Baseline Forecasting for Greenhouse Gas Reductions with the TAIGEM© Model

by

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Abstract

The analysis of GHG emission baseline in this paper is based on forecasting results from TAIGEM©-D. TAIGEM© (TAIwan General Equilibrium Model) is a dynamic, multisectoral, computable general equilibrium (CGE) model of the Taiwan's economy, developed specifically to analyze climate change response issues. TAIGEM©-D is derived from the ORANI model and the MONASH model. The most significant features that distinguish TAIGEM©-D and MONASH are the coverage of GHG emissions and the inclusion of interfuel substitution and technology bundles. We use historical simulations to generate up-to-date data for our baseline forecasting. A comparison with those projection results from Taiwan MARKAL model in Taiwan is provided. Although both models show a similar pattern of projection results, there are significant differences in the models' projections of CO2 emission in the electricity sector and future energy structure. Results show that the accuracy of baseline projection depends on the model used and the assumptions made. However, projection results from different models, either top-down or bottom-up models, complement each other.

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1. Introduction

The adoption of Kyoto Protocol in December 1997 by the COP3 (Third Conference of the Parties) to the UNFCCC (United Nations Framework Convention on Climate Change) sets the timetable and reduction targets of greenhouse gases emissions for the developed countries. To avoid the possible future international trade sanctions, Taiwan needs to take some obligations from the Kyoto Protocol, although there is no abatement responsibility specified by the Kyoto Protocol for the developing countries. Of most importance in fulfilling the abatement responsibility is the accurate forecasting for carbon dioxide (CO_2) baseline. Without a reasonable baseline projection, any economic evaluation of emissions reduction strategies could not be possible.

According to the conclusion of 1998 National Energy Conference, Taiwan proposes to reduce her greenhouse gas emissions to about 10% below or above her 2000 level for the commitment year, 2020. However, there were lots of debates on the baseline projection generated from the Taiwan MARKAL model. The distinction between a "top down" and "bottom up" approach to modelling the energy sector has received a great deal of attention in the discussions of projected emissions growth in Taiwan. One of the major conclusions of the Conference is to improve Taiwan's CO_2 baseline forecasting using both top-down and bottom-up approaches. The model adopted in the paper is the TAIGEM©-D (TAIwan General Equilibrium Model-Dynamic), a dynamic top-down CGE model.

The baseline (or reference case) provides projections of growth in labor and capital in each country or region, and the associated changes throughout the rest of the economy in the absence of any policy measures. The results of policy simulations are then interpreted as deviations from the baseline. For example, the influence of an emission reduction policy can be isolated from other economic trends by comparing emissions growth in the simulation against emissions in the baseline. The effect on emissions may also be reported as a percentage reduction from the baseline emission projection.

There are a number of factors which might affect baseline projection, for example, the difference of the models used, the degree of the substitution between factors of production, the adoption of the new energy-saving technologies and the difference of market mechanisms. Moreover, the baseline projections are also affected by different assumptions on future values of the exogenous variables, such as GDP growth rate, population growth rate, technical progress rate, etc.

The analysis of GHG emission baseline in this paper is based on forecasting results from

TAIGEM©-D. TAIGEM©-D is a dynamic, multisectoral, computable general equilibrium (CGE) model of the Taiwan's economy, developed specifically to analyze climate change response issues. TAIGEM©-D is derived from the ORANI model and the MONASH model. The most significant features that distinguish TAIGEM©-D and MONASH are the coverage of GHG emissions and the inclusion of interfuel substitution and technology bundles. We use historical simulations to generate up-to-date data for our baseline forecasting. Results from the TAIGEM©-D model and other models (e.g., the Taiwan MARKAL energy model) are compared and analyzed.

The next section provides an overview of TAIGEM©-D model. Main features like dynamic mechanism, technology bundles, etc., will be emphasized. Section 3 focuses on the major assumptions and baseline forecasting results of TAIGEM©-D model. Section 4 makes results comparison between TAIGEM©-D and Taiwan MARKAL energy model. The last section provides concluding comments.

2. An Overview of TAIGEM Dynamic General Equilibrium Model

TAIGEM©-D is descended from the TAIGEM© model, developed specifically to analyze climate change issues, such as baseline forecasting, climate change response policies. TAIGEM© is a multisectoral, computable general equilibrium (CGE) model of the Taiwan's economy derived from ORANI (Dixon, Parmenter, Sutton and Vincent, 1982). The input-output database was compiled from the 150-sector Use Table of the 1994 Taiwan's Input-Output tables. TAIGEM© distinguishes 160 sectors, 6 types of labor, 8 types of margins and 170 commodities. Like ORANI, TAIGEM© was designed for comparative-statics, i.e., for projecting what difference a shock would make to the economy at a point in time. The most significant features that distinguish TAIGEM©-D from TAIGEM©are the inclusion of interfuel substitution, technology bundles and dynamic mechanism capable of projecting the development of the economy through time. With TAIGEM©-D we have made annual projections of CO_2 emission, GDP growth rate, and other economic variables.

Dynamic mechanism

According to Dixon and Parmenter (1996), dynamic mechanisms of CGE model may be categorized into four broad cases, namely 1) exogenous investment, a recursive model, 2) endogenous investment but still recursive, 3) a non-recursive multi-period model, 4) a non-recursive multi-period model with optimizing investment behavior.

In Case 1 investment is exogenous. In Case 2, investment and capital accumulation in year t+1 depend on expected rates of return for year t+2, which we assume are determined by actual returns to and costs of capital in year t+1. In both Cases 1 and 2, the models are recursive, i.e., they can be solved for year 1 and then for year 2 and so on. In Case 3 expected rates of return for year t+2 are assumed to be equal to the actual rates of return for year t+2, namely, expections are rational or consistent. In Case 4, the behavior of investors is explicitly optimizing. Relative to the recursive models in Cases 1 and 2, solution of Cases 3 and 4 models require a more sophisticated computational approach for handling the computations for all of the years simultaneously.

In our TAIGEM©-D forecasting and policy simulations, we solve a large (160 industry) recursive model incorporated externally supplied, realistic macroforecasts. That is, our approach is an application of Case 2. A dynamic model such as TAIGEM©-D is beneficial when analyzing climate change policies since the timing of policy implementation and the adjustment path an economy follows are highly relevant in the climate change policy debate.

