indicators, employed in economy-wide assessment is significantly limited by data availability, but the following indicators encompassing GHG, air pollutants, water pollutants and solid wastes, are incorporated into the REPA model.

- GHG: carbon dioxide (CO_2)
- Air pollutants: sulphur oxide (SOx), nitrogen oxide (NOx), suspended particulate matter (SPM)
- Water pollutants: biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solid (SS), total nitrogen (TN)
- Solid waste: industrial wastes

CO_2 emissions are simulated by the standard GTAP-E module taking into account impacts of energy substitution.

The remaining environmental indicators were simulated as follows.

It is assumed that pollutant emissions from each production sector is given as:

$$EM_t(j,r) = EM_0(j,r) \times [1 + qo_t(j,r)] \times [1 - AEC_t(j,r)] \times [1 - AR_t(j,r)]$$

where $EM_t(j,r)$: pollutant emissions from sector j in region r in year t, $EM_0(j,r)$: pollutant emissions from sector j in region r in the base year, $qo_t(j,r)$: percentage change of output quantity of sector j in region r between the base year and year t, $AEC_t(j,r)$: autonomous emission coefficient reduction of sector j in region r between the base year and year t, and $AR_t(j,r)$: abatement rate of sector j in region r in year t.

It means that sectoral emissions are assumed to be proportional to the quantity, not the sales value, of sectoral output. Further, the proportion, or the emission coefficient in terms of tons of emissions per unit quantity of output, could evolve over time autonomously, regardless of price changes or environmental policies affecting the sector. The last term reflects the reduction due to abatement activities taken by the sector.

The additional GEMPACK codes for estimating environmental pollutant emissions are as follows:

```
!------------------------------------------------------------------------!
!     Additional sets related environmental policy                       !
!------------------------------------------------------------------------!
SET ENVMED # environmental media subject to environmental policies #
   (wat, air, carbon);
SET POLLUTE # type of pollutants #
(SOx, NOx, SPM, BOD, COD, SS, IWASTE);
```

```
! -------------------------------
!  E. Environmental Impacts
! -------------------------------
Variable (Default=Linear) ;
Equation (Default=Linear) ;
Formula (Default=Always) ;

Coefficient(all, i, TRAD_COMM)(all, r, REG)(all, j, POLLUTE)
   EMISSION(i,r,j) # pollutant emission in tons of pollutant #;
Read EMISSION from file GTAPDATA header "EMIT";

VARIABLE (all, i, TRAD_COMM)(all, r, REG)(all, j, POLLUTE)         AECR(i,r,j)
   #  Autonomous emission coefficient reduction % # ;

VARIABLE (all, i, TRAD_COMM)(all, r, REG)(all, j, POLLUTE)    pol_effect(i,r,j)
   #  Emission coefficient reduction due to env. policies % # ;

VARIABLE (all, i, TRAD_COMM)(all, r, REG)(all, j, POLLUTE)    del_emit(i,r,j)
   #  Change in emission % # ;

Equation DEMISSION
 (all, i, TRAD_COMM)(all, r, REG)(all, j, POLLUTE)
  del_emit(i,r,j) = qo(i,r) - AECR(i,r,j)- pol_effect(i,r,j);

Update (all, i, TRAD_COMM)(all, r, REG)(all, j, POLLUTE)
  EMISSION(i,r,j) = del_emit(i,r,j) ;
```

(2) Base year sectoral emissions

The base year sectoral emissions $EM_0(j,r)$ were estimated based on various data collected by the collaborative research institutes of the case study countries, with technical assistance provided by McGill University. The estimated base year sectoral emissions in each case study country are presented in Appendix.

(3) Autonomous evolution of emission coefficients

There is very limited information on the autonomous evolution of emission coefficients AEC_t (j,r). There is no projection directly corresponding to the sectoral coverage of this research. This research estimated AEC_t (j,r) only for CO_2 and air pollutants based on the assumption that autonomous energy efficiency improvement (AEEI) and autonomous changes in clean energy share to the total sectoral energy consumption consists of AEC_t (j,r).

For the former, this research employs the annual growth rate of AEEI of 0.4 percent, which is the lowest, or the most conservative, value of the plausible range of AEEI according to IPCC (2001).

For the latter, we estimated elasticities of clean energy share to the total sectoral energy consumption on emission coefficients, based on the Embodied Energy and Emission Intensity Data for Japan using Input-Output Tables (3EID) published by the National Institute of Environmental Studies, Japan. The estimated elasticities are shown in Table 3.9.

