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The Impact of WTO Accession on Taiwan's GHG emission: A Dynamic CGE Analysis

Shih-Hsun Hsu, Kuo-Jung Lin, Ping-Cheng Li, and Chung-Huang Huang *

Abstract

This paper investigates the potential impact of China's and Taiwan's accession to the WTO on Taiwan's international trade, industrial structure, energy demand and greenhouse gas (GHG) emission during 2001-2005. Two large applied general equilibrium models, GTAP and TAIGEM, are used in this paper to simulate China's and Taiwan's WTO accession. TAIGEM (TAIwan General Equilibrium Model), a dynamic, multisectoral, applied general equilibrium model of the Taiwan's economy is developed specifically to analyze climate change response issues. In this paper we use GTAP to provide the global context for the WTO accession, and TAIGEM to assess the detailed impacts on Taiwan.

It shows that the comparative advantages of China and Taiwan are in different economic sectors. In average, Taiwan's economic growth will increase yearly at 0.4% above the baseline projection for the period 2001-2005. Service sector is expected to grow. Its share of real GDP will increase from 62.97% to 64.46%. In contrast, agriculture and industry sectors are the losers. In particular, sectors related to fossil fuel, cement, and iron and steel will contract due to less international competitiveness. With reduction of coal consumption and increasing share of gas and oil consumption, CO₂ emission level is expected to be at the level of 296.6 million tons that is higher by 1.6 million tons than the baseline projection level at 295.0 million tons.

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1. Introduction

Global warming is the most important global environmental problem that may significantly affect the welfare of human beings in this century. Because only 30% of Taiwan's land is cultivable, and of that 30%, most is in a coastal area, prone to sea level rise that would be increased by global warming. Taiwan cannot afford to ignore her membership in the global communities' efforts to find solutions to such environmental problem.

The CO₂ emission target and several policy responses, including energy efficiency improvement, energy substitution, and economic instruments (e.g., carbon tax), have been proposed jointly by the Taiwan Environmental Protection Agency and the Taiwan Energy Commission to combat global warming. Following the international mitigation tendency and Taiwan's own economy development plan, one of the main conclusions of 1998 National Energy Conference is to set a mitigation target that Taiwan's CO₂ emission will be reduced to below or above her year 2000 level for the commitment year, 2020.

Lots of research efforts have been undertaken on the analysis of economic impacts of global warming mitigation policies (see, for example, IPCC, 1995; Global Climate Change, 1995; and various special issues of the Energy Journal and Resource and Energy Economics). In particular, the efficiency and equity implications of various policy instruments to reduce greenhouse gas emissions have been well studied. Of major focus is the controversy on accurate baseline projection. Absent from the policy debate is the potential impact of China's and Taiwan's WTO accession on emission projection and effectiveness of abatement policy responses.

This paper investigates the potential impact of China's and Taiwan's accession to the WTO on Taiwan's international trade, industrial structure, energy demand and greenhouse gas (GHG) emission during 2001-2005. Two large applied general equilibrium models, GTAP and TAIGEM, are used in this paper to simulate China's and Taiwan's WTO accession. TAIGEM (TAIWAN General Equilibrium Model), a dynamic, multisectoral, applied general equilibrium model of the Taiwan's economy is developed specifically to analyze climate change response issues. TAIGEM is derived from the ORANI model (Dixon, Parmenter, Sutton and Vincent, 1982) and the MONASH model.

In this paper we use GTAP to provide the global context for the WTO accession, and TAIGEM to assess the detailed impacts on Taiwan. The paper outline is as follows. In the next section we present TAIGEM-D dynamic general equilibrium model. The strengths of TAIGEM-D are addressed. A more comprehensive description is provided in Huang, *et al.* (1999). Next we discuss the application of TAIGEM-D to the baseline projection. Then we present the simulation result of China's and Taiwan's accession to the WTO on Taiwan's international trade, industrial structure, energy demand and greenhouse gas (GHG) emission during 2001-2005. The last section provides concluding comments.

2. 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, single region, 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. Additional data on energy sector, electricity sector and emissions are collected. 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. In addition to ORANI model, TAIGEM-D inherits the basic dynamic mechanism from the Australian MONASH model. The most significant features that distinguish TAIGEM[®]-D from TAIGEM are the inclusion of inter-fuel 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 CO₂ emission, GDP growth rate, and other economic variables. We use historical simulations to generate up-to-date data for our baseline forecasting, and we use TAIGEM-D model to evaluate the impact on Taiwan economy for the mitigation greenhouse gases emissions policies.