Structure of Production: Non-Electricity Sectors

TAIGEM©-D allows each industry to produce several commodities, using as inputs domestic and imported commodities, labor of several types, land, capital, energy of several types and "other costs". In addition, commodities destined for export are distinguished from those for local use. The multi-input, multi-output production specification is kept manageable by a series of separability assumptions, illustrated by the nesting shown in Figure 1 which shows the production structure of the non- electricity sectors of TAIGEM©-D model.

The input demand of industry production is formulated by a five-level nested structure, and the production decision-making of each level is independent. Assuming cost minimization and technology constraint at each level of production, producers will make optimal input demand decisions. At the top level, commodity composites and a primary-factor composite are combined using a Leontief production function. Consequently, they are all demanded in direct proportion to the industry activity. At the second level, each commodity composite is a CES (constant elasticity of substitution) function of domestic goods and the imported equivalent (the Armington assumption). Energy and primary-factor composites are a CES aggregation of energy composites and primary-factor composites.

At the third level, the primary-factor composite is a CES aggregation of labor, land, and capital, and the energy composite is a CES aggregation of coal products composites, oil products composites, natural gas products composites, and electricity. At the fourth level, the labor composite is a CES aggregation of managers, professional specialists, white collar, technical, workers, and unskilled workers; the coal products composite is a CES aggregation of coal and coal products; the oil products composite is a CES aggregation of gasoline, diesel oil, fuel oil, and kerosene; the natural gas products composite is a CES aggregation of refinery gas, gas, and natural gas. At the bottom level the energy composite is a CES aggregation of domestic goods and imported goods.

Like ORANI model, the output structure of TAIGEM©-D allows for each industry to produce a mixture of all the commodities. Moreover, conversion of an undifferentiated commodity into goods destined for export and local use is governed by a CET (constant elasticity of transformation) transformation frontier.

Technology Bundle in Electricity Sector

In TAIGEM©-D, production in the electricity sector is modeled using the "technology bundle" approach derived from Australia ORANI-E model and MEGABARE (GTEM) model,. With this approach, electricity can be generated from coal, petroleum, gas, nuclear, hydo or renewable based technologies. The electricity industry is able to substitute between technologies in response to changes in their relative costs. By modeling energy intensive industries in this way, TAIGEM©-D restrict substitution to known technologies, thereby preventing technically infeasible combinations of inputs being chosen as model solutions. While retaining the extensive interaction with other sectors of the economy obtained in "top down" models, TAIGEM©-D moves further toward the realism of the "bottom up" approach.

The way in which the technology bundle approach ensures that the pattern of input use is consistent with known technologies is illustrated in Figure 2. In TAIGEM©-D model, 10 known technologies are used to generate electricity, namely hydro, stream turbine-oil, stream turbine-coal, stream turbine-gas, combined cycle-oil, combined cycle-gas, gas turbine-oil, gas turbine-gas, diesel, and nuclear. All electricity generated from these technologies is transferred to the end-use electricity sector. The output of the electricity sector is a CRESH aggregate of each electricity technology, and this technology requires fixed proportions of intermediate inputs, with the exception of energy inputs and primary factors.

3. Baseline Projection Results from TAIGEM©- D

Like MONASH, three types of simulations are made routinely with TAIGEM©-D model. The first is historical simulation that we use to generate up-to-date data for our forecasting simulation. Since models designed for forecasting contain dynamic equations which require initial conditions from the base year. Forecasts can be rather sensitive to these initial conditions. Moreover, through the historical simulations, we can calibrate detailed patterns of changes in technology and household tastes over the historical period.

The second is forecasting simulation that is designed for us to incorporate into the forecasts as much specialist information as is available, allowing us to project prospects for likely developments in the structure of the economy. The third is policy simulation that is conducted by projecting deviations from an explicit control path (i.e., the forecasting simulation) showing the effects of policy changes or other shocks of interest (e.g., GHG mitigation policies).

The policy simulations are not made in this research since GHG mitigation strategies are not evaluated. The first two types of simulation which we use are achieved by the use of two different closures of the model, i.e., with two different selections of exogenous variables. Historical closures include in their exogenous set two types of variables: observables and assignables. Observables are those for which movements can be readily observed from statistical sources. Historical closures vary between applications depending on data availability. When we forecast the baseline, we need the results of technology movements and taste movements which are solved by historical simulation. Thus, in the historical closure, the technology movements and taste movements are endogenous variables.

In the forecasting closures, the experts' forecasting values are exogenous variables, such as tradable exports prices and quantities, employment, and economic growth rate. These exogenous variables are varied during the forecasting period and the closures must be modified to incorporate these new exogenous variables. If we can get more experts' forecast, then we can make the forecasting results more accurately.

For the CO_2 baseline forecasting, we consider the period from 1995 to 2020 as shown in Figure 3. The initial database of TAIGEM©-D model is the 1994 input-output tables. Three situations are specified as follows.

1) Historical closure in the period 1995-1997: Since official data on private consumption, investment, government consumption, exports, exchange rate and labor employed are available from the Directorate-General of Budget, Accounting Statistics, (DGBAS), we set growth rates of these variables as exogenous.

2) Closure for the year 1998: There are three differences between the closure for year 1998 and the historical closure for the period 1995-1997. Firstly, total labor employed is set exogenous in the historical simulation for the period 1995-1997. However, since official data on total labor employed at year 1998 is not available, we set it as endogenous. Secondly, aggregate price index is set as numeraire in the historical closure for the period 1995-1997, but consumer price index is set as numeraire in the closure for the year 1998. Thirdly, exchange rate is set exogenous in the historical closure for the period 1995-1997, but there is a closure swap between exchange rate and productivity growth rate of primary factors in the closure for the year 1998.

   Our aim with TAIGEM©-D was to use all the information for the final year (i.e., year 1998) which was available from the DGBAS, both in published and unpublished form. The results also provide quite detailed estimates of changes in technology over the historical period. We use these as the starting point for devising forecasting simulation on technical change to be incorporated into our baseline forecasts with TAIGEM©-D.

3) Forecast closure in the period 1999-2020: Most exogenous variables in the historical closure for the period 1995-1997 are set endogenous in the forecast closure. In the baseline forecast, private consumption, investment, government consumption, exports and imports are determined in the model.