Table 3.9 Elasticities of clean energy share on emission factors

	Elasticities based on data in 1990	Elasticities based on data in 1995	Elasticities based on data in 2000
CO_2	-0.60034	-0.52840	-0.46152
SOx	-0.66175	-0.56073	
NOx	-0.85105	-0.78075	
SPM	-0.78127	-0.70921	

The results clearly demonstrate diminishing tendency over time for all environmental indicators, which is consistent with the theory that marginal abatement cost increases along with advance of abatement technologies. Hence it is assumed that the elasticities diminish at the annual rates obtained by Table 3.9. Sectoral clean energy projections were estimated for China, Japan and Republic of Korea based on extrapolation of their past trends derived from national energy balance data, as shown in Tables 3.10-3.12.

Table 3.10 Annual changes in clean energy share (China)

(Unit: %)

	2001-2010	2010-15	2015-20
Agriculture, fishery and forestry	-1.49	-1.57	-1.61
Mining	-3.60	-4.75	-4.09
Food industry	10.58	4.68	3.01
Textile and apparel	0.97	1.09	0.86
Wood products	3.95	3.11	2.17
Paper products and pulp	7.21	4.83	3.01
Chemical products	0.94	1.19	0.93
Iron and steel	6.94	4.43	2.85
Non-ferrous metals	4.01	2.81	2.02
Motor vehicles	4.19	3.05	2.15
Other manufacturing	3.95	3.11	2.17
Transport	8.49	4.69	2.98
Construction	-7.24	-7.63	-6.52
Dwellings	2.94	2.45	1.79
Other services	2.39	2.25	1.65

Table 3.11 Annual changes in clean energy share (Japan)

(Unit: %)

	2001-2010	2010-15	2015-20
Agriculture, fishery and forestry	1.24	0.90	0.68
Mining	-1.01	-0.94	-0.95
Food industry	1.38	0.84	0.66
Textile and apparel	1.18	0.52	0.45
Wood products	0.27	0.21	0.19
Paper products and pulp	0.72	0.38	0.34
Chemical products	0.00	0.08	0.06
Iron and steel	0.41	0.35	0.28
Non-ferrous metals	0.42	0.51	0.39
Motor vehicles	0.12	0.32	0.24
Other manufacturing	0.27	0.21	0.19
Transport	0.59	0.54	0.42
Construction	6.11	1.65	1.21
Dwellings	-0.23	-0.09	-0.09
Other services	0.59	0.54	0.42

Table 3.12 Annual changes in clean energy share (Republic of Korea)

(Unit: %)

	2001-2010	2010-15	2015-20
Agriculture, fishery and forestry	4.35	2.09	1.79
Mining	1.57	0.24	0.53
Food industry	2.35	2.06	1.37
Textile and apparel	2.05	1.52	1.17
Wood products	2.91	3.01	1.69
Paper products and pulp	2.20	1.52	1.21
Chemical products	0.58	1.04	0.58
Iron and steel	-1.84	-1.09	1.34
Non-ferrous metals	2.85	1.51	1.45
Motor vehicles	0.12	0.32	0.24
Other manufacturing	2.91	3.01	1.69
Transport	7.86	3.02	2.40
Construction	0.00	0.00	0.00
Dwellings	2.11	2.10	1.24
Other services	-1.21	0.22	-0.95

Then, AEC_t (j,r) due to autonomous changes in clean energy share to the total sectoral energy consumption were obtained based on the estimated elasticities and clean energy share projections with an adjustment for different abatement level among countries based on an assumption that China is 15 years behind Japan and Republic of Korea is 5 years behind Japan in advancement in abatement technologies.

The additional GEMPACK related to energy efficiency improvement are as follows:

```
!--------------------------------------------------------------------------!
!          Variable associated with AEEI and non-energy related    !
!          regionwide carbon emission reduction                           !
!--------------------------------------------------------------------------!
VARIABLE (all,j,PROD_COMM)(all,r,REG)              TEEI(j,r)
   # Total energy efficiency improvement in sector j in region r #;

VARIABLE (all,j,PROD_COMM)(all,r,REG)              AEEIALL(j,r)
   # Sector and region specific AEEI in sector j in region r #;

VARIABLE (all,r,REG)              AEEIR(r)
   # Region specific AEEI #;

VARIABLE (all,j,PROD_COMM)(all,r,REG)              PIEEIALL(j,r)
   # Sector and region specific PIEEI in sector j in region r #;

VARIABLE (all,r,REG)              PIEEIR(r)
   # Region specific PIEEI #;

VARIABLE (all,r,REG)              NECER(r)
   # Non-energy related carbon emission reduction in region r #;

Equation TEEIWORLD
   (all,j,PROD_COMM)(all,r,REG)
    TEEI(j,r) = AEEIALL(j,r)+ AEEIR(r)+PIEEIALL(j,r)+ PIEEIR(r);

! LEVEL 2 : Demands for composite energy good  !
EQUATION ENDEMAND
(all,j,PROD_COMM)(all,r,REG)
   qen(j,r) =  - TEEI(j,r) + qke(j,r)
   - ELKE(j,r) * [pen(j,r)  - TEEI(j,r) - pke(j,r)] ;
```

(4) Abatement rates

In the REPA model, abatement costs were estimated for an exogenously given level of abatement rates which will be explained in the next subsection. The abatement rates are based on the following assumptions:

– Stepwise implementation of energy efficiency improvement targets is assumed as shown in Table 3.13.