2.1 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, expectations 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 macro-forecasts. 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.

2.2 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 where the production structure of the non-electricity sectors of TAIGEM-D model is shown.

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.

2.3 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 GTEM model. With this approach, electricity can be generated from coal, petroleum, gas, nuclear, hydro 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.

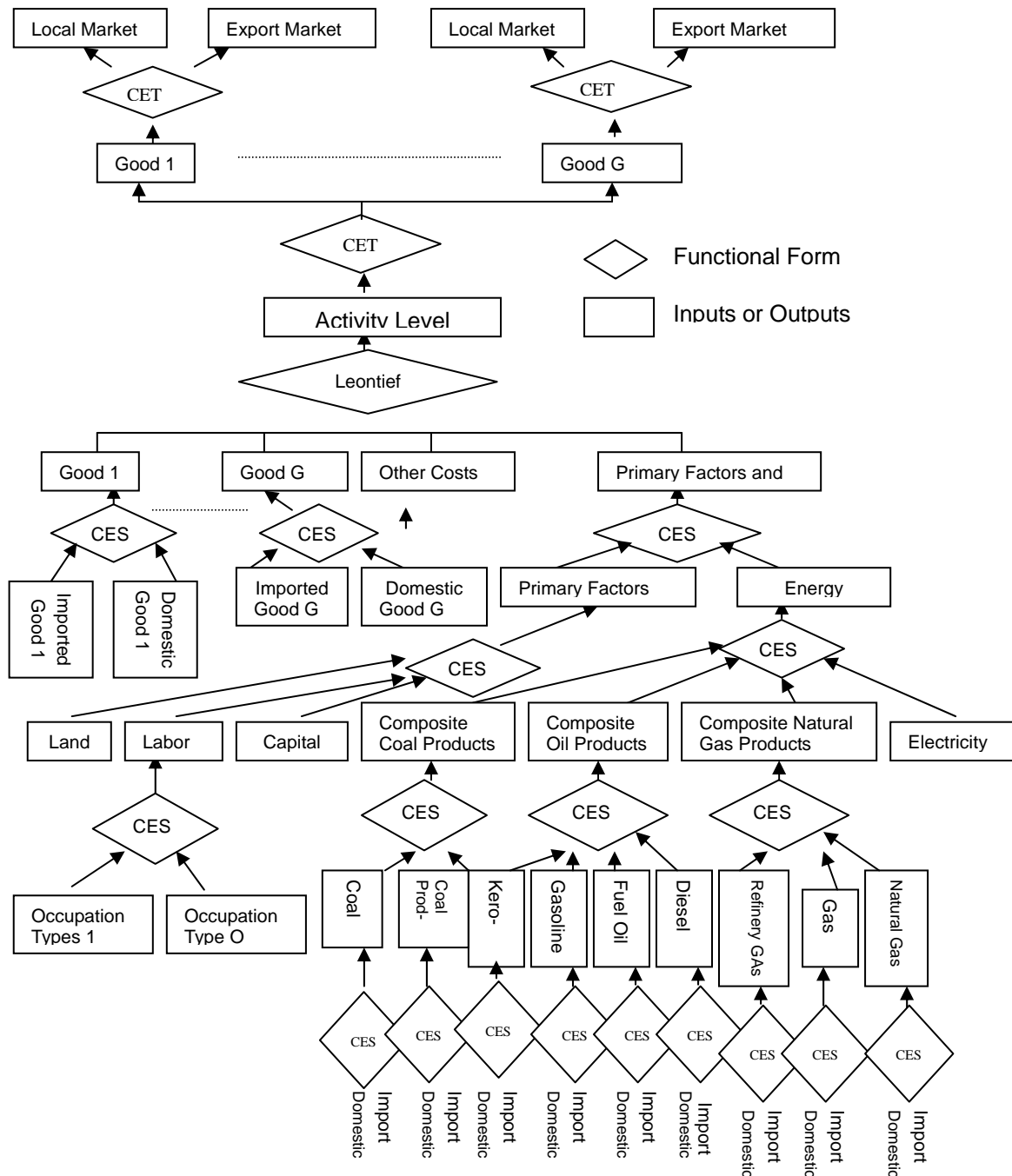


Figure 1. Structure of Production: Non-Electricity Sectors

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 tech-

nologies 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.