Table 1 shows the growth rate of major economic variables over the period 1995 to 2020. The historical economic statistics and projected values are taken from the publication of DGBAS, such as “Quarterly National Economic Trends Taiwan Area, the Republic of China”, “Commodity-Price Statistics Monthly in Taiwan Area of the Republic of China”, “Report on the Survey of Family Income and Expenditure in Taiwan Area of Republic of China” and “Monthly Statistics of the Republic of China”. Moreover, data from CEPD (Council for Economic Planning and Development) are also used, for example, “industry of Free China” and “The Plan for National Development into the Next Century”.

For the historical simulation, for example, the growth rates of export are set at 12.79%, 7.07%, 8.67%, and 3.07% for the period 1995-1998. Growth rates of investment are given as 5.51%, 2.39%, 9.99%, and 9.88%. Growth rates of household consumption are set at 5.5%, 6.21%, 7.71%, and 7.01%. Growth rates of government expenditure are 1.29%, 5.18%, 5.77%, and 1.23%. Growth rats of aggregate price index are set at 1.94%, 2.68%, and 1.85% for the period 1995-1997. Growth rats of exchange rate are set at 3.93%, 0.81%, and 4.52%. Growth rates of the import price index (c.i.f.) are 5.2%, -2.21%, and -4.77%. Finally, growth rates of export price index are 5.97%, 0.86%, and 1.48%.

As shown in Table 1, after 1998, the growth rates of the traditional exports and non-traditional exports almost increase at the rate of 2-3%, and the exports price index is expected to decline at the rate of 3%. We also assume that productivity growth rate of primary factors and CPI growth rate will increase by the annual rate of 2% from 1998 up on.

Table 2 and Figure 4 demonstrates four cases with different assumptions on GDP growth rates. In the first case GDP growth rates are endogenously determined. Forecasting result shows that CO_2 emission is at 419 million tons at year 2020. Of most interest is the historical simulation from 1995 to 1998 for GDP growth rates solved from TAIGEM©-D. They are very close to the actual values published by the DGBAS. The other three cases are under the assumption that GDP growth rates are exogenous. The growth rates are taken from Economics Institute, Academia Sinica. Three emissions growth projections are specified as “TAIGEM - high GDP growth rate”, “TAIGEM – mid GDP growth rate” and “TAIGEM – low GDP growth rate”. Results show that CO2 emission in 2020 is 540 million tons with high GDP growth rate, 485 million tons with medium GDP growth rate, and 441 million tons with low GDP growth rate. The average growth rates of CO_2 Emissions from 2000 to 2020 are 4.30% (high GDP growth rate), 3.82% (medium GDP growth rate), 3.40% (low GDP growth rate) and 3.09% (endogenous GDP growth rate).

4. Results Comparison with Taiwan-MARKAL model

A key determinant of projected emissions growth is different model structures that are based on different theories. In this section baseline forecasting results from TAIGEM©-D are compared with those from Taiwan-MARKAL model developed by Energy and Resources Laboratories of Industrial Technology Research Institute (ITRI), Taiwan. Taiwan-MARKAL energy model is a partial-equilibrium 'bottom up' model: it focuses only on energy sector and sets exogenous variables of other sectors. That is, it treats prices exogenous and includes insufficient specification of the behavior of economic agents outside the energy sector. Taiwan-MARKAL has a highly detailed modeling structure of the energy sector identifying alternative technologies that can be used in the production of a given output (e.g., electricity). Its strength is that it is superior in achieving much greater realism in modelling the substitution options in energy production technology.

In contrast, TAIGEM©-D model is a general-equilibrium 'top down' model which imbeds Walras' law into the complete economic system. In the model most variables of all sectors (for example, output prices) are set endogenous and the energy sector is only one of many sectors identified. Interactions among different sectors of the economy through market mechanism are captured. With the 'technology bundle' approach, we made significant progress in taking MARKAL-like structures into TAIGEM©-D model.

For baseline projection comparison, common assumptions are adopted in TAIGEM©-D model and Taiwan-MARKAL model. GDP growth rates up to year 2020 are set exogenous. Common energy-saving rate is used. Taiwan's oil trade liberalization is expected at year 2005. Projections from International Energy Outlook 1998 about international energy prices are used. Moreover, the amounts of electricity produced from nuclear power are set exogenous.

Table 3 and Figure 5 demonstrate four cases with different assumptions on energy usage efficiency rates. GDP growth rates are endogenously determined for case 1 to case 3. When the energy usage efficiency rates are 0.3%, 0.5%, and 0.7%, the fossil fuel related CO_2 emission at year 2020 are 429, 417, and 404 million tons respectively. The other case is under the assumption that GDP growth rate is exogenous. In case 4, we set GDP growth rates exogenous and energy usage efficiency rate at 1.2%. Results show that TAIGEM©-D projects the fossil fuel related CO_2 emission at year 2020 is 457 million tons which is higher than Taiwan-MARKAL's 441 million tons.

Fossil fuel related emissions and industrial process emissions projected from TAIGEM©-D model are shown in Table 4. Furthermore, per capita and per-household CO_2 emissions for both models are presented. Both models have similar per capita CO2 emissions projections.

Table 5 presents model projections of the sectoral emission structure. The economy is aggregated into 5 sectors: agricultural, industrial, electricity, transportation, and residential-commercial sectors. Results show that CO_2 emissions trend in electricity sector is quite different. It seems that TAIGEM©-D model is less optimistic than Taiwan-MARKAL model.

Energy structure projections are shown in Table 6. While Taiwan-MARKAL model being an energy model can estimate the "new energy" usage, TAIGEM©-D model do not have such capability due to lack of 'new energy' data in the IO database. Taiwan-MARKAL projects more usage in oil and nuclear than those from TAIGEM©-D model. In contrast, More usage of coal, natural gas, and hydro are projected from TAIGEM©-D model. Table 7 provides comparison in major energy index projected from both models. They are quite similar.

5. Concluding Remarks

The major goal of this paper is to provide a baseline forecasting of CO_2 and have a comparison with those projection results from Taiwan MARKAL model in Taiwan. We use the TAIGEM©-D model – a dynamic computable general equilibrium model – to project Taiwan's CO2 emission baseline up to year 2020. Although both models show a similar pattern of projection results, there are significant differences in the models' projections of CO2 emission in the electricity sector and future energy structure. Results show that the accuracy of baseline projection depends on the model used and the assumptions made. However, projection results from different models, either top-down or bottom-up models, complement each other.