Table 3.13 Energy efficiency improvement targets

	2010	2015	2020
China	15.0 %	25.0 %	20.0 %
Japan	15.0 %	15.0 %	15.0 %
Republic of Korea	15.0 %	15.0 %	15.0 %
Indonesia	15.0 %	25.0 %	20.0 %
Malaysia	15.0 %	25.0 %	20.0 %
Philippines	15.0 %	25.0 %	20.0 %
Singapore	15.0 %	25.0 %	20.0 %
Thailand	15.0 %	25.0 %	20.0 %
Viet Nam	15.0 %	25.0 %	20.0 %
Other ASEAN	15.0 %	25.0 %	20.0 %

- SOx abatement rates are set at 70% except for Japan where advanced abatement technologies have already been introduced.
- Water pollutants abatement rates, except for Japan, are assumed to be the same as those achieved in Japan for the period of the early 1980s, which are shown in Table 3.14.

Table 3.14 Pollution reduction rates due to abatement activities

(Unit: %)

Sector	BOD	COD	SS
Food products	94.8	90.8	85.5
Textiles, apparel and leather	94.8	90.8	85.5
Wood products	78.8	71.3	66.8
Paper products, publishing	76.5	69.8	83.5
Petroleum, coal products	73.0	72.0	85.5
Chemical, rubber, plastic products	76.5	69.8	83.5
Ferrous metals	87.5	79.0	76.3
Other metals	77.0	72.3	83.3
Motor vehicles and parts	76.5	69.8	83.5
Electronic equipment	76.5	69.8	83.5
Other manufactures	76.5	69.8	83.5

Source: Ministry of the Environment, Japan (1982, 1983, 1984, 1985, 1986), Comprehensive Survey on Water Pollutant Discharge

3.4 Policy cost module

The current version of REPA model covers the following environmental policy instruments:

- Carbon tax
- Carbon emission trading
- Binding environmental standards for pollutant emissions and energy efficiency improvement

– Subsidies for abatement activities by firms
– International financial cooperation financed by revenues from carbon tax and emission trading

The binding environmental standards are modelled through abatement activities of firms for achieving the standards.

The economic cost of carbon tax and emission trading, together with their environmental impacts, were modelled exactly following the methodology of the GTAP-E model. For other environmental policies, their economic costs were reflected as decreased productivity of value-added (capital and labour) caused by diverting a fraction of value added from the production process to abatement activities responding to the binding environmental standards. The same approach is applied to modelling the costs of energy efficiency improvement.

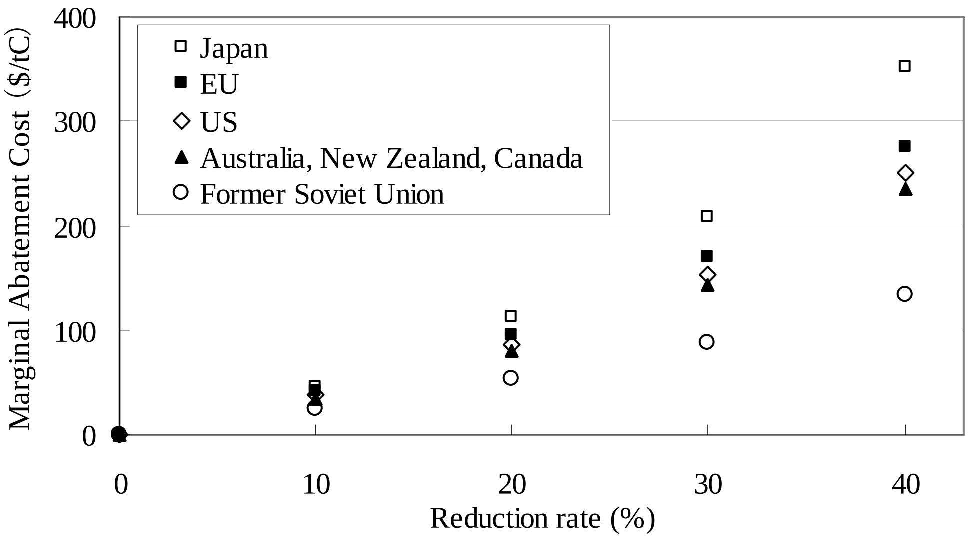
The additional GEMPACK for policy cost module are as follows:

```
!-----------------------------------------------------------------------------------!
!    Variables associated with abatement cost and government subsidies   !
!-----------------------------------------------------------------------------------!

! Government subsidies for firms' abatement expenditure !
Variable(Change)(all,r,REG)              ENVSUBSTOT(r)
   # Region specific government environmental subsidies in million USD #;

Variable (all,j,PROD_COMM)(all,r,REG)                 SUBSIDY(j,r)
   # Region-sector specific government subsidy rate for pollution abatement #;
! Government expenditure for international env. technical cooperation  !

Variable(Change)(all,r,REG)(all,s,REG)               INTCOOP(r,s)
  # Real international cooperation expenditure from r to s in million USD #;

Variable(Change)(all,r,REG)(all,s,REG)               NINTCOOP(r,s)
  # Nominal international cooperation expenditure from r to s in million USD #;

Variable (all,j,PROD_COMM)(all,r,REG)          ac_total (j,r)
  # Sector j's total input allocated to all abatement activities #;

!> ac_total is calculated outside GEMPACK as
  ac_total (j,r) = sum(i,ENVMED,(1 - sratio(r,i)/100)* abcost(j,r,i)) >!


Equation ENDWDEMAND
# demands for endowment commodities (HT 34) #
(all,i,ENDWNA_COMM)(all,j,PROD_COMM)(all,r,REG)
   qfe(i,j,r)= ac_total(j,r)- afe(i,j,r) + qvaen(j,r) - ESUBVA(j)
```