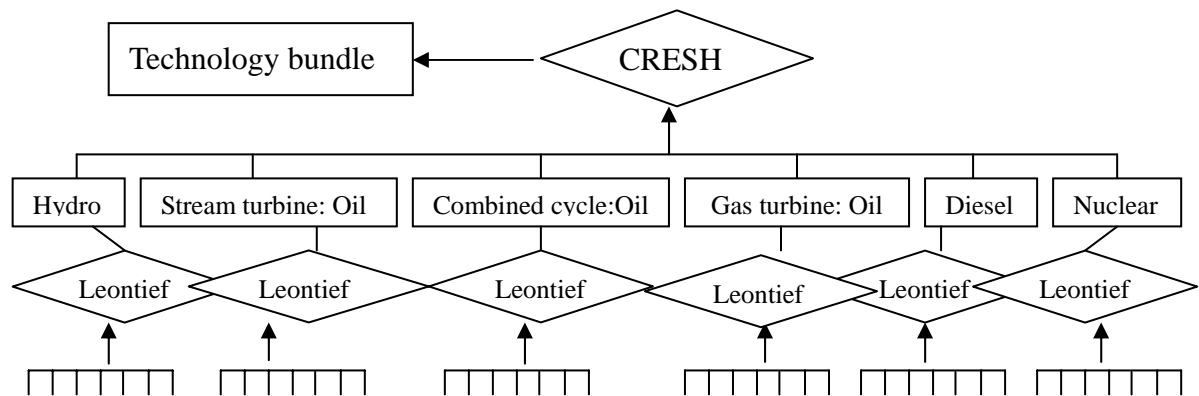


Figure 2. Technology Bundle of TAIGEM[®]-D Model: Electricity Sector

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 that 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 that 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 assignable. 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 that are solved by historical simulation. Thus, in the historical closure, the technology movements and taste movements are endogenous vari-

ables.

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 CO₂ baseline forecasting, we consider the period from year 1995 to year 2020¹ 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 1995-1999: 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 2000: There are two differences between the closure for year 2000 and the historical closure for the period 1995-1999.

Our aim with TAIGEM-D was to use all the information for the final year (i.e., year 2000) that 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 over the period 2001-2020: Most exogenous variables in the historical closure for the period 1995-2000 are set endogenous in the forecast closure. In the baseline forecast, private consumption, investment, government consumption, exports and imports are determined in the model.

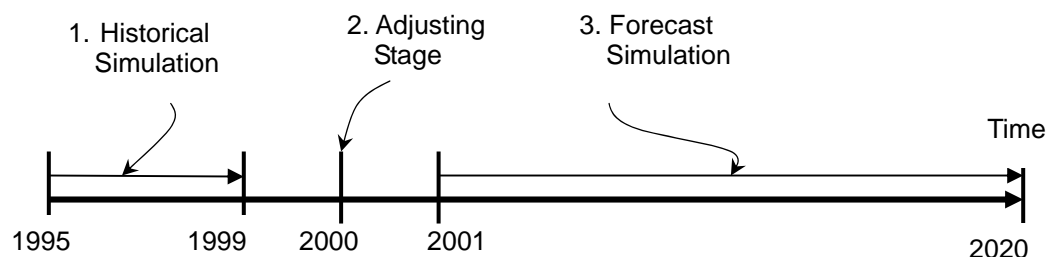


Figure 3. Simulation Closure of TAIGEM-D Model

¹ The timetable is proposed on the Energy Policy White Papers published by Energy Commission (1998).

As shown in Table 1, GDP growth rates are endogenously determined by TAIGEM-D. Of most interest is the historical simulation from 1995 to 2000 for GDP growth rates solved from TAIGEM-D. They are very close to the actual values published by the DGBAS. Forecasting result shows that total CO₂ emission is 443 million tons in 2020. With regard to the assumption on power generation, in the baseline we assume that two new generation units of the fourth nuclear plant are brought into operation in year 2005 and 2006 respectively, and one old generation unit of the first nuclear plant is retired in year 2019². As a result, GDP growth rate declines in 2019.