Further improvements on TAIGEM©-D baseline forecasting are underway. They include 1) updating the input-output table to the newly released 1996 edition, 2) econometric estimation of more elasticities and parameters, 3) extending periods of historical simulation to improve model validation, 4) incorporating other greenhouse gases into the model, e.g., methane and nitrous oxide.

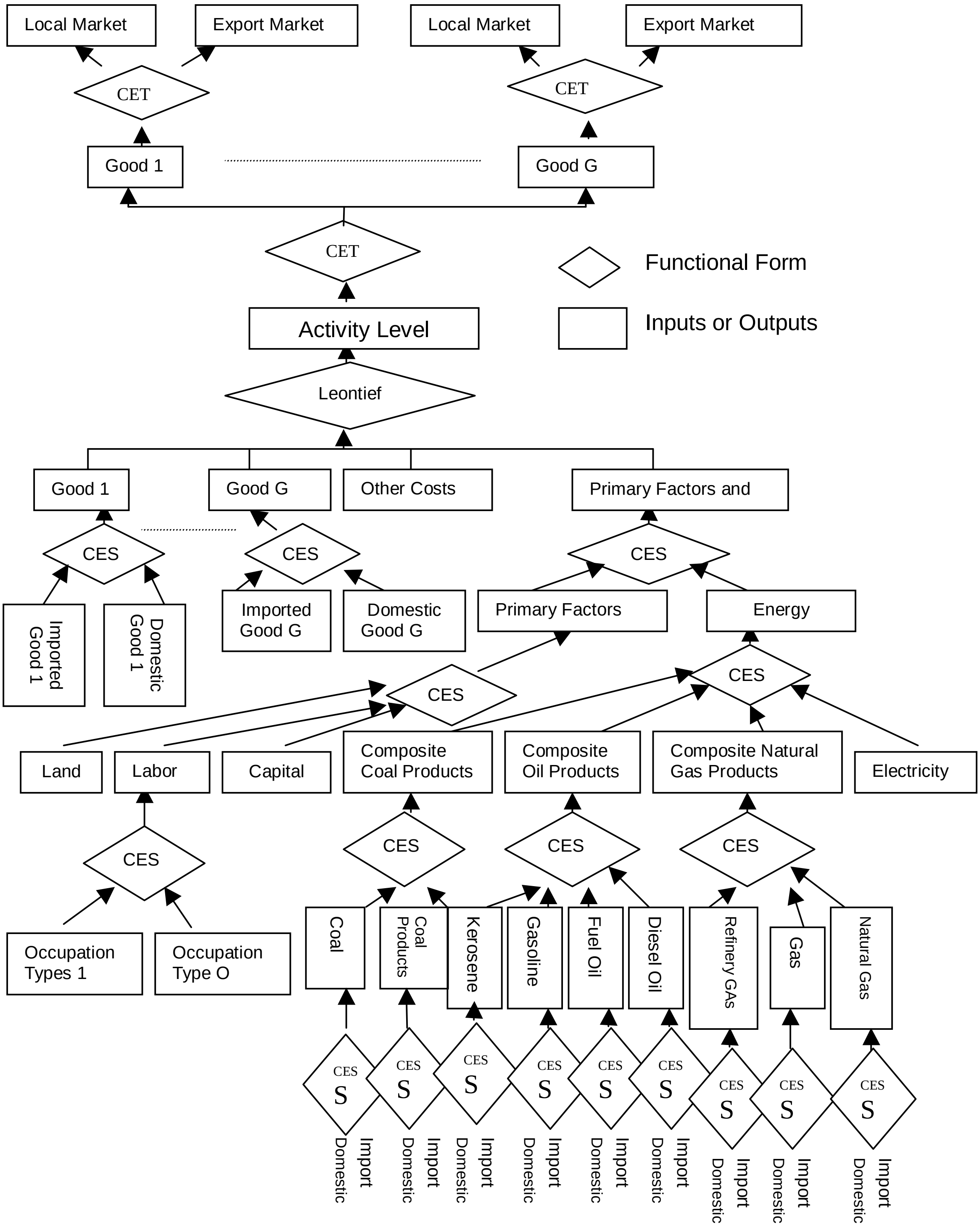

Figure 1. Structure of Production: Non-Electricity Sectors

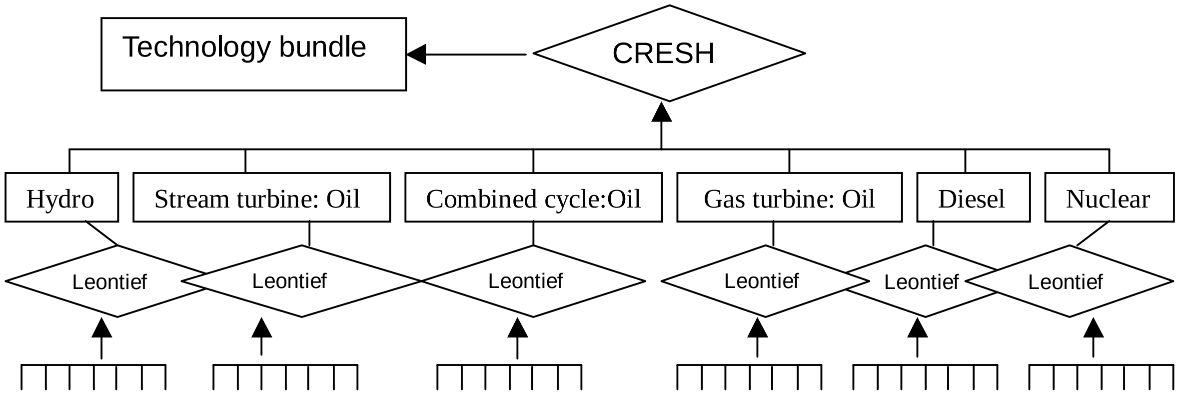

Figure 2. Technology Bundle of TAIGEM©-D Model: Electricity Sector

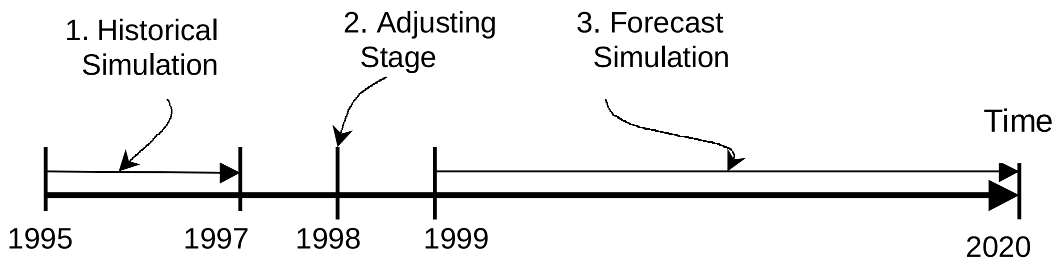

Figure 3. Simulation Closure of TAIGEM©-D Model

Table 1. Exogenous Shocks for Forecasting CO_2 Emissions Baseline• From 1995 to 2020