* [ac_total(j,r)+pfe(i,j,r) - afe(i,j,r) - pvaen(j,r)];

(1) Costs of energy efficiency improvement

The fraction of diverted value added to satisfy energy efficiency improvement standards was estimated based on marginal abatement cost data by Klepper and Peterson (2004), shown in Figure 3.1.



Source: Klepper and Peterson（2004）

Figure 3.1 Marginal abatement cost curves for carbon emission reduction

Based on this data, the relationships between marginal abatement costs and the rates of carbon reduction were approximated by quadratic functions. Separately, the relationships between nationwide energy efficiency improvement and carbon reduction were approximated by quadratic functions based on the simulation results of the REPA model. Based on these relationships, the relationships between the rates of energy efficiency improvement and the total costs were approximated by quadratic functions.

Then, the following assumptions were employed for case study countries other than Japan:

– Republic of Korea: The same marginal abatement cost as Australia, New Zealand and Canada.

– Indonesia and Thailand: 20 % lower marginal abatement cost than those of the former Soviet Union.

– China, Viet Nam and other ASEAN countries: 50 % lower marginal abatement cost than those of the former Soviet Union.

The obtained shares of energy efficiency improvement costs to total value-added costs in the case of 15% improvement are shown in Table 3.15.

Table 3.15 Shares of costs of energy efficiency improvement by 15% to total value-added costs

(Unit:%)

Sector	CHN	JPN	KOR	IDN	MYS	PHL	SGP	THA	VNM	XSE
Petroleum, coal products	0.19	0.30	0.46	0.51	0.29	0.23	0.28	0.22	0.26	0.09
Chemical, rubber, plastic products	0.19	0.30	0.46	0.51	0.29	0.23	0.28	0.22	0.26	0.09
Ferrous metals	0.19	0.30	0.46	0.51	0.29	0.23	0.28	0.22	0.26	0.09
Other manufactures	0.19	0.30	0.46	0.51	0.29	0.23	0.28	0.22	0.26	0.09
Electricity	0.19	0.30	0.46	0.51	0.29	0.23	0.28	0.22	0.26	0.09

(2) SOx abatement costs

The shares of abatement costs for 70% SOx reduction to the total sectoral value-added costs were estimated based on Pasurka (2001) that estimated sectoral total abatement costs for SOx emission reduction by 10%, 30%, 70% and 90% for 20 industrial sectors in the United States. Based on his estimates, the shares of abatement costs for 70% SOx reduction to the total sectoral value-added costs were estimated as shown in Table 3.16.

Table 3.16 Share of costs of SOx reduction by 70% to total value-added costs

Sector	(%)
Processed rice	37.4
Food products	37.4
Textiles, apparel and leather	3.8
Wood products	0.0
Paper products, publishing	32.4
Petroleum, coal products	65.3
Chemical, rubber, plastic products	27.5
Ferrous metals	31.3
Other metals	31.3
Motor vehicles and parts	0.0
Electronic equipment	1.7
Other manufactures	11.8

(3) Water pollutants abatement costs

For water pollutants, pollutant reduction rates and abatement costs of 6 sectors (food, textile, paper and pulp, chemical, steel and other manufacturing) were obtained from Comprehensive Survey on Water Pollutant Discharge (Ministry of the Environment, Japan 1982, 1983, 1984, 1985, 1986), and the fraction of abatement costs to the total sectoral value-added costs were estimate as shown in Table 3.17.