Table 1. Forecasting GDP Growth Rate and CO₂ Emissions Baseline with TAIGEM-D Model

| (unit : %, million tons CO ₂) | | | | | | | |
|--|---------|---------|---------|---------|---------|-------------------|-------------------|
| Year | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
| Real GDP | 6.42 | 6.10 | 6.68 | 4.57 | 5.42 | 5.98 ^a | 5.25 ^a |
| GDP(TAIGEM-D) | 6.38* | 6.26* | 6.73* | 4.57* | 5.61* | 5.87 | 5.35 |
| CO ₂ | 176.458 | 185.98 | 200.547 | 208.882 | 225.372 | 240.161 | 251.812 |
| Year | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
| GDP(TAIGEM-D) | 3.69 | 3.61 | 3.54 | 3.44 | 3.38 | 3.32 | 3.27 |
| CO ₂ | 314.133 | 324.426 | 334.739 | 344.836 | 354.918 | 365.026 | 375.211 |
| Year | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| GDP(TAIGEM-D) | 3.61 | 3.54 | 3.44 | 3.38 | 3.32 | 3.27 | 3.22 |
| CO ₂ | 324.426 | 334.739 | 344.836 | 354.918 | 365.026 | 375.211 | 385.505 |
| Year | 2016 | 2017 | 2018 | 2019 | 2020 | | |
| GDP(TAIGEM-D) | 3.19 | 3.14 | 3.09 | 2.61 | 3.03 | | |
| CO ₂ | 396.119 | 406.849 | 417.674 | 431.848 | 443.143 | | |

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

a: For year 2000 to 2001, GDP growth rates are from the Directorate-General of Budget, Accounting Statistics (DGBAS) forecasting results.

4.The Economic Impacts of WTO Accession on Taiwan's GHG emission

An assessment of the economy-wide impacts of WTO Accession on Taiwan's GHG emission is provided in this section. Table 2 shows sectoral CO₂ Emissions in Taiwan. Table 3 is a summary of Tariff and Non-Tariff Reduction Required by WTO. It displays the reduction schedules of import tariffs for the period 1998-2005. It is assumed that 2000 is the year for Taiwan's entry into WTO. This schedule will reflect our policy shocks due to WTO entry in our policy simulations.

These tariff reduction schedules are used, along with the changes in trade prices from the simulations by the global GTAP model, as exogenous shocks in our policy simulation on WTO entry. The results indicates that the total employment growth during the period 2000-2005 will be 2.96%, 2.67%, 2.32%, 2.17%, 1.88%, and 1.79%, which are higher than their corresponding levels in the baseline forecasts. The entry of WTO is beneficial to the overall labor market, largely due to the demand expansions in the service sector. Therefore, a significant structural change might occur in the labor market after joining the WTO.

As for the agricultural sector, the downsizing in the employment will be accelerated. The most

² The scheduled power generation from nuclear power plants is set up by the plan from Taiwan Power Company owned by the government.

affected sector is the crop and livestock. The decrease in employment will be above 5 percent during the initial entry year. As the market continues to open, the terms of trade for agriculture will improve so that the annual decreasing rate in employment will go down to about 4 percent by the year 2005. On the other hand, the impacts of WTO entry on the employment in the fishery and forestry sectors are positive.

Table 4 shows exogenous shocks for forecasting from 1995 to 2005. Table 5 outlines tariff rate reduction for Taiwan's WTO accession. Table 6 illustrates sectoral comparison of the simulation results on real GDP under different scenarios. The comparison of energy structure and electricity structure under different scenarios are shown in Table 7. Table 8 shows sectoral comparison of the simulation results on CO₂ emissions under different scenarios.

It shows that the comparative advantages of China and Taiwan are in different economic sectors. In average, Taiwan's economic growth will increase yearly at 0.4% above the baseline projection for the period 2001-2005. Service sector is expected to grow. Its share of real GDP will increase from 62.97% to 64.46%. In contrast, agriculture and industry sectors are the losers. In particular, sectors related to fossil fuel, cement, and iron and steel will contract due to less international competitiveness. With reduction of coal consumption and increasing share of gas and oil consumption, CO₂ emission level is expected to be at the level of 296.6 million tons that is higher by 1.6 million tons than the baseline projection level at 295.0 million tons.