Macroeconomic variables growth rate(%)	1995	1996	1997	1998	1999	2000~ 2020
Imports	9.83	5.1	13.36	5.36	endog.*	endog.
Household consumption	5.5	6.21	7.71	7.01	endog.	endog.
Export	12.79	7.07	8.67	3.07	endog.	endog.
Investment	5.51	2.39	9.99	9.88	endog.	endog.
Government expenditure	1.29	5.18	5.77	1.23	endog.	endog.
Household	2.94	3.09	3.32	2	2	2
Employment (labor force)	1.19	0.26	1.19	endog.	endog.	endog.
Aggregate price index	1.94	2.68	1.85	endog.	endog.	endog.
Exchange rate	3.93	0.81	4.52	endog.	endog.	endog.
Imports price index (c.i.f)	5.2	-2.21	-4.77	endog.	endog.	endog.
Exports price index	5.97	0.86	1.48	endog.	endog.	endog.
Tradable exported demand shifter	N/A	N/A	N/A	3	3	2
Non-tradable exported demand shifter	N/A	N/A	N/A	3	3	2
Tradable exported price shifter	N/A	N/A	N/A	N/A	-3	N/A
Non-tradable exported price shifter	N/A	N/A	N/A	N/A	-3	N/A
Primary factors productivity	endog.	endog.	endog.	-2	-2	-2
Consumer price index	endog.	endog.	endog.	2	2	2

* : Endogenous solution
N/A : Not Available•

Table 2. Forecasting CO_2 Emissions Baseline with TAIGEM©-D Model

• unit• million tons CO_2•

Year	GDP Growth rate (Exogenous)			GDP Growth rate (Endogenous)
	High-Growth	Mid-Growth	Low-Growth	
1995	174.865	174.865	174.865	174.517
1996	182.796	182.796	182.796	182.347
1997	193.475	193.475	193.475	192.778
1998	201.893	201.893	201.893	201.139
1999	212.577	211.583	210.391	211.168
2000	223.122	221.020	218.510	221.249
2001	234.451	231.107	227.242	230.812
2002	246.709	241.977	236.610	240.374
2003	259.961	253.681	246.774	250.167
2004	274.100	266.057	257.582	260.006
2005	288.970	279.331	268.678	269.648
2006	304.382	293.002	280.231	279.032
2007	320.442	307.053	291.935	288.220
2008	337.081	321.083	303.708	297.291
2009	353.938	335.140	315.243	306.306
2010	370.959	348.902	326.588	315.333
2011	388.182	362.674	337.994	324.456
2012	405.514	376.518	349.409	333.763
2013	422.641	390.431	360.869	343.324
2014	439.811	404.019	372.232	353.183
2015	456.887	417.689	383.617	363.363
2016	473.887	431.256	395.116	373.870
2017	490.655	444.761	406.678	384.704
2018	506.920	458.165	418.159	395.857
2019	523.332	471.655	429.608	407.320
2020	539.827	485.214	441.037	419.078