Table 3.17 Proportion of water pollution abatement costs to total value-added costs

(Unit: %)

Sector	BOD	COD	SS	Total
Food products	0.83	0.78	0.83	2.45
Textiles, apparel and leather	0.30	0.14	0.39	0.83
Wood products	0.04	0.02	0.03	0.08
Paper products, publishing	0.06	0.05	0.07	0.18
Petroleum, coal products	1.47	0.80	1.25	3.52
Chemical, rubber, plastic products	0.66	0.34	0.43	1.43
Ferrous metals	3.87	1.37	2.03	7.27
Other metals	1.12	0.61	0.95	2.67
Motor vehicles and parts	0.09	0.05	0.08	0.22
Electronic equipment	0.29	0.16	0.25	0.69
Other manufactures	0.68	0.37	0.57	1.62

Source: Ministry of the Environment, Japan (1982, 1983, 1984, 1985, 1986), Comprehensive Survey on Water Pollutant Discharge

3.5 Poverty module

There is a body of literature linking economic growth and poverty. Most of the studies in this literature focused on effects of GDP growth on poverty headcounts (for example, population subsiding on USD 1 a day or less). World Bank (2002) developed a more sophisticated methodology in which the averaged unskilled labour wage deflated by a food and clothes consumer price index (CPI), instead of GDP, affects poverty headcounts (Anderson et al. 2006). The poverty module of the REPA model employs this World Bank approach with population subsisting on USD 2 a day or less as the poverty headcount.

Changes in the food-clothing CPI are estimated based on the changes in consumer prices of food and clothing commodities simulated by the REPA model. Weighting factors applied to the basket of foods and clothes were assumed to be 0.8 for the aggregate foods and 0.2 for clothes, as the proportion of weighting factors between foods and clothes are around 8:2 in both the United States and China.

The elasticities of the adjusted unskilled labour wage on $2-a-day poverty headcount, which indicates percentage reduction of the poverty headcount due to 1% increase of adjusted unskilled labour wage, is assumed to be 2.0 following the value employed in World Bank (2002).

The $2-a-day poverty headcount in the base year was estimated based on the World Development Indicators and the data in Cline (2004), as shown in Table 3.18.

Table 3.18 Population subsiding on USD 2 per day or below in 2001

(Unit: Million people)

China	520.7
Japan	0.0
Republic of Korea	0.0
Indonesia	112.6
Malaysia	6.8
Philippines	36.0
Singapore	0.0
Thailand	17.8
Viet Nam	41.0
Other ASEAN	41.6
Other OECD	0.0
Rest of the world	2,088.0
China	2,864.4

The additional GEMPACK for the poverty module are as follows:

```
! --------------------------------
!    Poverty Impacts
! --------------------------------

VARIABLE (all,r,REG)          FCCPI(r)
   #  Change in food-clothing consumer price index  # ;
VARIABLE (all,r,REG)          ppov(r)
   #  Change in population below 2 USD/day  # ;

Equation CPI (all,r,REG)
   FCCPI(r) = sum(i,AGR_COMM,0.08*pp(i,r))
            +0.08*pp("pcr",r)+0.08*pp("fdp",r) + 0.2*pp("twl",r);

Coefficient(Parameter)(all, r, REG)
   EPOV(r) # elst.of poverty wrt real unskilled labour wage #;
Read EPOV from file GTAPPARM header "EPOV";

Equation POVERTY (all,r,REG)
   ppov(r) = EPOV(r)*[ FCCPI(r)-pm("UnSkLab",r)-qo("UnSkLab",r) ];

Coefficient(all, r, REG)
   POPPOV(r) # population below 2 USD/day (million) #;
Read POPPOV from file GTAPDATA header "PPOV";
Update (all, r, REG)
```

POPPOV(r)= ppov(r);

3.6 Closure rules

The employed closure rules follows the default setting of the standard GTAP model with exogenous aggregate capital stock, except for the treatment of trade balance. Trade balance is exogenised for all regions except for one region (the Rest of the World).

It has been argued that trade liberalisation affects economic performance not only through improvement of allocative efficiency but also through capital accumulation effects (Francois et al. 1996, Walmsley 1998). The GTAP model can reflect such capital accumulation effects by endogenising aggregate capital stock by assuming that the changes in investment level are equal to the changes in capital stock. Endogenous aggregate capital stock specification was not employed in the REPA model, however, due to the very sensitive behaviour of the model with such a specification.

4. Conclusions

This paper has presented the Regional Environmental Policy Assessment (REPA) model, a multiregional CGE model developed based on the GTAP-E model, as a policy-making support tool to promote sustainable development. The REPA model is best regarded as a prototype of a sustainable development policy-making support tool covering economic, environmental and social aspects, and further elaboration must follow. In particular further data collection is important to improve reliability of assessment results.