Table 2. Sectoral CO₂ Emissions in Taiwan

| | unit : million tons; % | | | | |
|---|------------------------|--------|--------|--------|--------|
| | 1995 | 1996 | 1997 | 1998 | 1999 |
| CO₂ Emissions | | | | | |
| Total | 171.87 | 181.66 | 194.04 | 205.29 | 218.12 |
| Agriculture | 3.34 | 3.35 | 3.40 | 3.42 | 3.43 |
| Industry | 137.15 | 145.02 | 155.11 | 164.25 | 174.97 |
| Chemical and Petroleum products manufacturing | 17.40 | 18.14 | 19.06 | 19.75 | 21.06 |
| Non-metallic mineral products manufacturing | 1.97 | 2.14 | 2.38 | 2.61 | 2.80 |
| Basic metal industry | 13.95 | 14.69 | 15.70 | 16.57 | 17.97 |
| Services | 31.38 | 33.29 | 35.54 | 37.62 | 39.72 |
| Share Structure (%) | | | | | |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| Agriculture | 1.94 | 1.84 | 1.75 | 1.66 | 1.57 |
| Industry | 79.80 | 79.83 | 79.94 | 80.01 | 80.22 |
| Chemical and Petroleum products manufacturing (1) | 10.13 | 9.99 | 9.82 | 9.62 | 9.65 |
| Non-metallic mineral products manufacturing (2) | 1.15 | 1.18 | 1.23 | 1.27 | 1.28 |
| Basic metal industry (3) | 8.12 | 8.09 | 8.09 | 8.07 | 8.24 |
| ×High Energy-Consumption Industries(1) + (2) + (3) | 19.39 | 19.25 | 19.14 | 18.97 | 19.17 |
| Services | 18.26 | 18.33 | 18.31 | 18.32 | 18.21 |

Table 3. Tariff and Non-Tariff Reduction Required by WTO

| | | Developed Countries | Developing Countries |
|---------------|------------------|---------------------------------|---------------------------------|
| Agriculture | Tariff | 36% | 24% |
| | Non-Tariff | 36% | 24% |
| | Domestic support | 20% | 13.33% |
| | Export Subsidy | 36% (or 21% cut in quantity) | 24% (or 14% cut in quantity) |
| Manufacturing | Tariff | 33.3% | 33.3 |
| | Non-Tariff | None | None |
| Chemicals | Tariff | 5%, 5.5%, or 6.5% | 5%, 5.5%, or 6.5% |
| | Non-Tariff | None | None |
| Zero-to-zero | Tariff | 100% | 100% |
| | Non-Tariff | 100% | 100% |

Source : Board of Foreign Trade, Republic of China.

Table 4. Exogenous Shocks for Forecasting From 1995 to 2005

| Macroeconomic variables | Unit: % | | | | | |
|------------------------------|---------|--------|--------|--------|--------|------------------------|
| | 1995 | 1996 | 1997 | 1998 | 1999 | 2000-2005 |
| Energy-saving decline rate | -0.31 | -0.16 | -0.08 | -0.15 | -0.6 | -0.6 |
| Imports | 9.78 | 6.03 | 13.74 | 6.34 | 4.38 | en-dog. ⁽²⁾ |
| Household consumption | 5.63 | 6.54 | 7.26 | 6.52 | 5.72 | endog. |
| Export | 12.35 | 6.74 | 9.08 | 2.41 | 9.59 | endog. |
| Investment | 7.31 | 1.67 | 10.65 | 8.01 | 2.24 | endog. |
| Government expenditure | 3.15 | 6.65 | 5.87 | 4.12 | -6.28 | endog. |
| Household ⁽¹⁾ | 3.01 | 3.49 | 3.02 | 2.68 | 1.55 | 2 |
| Employment | 3.51 | -1.15 | -1.66 | 4.12 | 1.56 | endog. |
| Aggregate price index | 3.68 | 3.07 | 0.90 | 1.68 | 0.42 | endog. |
| Exchange rate | 4.04 | 0.81 | 18.45 | 1.29 | 1.29 | endog. |
| Imports price index (c.i.f) | 9.12 | -1.90 | -0.11 | 2.22 | -2.95 | endog. |
| Exports price index | 6.23 | 1.29 | 1.24 | 3.83 | -6.11 | endog. |
| Primary factors productivity | endog. | endog. | endog. | endog. | endog. | -3 |

Source: DGBAS, Quarterly National Economic Trends.

Note: ⁽¹⁾ Because of the trend of household numbers is declining, we assume that the annual growth rate of household is 2% for year 2000 to 2005.

⁽²⁾ Endogenous solution

Table 5. Tariff Rate Reduction for Taiwan's WTO Accession

Unit : %

| Item | 1998 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---------------------------------|-------|-------|-------|-------|-------|-------|-------|
| All Industries | 8.22 | 7.28 | 6.61 | 5.93 | 5.75 | 5.58 | 5.55 |
| Agriculture | 20.02 | 15.21 | 14.33 | 13.45 | 13.26 | 13.07 | 12.92 |
| Manufacturing | 6.08 | 5.79 | 5.16 | 4.51 | 4.34 | 4.17 | 4.17 |
| Chemical and Petroleum products | 6.16 | 6.16 | 5.61 | 5.16 | 5.09 | 5.02 | 5.01 |
| Non-metallic mineral products | 8.43 | 8.42 | 7.68 | 7.31 | 7.12 | 6.94 | 6.94 |
| Basic metal industry | 6.07 | 6.07 | 4.65 | 3.61 | 3.05 | 2.45 | 2.45 |

Source : Ministry of Finance, Republic of China.