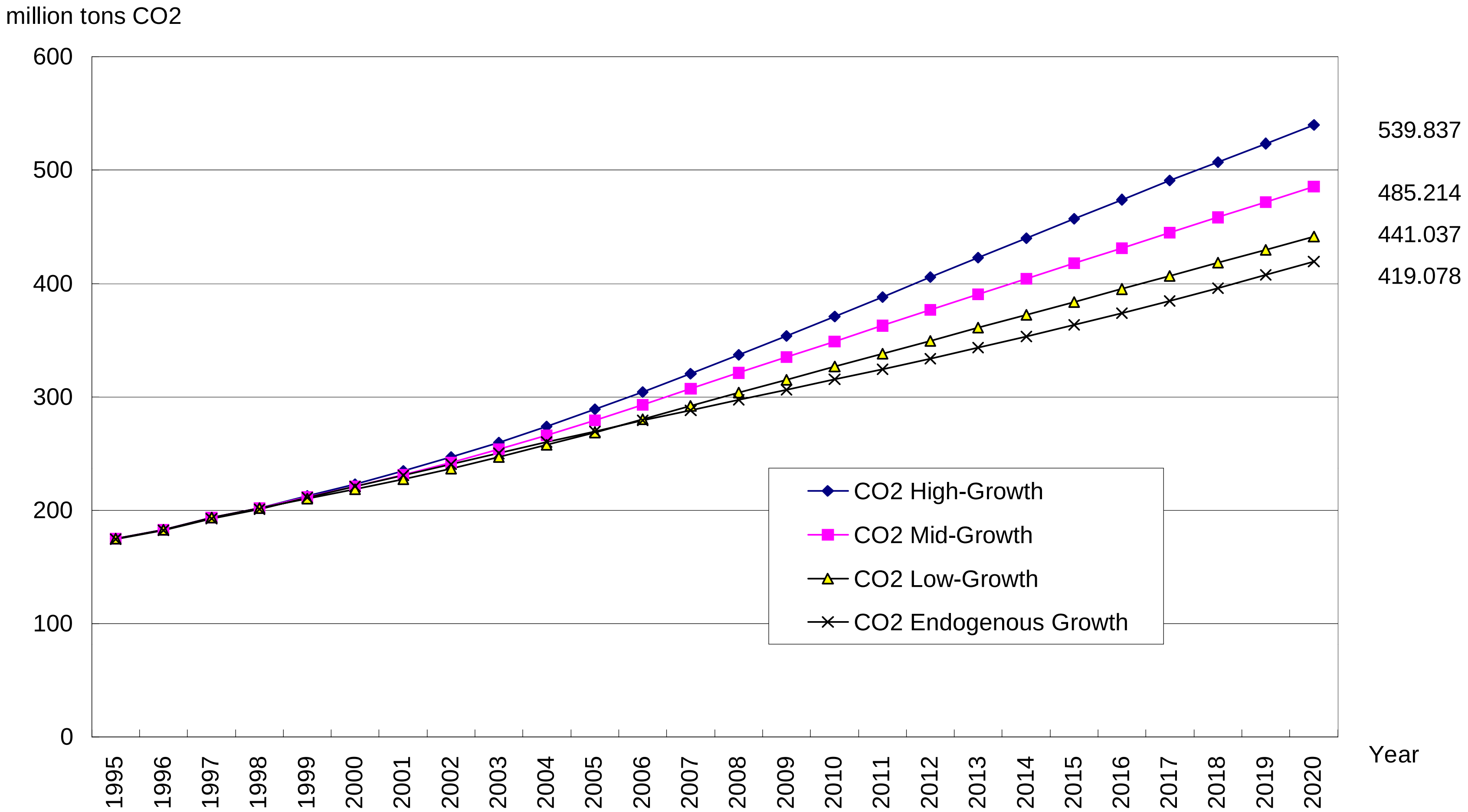

Figure 4. TAIGEM©-D Model Results: CO_2 Emissions Baseline

Table 3. Fossil Fuel Related CO_2 Baseline Emissions Forecasting

unit：%, million tons

year	Real GDP Growth rate	Endogenous GDP growth rate						Exogenous GDP growth rate		
		TAIGEM©-D with energy usage efficiency=0.3%		TAIGEM©-D with energy usage efficiency =0.5%		TAIGEM©-D with energy usage efficiency =0.7%		TAIGEM©-D with energy usage efficiency =1.2%		Taiwan-MARKAL
		%	CO_2	%	CO_2	%	CO_2	%	CO_2	CO_2
1994	6.54		154.626		154.626		154.626		154.626	
1995	6.03	5.93*	162.211	5.93*	162.211	5.93*	162.211	5.93*	162.211	162
1996	5.67	5.57*	169.394	5.57*	169.394	5.57*	169.394	5.57*	169.394	174
1997	6.77	6.90*	180.712	6.90*	180.712	6.90*	180.712	6.90*	180.712	186
1998	4.83	4.81*	186.491	4.81*	186.491	4.81*	186.491	4.81*	186.491	196
1999	5.48	5.43*	198.911	5.43*	198.911	5.43*	198.911	5.43*	198.911	209
2000		6.39	210.568	6.40	210.232	6.42	209.895	5.60	208.107	222
2001		5.75	222.137	5.77	221.435	5.78	220.734	5.00	216.79	231
2002		5.21	233.318	5.22	232.219	5.24	231.123	5.00	226.102	240
2003		4.81	244.661	4.83	243.131	4.85	241.609	5.00	236.462	249
2004		4.51	256.37	4.52	254.372	4.54	252.388	5.00	248.03	259
2005		4.63	263.718	4.65	261.263	4.66	258.83	5.00	255.105	269
2006		4.21	270.455	4.23	267.533	4.24	264.64	4.70	261.972	280
2007		3.81	282.137	3.83	278.669	3.85	275.242	4.70	275.057	291
2008		3.71	293.782	3.72	289.734	3.74	285.739	4.70	288.71	302
2009		3.63	305.378	3.65	300.713	3.66	296.118	4.70	302.891	314
2010		3.60	317.083	3.61	311.765	3.63	306.536	4.70	317.683	326
2011		3.61	329.169	3.62	323.163	3.64	317.265	4.40	332.105	336
2012		3.64	341.915	3.66	335.177	3.67	328.571	4.40	347.393	346
2013		3.68	355.457	3.70	347.935	3.71	340.572	4.40	363.661	356
2014		3.94	364.859	3.95	356.621	3.96	348.569	4.40	374.985	366
2015		3.23	361.68	3.26	353.25	3.29	345.015	4.40	376.546	377
2016		3.71	375.757	3.73	366.471	3.74	357.412	4.20	393.206	389
2017		3.70	389.972	3.71	379.792	3.73	369.876	4.20	410.055	402
2018		3.69	404.428	3.71	393.311	3.72	382.499	4.20	427.084	414
2019		3.70	418.966	3.72	406.877	3.73	395.136	4.20	444.268	428
2020		3.86	429.406	3.87	416.468	3.88	403.92	4.20	456.808	441

* For year 1995 to 1999, GDP growth rates are the results of historical simulation.