In addition to data quality, there are some weaknesses of the model inherited from the GTAP model. The most serious drawback may be lack of independent budget constraint of the government. Considering the importance of public infrastructure investment or the potential of the government revenues from market based policy instruments in promoting sustainable development, better treatment of the role of the government reflecting its budget constraint must be sought.

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Appendix: Sectoral emissions of pollutants in 6 case study countries

Table A1 Sectoral emissions in China

	SOx (ton)	NOx (ton)	SPM (ton)	BOD (ton)	COD (ton)	SS (ton)	TN (ton)	Ind. waste (1000 t)
Paddy rice								
Other grains								
Vegetables, fruit, nuts								
Oil seeds								
Sugar cane, sugar beet								
Livestock and dairy								
Other agriculture								
Forestry								
Fishing								
Coal								
Oil								
Gas								
Minerals nec	330,648		215,467		116,628	515,451		392,033
Processed rice	63,203		40,487		252,958	50,935		3,194
Other food products	342,445		219,368		1,370,581	275,978		17,304
Textiles, apparel and leathers	376,132		178,778		730,184	190,207		6,767
Wood products	252,103		332,176		16,757	8,058		3,616
Paper products, publishing	340,225		211,812		2,879,516	958,978		7,757
Petroleum, coal products	375,009		247,596		55,401	29,641		8,953
Chemical, rubber, plastic prod	1,094,867		537,909		829,929	569,213		55,352
Ferrous metals	753,357		289,663		146,165	278,588		120,715
Metals nec	714,168		217,654		20,969	25,080		29,487
Motor vehicles and parts	310,813		409,534		20,660	9,934		4,458
Electronic equipment	67,131		36,927		25,916	13,602		2,464
Manufactures nec	4,131,187		5,443,336		274,598	132,044		59,260
Electricity	6,285,613		2,677,962		88,978	200,504		117,971
Gas manufacture, distribution	155,812		66,383		2,206	4,970		2,924
Construction								
Transport nec								
Air transport								
Dwellings								
Other services								

Table A2 Sectoral emissions in Japan

	SOx (ton)	NOx (ton)	SPM (ton)	BOD (ton)	COD (ton)	SS (ton)	TN (ton)	Ind. waste (1000 t)
Paddy rice	334	4,097	13,341	-	70,957	-	19,495	2,048
Other grains	18	199	14	-	5,607	-	9,207	137
Vegetables, fruit, nuts	7,727	11,470	952	-	21,262	-	34,913	521
Oil seeds	6	75	4	-	6	-	9	0
Sugar cane, sugar beet	8	117	7	-	1,668	-	2,739	41
Livestocks and dairy	123	843	57	7,771	89,480	8,039	47,926	3,662
Other agriculture	3,889	5,649	698	-	16,884	-	27,725	414
Forestry	1,646	5,206	409	0	747	-	219	8
Fishing	102,840	177,774	13,666	237	201	192	48	12
Coal	70	102	12	482	9,470	63,881	-	-
Oil	11	29	3	20	109	39	199	-
Gas				-	-	-	-	-
Minerals nec	1,382	5,961	360	752	1,492	3,681	343	18
Processed rice				-	-	-	-	-
Other food products	46,953	17,914	3,101	894	1,147	991	616	141
Textiles, apparel and leathers	22,661	15,246	2,224	15,517	28,440	15,955	12,633	670
Wood products	1,793	2,655	561	392	546	390	361	24
Paper products, publishing	46,186	33,972	8,956	8,344	12,284	6,062	1,374	103
Petroleum, coal products	69,856	92,512	6,782	13,811	13,279	12,183	10,565	394
Chemical, rubber, plastic prod	73,036	64,725	8,917	27,830	41,748	25,827	147,654	2,659
Ferrous metals	62,574	83,951	9,916	12,963	16,203	16,215	25,756	732
Metals nec	13,411	11,871	1,211	2,430	2,742	2,185	13,873	195
Motor vehicles and parts	3,413	7,109	840	3,147	4,593	2,556	5,038	618
Electronic equipment	3,006	4,624	346	942	1,190	666	1,523	163
Manufactures nec	45,483	178,785	11,054	4,802	4,651	2,607	7,567	598
Electricity	217,402	253,065	24,329	1,895,661	3,285,445	2,466,232	5,085,608	539,286
Gas manufacture, distribution	1,398	1,522	164	993	2,299	1,322	1,684	274
Construction	13,179	144,528	13,500	948	1,368	2,065	306	28
Transport nec	964,572	2,003,297	135,026	1,943	2,595	1,641	3,021	386
Air transport	331	103,664	6,312	0	1	0	0	0
Dwellings	4,305	9,454	785	4,089	6,695	4,144	7,852	1,107
Other services	130,404	152,096	41,865	17,402	24,711	17,139	29,422	4,265