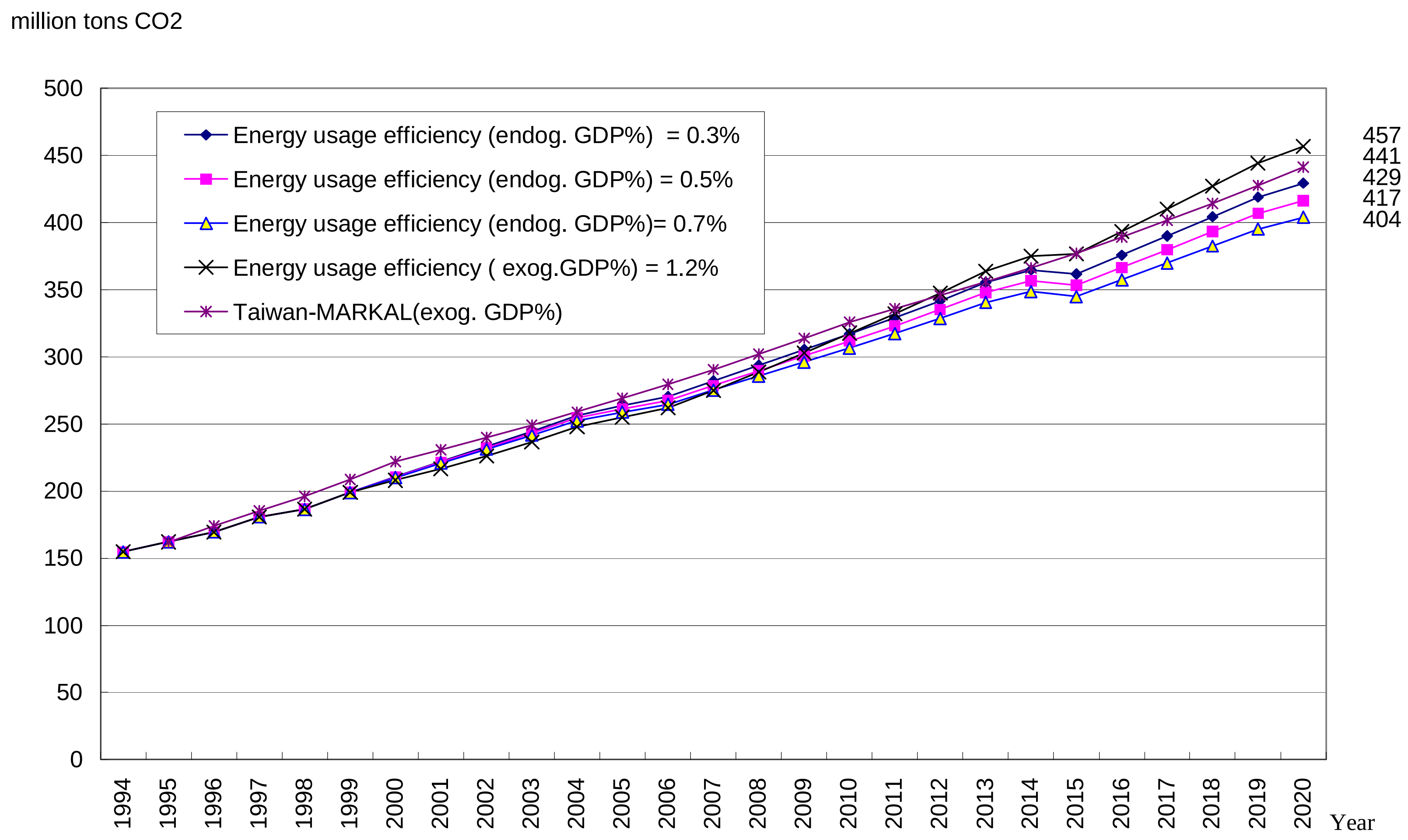

Figure 5. Fossil Fuel Related CO2 Baseline Emissions Forecasting

Table 4. Comparison of CO_2 Emissions Baseline Forecasting

-- TAIGEM©-D model and Taiwan-MARKAL model

year	Fossil Fuel related emissions					Industrial process emissions		
	Total emissions (million tons)		Per Capita emissions (tons)		Per-household emissions (tons)	TAIGEM©-D		
	TAIGEM©-D	MARKAL	TAIGEM©-D	MARKAL	TAIGEM©-D	Total emissions	Per Capita emissions	Per-household emissions
1994	154.626		7.30		27.37	12.514	0.59	2.22
1995	162.211	162	7.60	7.6	27.88	12.943	0.61	2.22
1996	169.394		7.87		28.13	13.273	0.62	2.20
1998	186.491	196	8.50	9.0	29.28	14.835	0.68	2.33
2000	208.107	222	9.39	10.0	31.23	16.196	0.73	2.43
2005	255.105	269	11.11	11.7	34.68	17.076	0.74	2.32
2010	317.683	326	13.36	13.7	39.12	21.549	0.91	2.65
2015	376.546	377	15.30	15.3	41.99	27.191	1.10	3.03
2020	456.808	441	17.92	17.3	46.14	34.687	1.36	3.50

Note: For years 1995~1999, the emissions of TAIGEM©-D model are the results of historical simulation.

Table 5. Sectoral Comparison of CO_2 Emissions Baseline Forecasting

-- TAIGEM©-D model and Taiwan-MARKAL model

Unit : %

Year	Model	Agricultural sector	Electricity sector	Residential-Commercial sector	Transportation sector	Industrial sector
1994	TAIGEM©-D	2.00	36.53	8.06	10.16	43.25
	MARKAL					
1995	TAIGEM©-D	1.98	36.57	8.02	10.34	43.09
	MARKAL	1.5	36.0	4.7	17.2	40.6
1996	TAIGEM©-D	1.91	36.41	8.13	10.44	43.11
	MARKAL					
1997	TAIGEM©-D	1.74	36.43	8.14	10.50	43.19
	MARKAL					
1998	TAIGEM©-D	1.69	36.53	8.28	10.54	42.95
	MARKAL					
1999	TAIGEM©-D	1.62	36.70	8.04	10.39	43.25
	MARKAL					
2000	TAIGEM©-D	1.62	36.70	8.04	10.39	43.25
	MARKAL	1.1	38.4	3.8	14.5	41.4
2005	TAIGEM©-D	1.54	37.32	7.78	10.20	43.16
	MARKAL	0.9	42.4	3.5	14.5	38.7
2010	TAIGEM©-D	1.48	37.07	7.60	9.93	43.92
	MARKAL	0.7	47.3	2.9	13.1	35.9
2015	TAIGEM©-D	1.51	36.34	7.57	9.94	44.64
	MARKAL	0.6	50.8	2.5	12.6	33.4
2020	TAIGEM©-D	1.58	36.59	7.47	10.02	44.34
	MARKAL	0.5	54.5	2.2	12.7	30.1

Note: For years 1995~1999, the sectoral emissions of TAIGEM©-D model are the results of historical simulation.