Table A3 Sectoral emissions in Korea

	SOx (ton)	NOx (ton)	SPM (ton)	BOD (ton)	COD (ton)	SS (ton)	TN (ton)	Ind. waste (1000 t)
Paddy rice	2,342	1,642	979	26,437	24,130	80,941	25,844	2,357
Other grains	454	319	190	2,243	1,501	26,691	3,134	80
Vegetables, fruit, nuts	2,725	1,911	1,140	41,956	5,710	101,527	11,921	305
Oil seeds	55	38	23	-	-	-	-	-
Sugar cane, sugar beet	0	0	0	-	-	-	-	-
Livestocks and dairy	2,145	1,505	897	955,524	8,236	29,123	612	196
Other agriculture	673	472	281	3,020	2,021	35,938	4,220	108
Forestry	594	161	248	157,627	59,464	2,012,176	51,279	3,325
Fishing	15,721	7,519	588	-	-	-	-	-
Coal	43	24	9	39	0	3	0	0
Oil	-	-	-	-	-	-	-	-
Gas	-	-	-	-	-	-	-	-
Minerals nec	814	449	162	729	9	292	2	0
Processed rice	1,801	736	141	67,816	0	0	0	0
Other food products	10,751	4,540	840	384,109	3	2	0	0
Textiles, apparel and leathers	13,927	5,509	997	176,895	1	1	0	0
Wood products	2,099	770	152	623	0	0	0	0
Paper products, publishing	23,555	8,681	1,820	166,714	3	2	0	0
Petroleum, coal products	49,217	19,381	3,542	3,146	3	1	2	0
Chemical, rubber, plastic prod	52,812	23,683	5,438	178,210	41	3	1	0
Ferrous metals	194,429	145,580	74,478	107,480	0	0	0	0
Metals nec	666	399	47	11,898	0	0	0	0
Motor vehicles and parts	945	1,146	67	-	-	-	-	-
Electronic equipment	412	964	35	2,468	0	0	0	0
Manufactures nec	72,586	49,856	20,006	34,856	63	2	1	0
Electricity	221,919	351,779	172,424	177	0	0	0	0
Gas manufacture, distribution	13	25,884	385	0	0	1	0	0
Construction	3,316	2,663	250	-	-	-	-	-
Transport nec	3,242	110,366	19,400	-	-	-	-	-
Air transport	604	20,561	3,614	-	-	-	-	-
Dwellings	27	45	4	-	-	-	-	-
Other services	15,093	15,182	1,616	11,348	151	242	16	0

Table A4 Sectoral emissions in Indonesia

	SOx (ton)	NOx (ton)	SPM (ton)	BOD (ton)	COD (ton)	SS (ton)	TN (ton)	Ind. waste (1000 t)
Paddy rice	0	21	0	0	0	0	0	
Other grains	0	13	0	0	0	0	0	
Vegetables, fruit, nuts	0	263	26,184	0	0	0	0	
Oil seeds	0	730	0	0	0	0	0	
Sugar cane, sugar beet	0	126	0	0	0	0	0	
Livestock and dairy	0	6,867	28,358	68	9,151	606	0	
Other agriculture	0	1,007	0	0	0	0	0	
Forestry	0	7,698	0	0	0	0	0	
Fishing	0	9,746	0	0	0	0	0	
Coal	0	27	0	0	0	0	0	
Oil	0	1	0	0	0	0	0	
Gas	0	653	0	0	0	0	0	
Minerals nec	0	12,912	0	0	0	0	0	
Processed rice	0	8,075	0	0	0	0	0	
Other food products	7,813	1,978	44,778	10,249	49	0	7,813	
Textiles, apparel and leathers	10,599	15,407	22,056,242	54,032,694	35,190	3,283	10,599	
Wood products	5,422	9,761	36,041,824	4,654,472	70	1,092	5,422	
Paper products, publishing	2,690	11,680	3,476	0	43	0	2,690	
Petroleum, coal products	761	20,868	0	0	0	0	761	
Chemical, rubber, plastic prod	6,940	57,193	17,377,248	20,421,559	19,319	0	6,940	
Ferrous metals	0	25,601	83	4	25	0	0	
Metals nec	863	2,201	0	0	0	0	863	
Motor vehicles and parts	0	363	0	0	0	0	0	
Electronic equipment	851	214	0	0	0	0	851	
Manufactures nec	5,271	53,583	145	41	16	0	5,271	
Electricity	0	258,160	9,490	73,331	1,233,678	0	0	
Gas manufacture, distribution	0	56,969	0	0	0	0	0	
Construction	0	3,733	0	0	0	0	0	
Transport nec	7,272	45,190	0	0	0	0	7,272	
Air transport	0	5,440	0	0	0	0	0	
Dwellings	0	19	0	0	0	0	0	
Other services	0	13,766	0	0	0	0	0	

Table A5 Sectoral emissions in Thailand

	SOx (ton)	NOx (ton)	SPM (ton)	BOD (ton)	COD (ton)	SS (ton)	TN (ton)	Ind. waste (1000 t)
Paddy rice		7	155	332,418			363,125	
Other grains		3	65					
Vegetables, fruit, nuts	4,728	45	1,895	18,197			106,068	
Oil seeds	1	4	34					
Sugar cane, sugar beet		14	34					
Livestock and dairy	501	20	688	26,309	99,319	60,275	7,108	
Other agriculture	1,518	18	389	89,687			324,270	
Forestry	917	8,400	377	30,928			1,712	
Fishing	12,830	12	4,389	85,325			12,953	
Coal	0	0	106					
Oil		0	1,346					
Gas		0	150					
Minerals nec	0	48,000	796					5
Processed rice	-	1	265	878	50,595	24,196		284
Other food products	94,763	22	30,101	724,820	1,781,627	915,421		1,248
Textiles, apparel and leathers	17,027	12	6,816	850,351	3,780,589	931,969		378
Wood products	81	1	317					730
Paper products, publishing	4,729	22	6,841	52,935	438,831	147,580		167
Petroleum, coal products	7,641	11	1,238	1,077	8,236	2,245		7
Chemical, rubber, plastic prod	8,067	49	14,852	35,863	263,120	428,241		516
Ferrous metals	0	157	604	207	3,328	1,549		942
Metals nec								
Motor vehicles and parts	8,512	8	2,073	24,085	104,982	15,036		105
Electronic equipment	7,173	2	1,766	32,226	242,487	32,528		475
Manufactures nec	9,892	39	36,352	2,394	43,514	45,210		1,695
Electricity	31,437	195,000	153,000	176				19
Gas manufacture, distribution	854	3	628					4
Construction		11	9,705					
Transport nec	30,030	221	14,430					
Air transport	1,233	41	2,067					
Dwellings	25	3,460	931	122,716	278,900	122,716		
Other services	101,455	47	34,579	288,602	711,026	298,808		171

Table A6 Sectoral emissions in Viet Nam

	SOx (ton)	NOx (ton)	SPM (ton)	BOD (ton)	COD (ton)	SS (ton)	TN (ton)	Ind. waste (1000 t)
Paddy rice	192	90	46	19	33	18	1	
Other grains	81	38	19	1,480	3,111	1,474	22	
Vegetables, fruit, nuts	201	94	48	2,724	5,782	2,694	42	
Oil seeds	70	32	19	564	1,193	561	10	
Sugar cane, sugar beet	42	20	10	5	8	5	0	
Livestock and dairy	268	78	260	2,229	4,749	2,232	35	
Other agriculture	189	89	45	3,066	6,500	3,033	51	
Forestry	310	145	77	332	694	330	6	
Fishing	5,124	2,404	1,242	16,328	34,787	16,283	269	
Coal	261	123	62	886	1,876	882	15	
Oil	1,660	780	395	3,832	8,150	3,828	64	
Gas	184	87	44	65	135	67	1	
Minerals nec	460	128	468	496	1,051	499	9	
Processed rice	690	147	78	5	9	6	0	
Other food products	4,445	860	2,086	12,348	26,243	12,302	206	
Textiles, apparel and leathers	3,508	651	2,146	5,325	11,315	5,301	86	
Wood products	1,068	226	157	1,119	2,376	1,106	20	
Paper products, publishing	1,541	294	804	1,127	2,385	1,102	18	
Petroleum, coal products	427	200	102	48	90	47	1	
Chemical, rubber, plastic prod	6,507	993	7,812	4,531	9,651	4,515	74	
Ferrous metals	276	41	355	559	1,177	557	10	
Metals nec	997	179	711	244	516	246	5	
Motor vehicles and parts	209	38	141	704	1,483	702	13	
Electronic equipment	398	82	103	833	1,760	832	15	
Manufactures nec	22,820	3,734	22,906	34,327	73,062	34,208	567	
Electricity	5,494	1,729	4,785	1,676	3,581	1,671	27	
Gas manufacture, distribution	275	86	239	51	107	56	1	
Construction	4,741	1,806	2,851	7,532	16,043	7,525	121	
Transport nec	3,743	1,723	1,040	2,705	5,762	2,711	46	
Air transport	1,815	853	432	616	1,307	624	10	
Dwellings	1,241	523	543	1,484	3,162	1,477	25	
Other services	12,452	5,525	4,310	40,848	86,977	40,738	664	

Economic Analysis Team

Mission

Promotion of sustainable development requires poverty alleviation without destroying sound environmental and ecological systems that are the basis of human existence. The effectiveness and feasibility of proposed policies must also be ensured through quantitative assessment of the economic costs of implementing the policies. The Economic Analysis Team carries out policy analysis based on various economic analysis methods to reflect these aspects in the policy recommendations of IGES research projects.

For further information & Contact

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