Table 6. Baseline Comparison: Energy Structure Projections

-- TAIGEM©-D model and Taiwan-MARKAL model

unit• 10^3 KLOE

year	Model	Coal		Oil		Natural gas		Nuclear		Hydro		New energy		Sum
		quantity	%	quantity	%	quantity	%	quantity	%	quantity	%	quantity	%	
1994	TAIGEM©-D	18522	28.06	33958	51.44	3739	5.66	7806	11.82	1989	3.01			66014
	MARKAL													
1995*	TAIGEM©-D	18836	27.33	36184	52.51	4022	5.84	7844	11.44	1982	2.88			68908
	MARKAL	18804	26.8	36637	52.3	4496	6.4	8430	12.0	1197	1.7	550	0.8	70115
1996	TAIGEM©-D	21266	29.45	36332	50.31	4197	5.81	8409	11.64	2012	2.79			72216
	MARKAL													
1997	TAIGEM©-D	24628	32.06	37072	48.27	4778	6.22	8173	10.64	2344	2.89			76807
	MARKAL													
1998	TAIGEM©-D	26912	33.18	37902	46.72	5888	7.26	8072	9.95	2344	2.89			81118
	MARKAL	26374	31.7	39030	47.0	6516	7.8	8797	10.6	1535	1.8	821	1.0	83072
1999-2000	TAIGEM©-D	30281	34.12	40764	45.93	6504	7.33	8674	9.77	2529	2.85			88752
	MARKAL	28385	29.0	50761	51.9	7390	7.36	8765	9.0	1535	1.6	1001	1.0	97837
2001-2005	TAIGEM©-D	36461	35.57	46647	45.50	7658	7.47	9056	8.83	2690	2.62			102513
	MARKAL	35369	30.4	58522	50.3	8477	7.3	11042	9.5	1565	1.3	1317	1.1	116293
2006-2010	TAIGEM©-D	46264	36.73	55556	44.10	9000	7.14	12217	9.70	2932	2.33			125970
	MARKAL	43998	32.0	67403	49.0	9565	7.0	13182	9.6	1596	1.2	1827	1.3	137570
2011-2015	TAIGEM©-D	56698	37.41	67133	44.34	11205	7.39	13323	8.79	3193	2.11			151552
	MARKAL	51809	32.6	75188	47.2	10653	6.7	17531	11.0	1626	1.0	2325	1.5	159131
2016-2020	TAIGEM©-D	67533	37.23	80441	44.34	13678	7.54	16277	8.97	3472	1.91			181400
	MARKAL	60963	33.4	85652	46.9	11707	6.4	19877	10.9	1656	0.9	2805	1.5	182660

*: For years 1995~1999, the energy structures of TAIGEM©-D model are the results of historical simulation.

Table 7. Baseline Comparison: Energy Index -- TAIGEM©-D model and Taiwan-MARKAL model

year	model	Energy elasticity	CO_2 elasticity	Energy intensity (10^3KLOE/million NT$)	CO_2 intensity (ton/ million NT$) Fossil fuel related
1994	TAIGEM-D	1.11		11.35	26.58
	MARKAL				
1995	TAIGEM-D	0.73	0.81	11.17	26.30
	MARKAL	0.89	1.12	11.37	26.21
1996	TAIGEM-D	0.85	0.80	11.08	26.03
	MARKAL				
1997	TAIGEM-D	0.94	1.09	11.04	26.15
	MARKAL				
1998	TAIGEM-D	1.16	0.80	11.12	25.91
	MARKAL	1.01	1	11.39	26.94
1999~2000	TAIGEM-D	1.07	1.11	11.24	26.25
	MARKAL	1.26	1.2	12.08	27.45
2001~2005	TAIGEM-D	0.86	0.84	10.92	25.92
	MARKAL	0.68	0.76	11.25	26.03
2006~2010	TAIGEM-D	0.85	0.88	10.61	25.03
	MARKAL	0.71	0.82	10.58	25.05
2011~2015	TAIGEM-D	0.87	0.82	10.24	24.48
	MARKAL	0.65	0.65	9.84	23.35
2016~2020	TAIGEM-D	0.84	0.86	9.94	23.72
	MARKAL	0.65	0.75	9.22	22.27

*: For years 1995~1999, the energy index of TAIGEM©-D model are the results of historical simulation.

References

Brown, S., Kennedy, D., Polidano, C., Woffenden, K., Jakeman, G., Graham, B., Jotzo, F. and Fisher, B.S.(1999), ***Economic Impacts of the Kyoto Protocol: Accounting for the Three Major Greenhouse Gases***, ABARE, Canberra.

Dixon, P.B. and Maureen T. Rimmer (1998), ***Forecasting and Policy Analysis with a Dynamic CGE Model of Australia***, available from the Centre of Policy Studies, Monash University, Australia.

Dixon, P.B., and B.R. Parmenter (1996). "Computable General Equilibrium Modelling for Policy Analysis and Forecasting." In H.M. Amman, D.A. Kendrick, and J. Rust (eds.) ***Handbook of Computational Economics, Volume 1.*** Elservier Science B.V., Amsterdam.

Dixon, P.B., B.R. Parmenter, J. Sutton, and D.P. Vincent (1982). ***ORANI: A Multisectoral Model of the Australian Economy.*** North-Holland, Amsterdam.

Dixon, P.B., Brian R. Parmenter and Maureen T. Rimmer(1998), ***MONASH: A Dynamic, Computable General Equilibrium Model of the Australian Economy***, available from the Centre of Policy Studies and IMPACT Project, Monash University, Australia.

Dixon, P.B., M. Malakellis and M.T. Rimmer (1997), ***The Australian Automotive Industry from 1986-87 to 2009-10: Analysis using the MONASH Model***, a report to the Industry Commission be the Centre of Policy Studies and IMPACT Project, Monash University.

Kennedy, D., Brown, S., Graham, B., and Fisher, B.(1998), ***Kyoto Protocol: advantages of emissions trading over independent abatement, Australian Commodities, vol. 5 no. 4***, Canberra, December.

OECD/EIA (1998). ***Mapping the Energy Future: Energy Modelling and Climate Change Policy,***. OECD/IEA.

Office Integrated Analysis and Forecasting (1998). ***Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity***. SR/OIAF/98-03, Washington, DC: Energy Information Administration.

Office Integrated Analysis and Forecasting (1998). ***International Energy Outlook 1998***. DOE/EIA/0484(98), Washington, DC: Energy Information Administration.

Office Integrated Analysis and Forecasting (1998). ***The National Energy Modeling System: An Overview 1998***. DOE/EIA/0581(98), Washington, DC: Energy Information Administration.

Office of Coal, Nuclear, Electric and Alternate Fuels (1997). ***The Effects of Title IV of the Clean Air Act Amendments of 1990 on Electric Utilities: An Update***. DOE/EIA-0582(97), Washington, DC: Energy Information Administration.

Office of Coal, Nuclear, Electric and Alternate Fuels (1998). ***The Changing Structure of the Electric Power Industry: Selected Issues, 1998***. DOE/EIA-0562(98), Washington, DC: Energy Information Administration.

Powell, A.A., and R.H. Snape (1993). "The Contribution of Applied General Equilibrium Analysis to Policy Reform in Australia." ***Journal of Policy Modeling,*** 4: 393-414.

Tulpule, V., Brown, S., Lim, J., Polidano, C., Pant, H., and Fisher B.(1998), ***An economic assessment of the Kyoto Protocol using the Global Trade and Environment Model***, ABARE paper presented at the 27th Conference of Economists, Sydney, 28 September - 1 October.