Table 6. Sectoral Comparison of the Simulation Results on Real GDP under Different Scenarios

| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|--------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| Baseline Forecasting | | | | | | |
| Real GDP (hundred million NT\$) | 96,139 (100.00) | 102,121 (100.00) | 108,315 (100.00) | 114,750 (100.00) | 121,362 (100.00) | 128,188 (100.00) |
| Share Structure (%) | | | | | | |
| Agriculture | 2.44 | 2.41 | 2.37 | 2.33 | 2.28 | 2.23 |
| Industry | 34.59 | 34.80 | 34.85 | 34.78 | 34.58 | 34.28 |
| Chemical and Petroleum products manufacturing (1) | 6.54 | 6.89 | 7.16 | 7.37 | 7.50 | 7.60 |
| Non-metallic mineral products manufacturing (2) | 0.93 | 0.92 | 0.89 | 0.86 | 0.83 | 0.81 |
| Basic metal industry (3) | 2.10 | 2.24 | 2.36 | 2.46 | 2.55 | 2.62 |
| ×High Energy-Consumption Industries (1) + (2) + (3) | 9.57 | 10.05 | 10.41 | 10.69 | 10.88 | 11.03 |
| Services | 62.97 | 62.79 | 62.77 | 62.89 | 63.14 | 63.49 |
| Tariff Rate Reduction³ | | | | | | |
| Real GDP (hundred million NT\$) | 96,139 (100.00) | 102,323 (100.00) | 108,698 (100.00) | 115,127 (100.00) | 121,670 (100.00) | 128,351 (100.00) |
| Share Structure (%) | | | | | | |
| Agriculture | 2.44 | 2.40 | 2.36 | 2.32 | 2.27 | 2.22 |
| Industry | 34.59 | 34.87 | 34.98 | 34.94 | 34.77 | 34.49 |
| Chemical and Petroleum products manufacturing (1) | 6.54 | 6.88 | 7.14 | 7.34 | 7.49 | 7.59 |
| Non-metallic mineral products manufacturing (2) | 0.93 | 0.92 | 0.89 | 0.86 | 0.84 | 0.81 |
| Basic metal industry (3) | 2.10 | 2.23 | 2.34 | 2.44 | 2.53 | 2.61 |
| ×High Energy-Consumption Industries (1) + (2) + (3) | 9.57 | 10.03 | 10.37 | 10.64 | 10.86 | 11.01 |
| Services | 62.97 | 62.73 | 62.66 | 62.74 | 62.96 | 63.29 |
| Joining the WTO⁴ | | | | | | |
| Real GDP (hundred million NT\$) | 96,139 (100.00) | 103,272 (100.00) | 110,726 (100.00) | 118,487 (100.00) | 126,495 (100.00) | 134,783 (100.00) |
| Share Structure (%) | | | | | | |
| Agriculture | 2.44 | 2.37 | 2.31 | 2.24 | 2.18 | 2.11 |
| Industry | 34.59 | 34.66 | 34.56 | 34.31 | 33.92 | 33.43 |
| Chemical and Petroleum products manufacturing (1) | 6.54 | 6.75 | 6.89 | 6.95 | 6.94 | 6.90 |
| Non-metallic mineral products manufacturing (2) | 0.93 | 0.90 | 0.86 | 0.82 | 0.79 | 0.76 |
| Basic metal industry (3) | 2.10 | 2.18 | 2.24 | 2.29 | 2.32 | 2.34 |
| ×High Energy-Consumption Industries (1) + (2) + (3) | 9.57 | 9.83 | 9.99 | 10.06 | 10.05 | 10.00 |
| Services | 62.97 | 62.96 | 63.13 | 63.45 | 63.91 | 64.46 |

³ Policy simulation without GTAP international trade shocks.⁴ Policy simulation with GTAP trade shocks from China's and Taiwan's accession to the WTO.

Source: Compiled from the results from TAIGEM[®]-D.

Table 7. Comparison of Energy Structure and Electricity Structure under Different Scenarios

unit : 10³ KLOE

| Year | Coal | | | Fuel Oil | | | Natural Gas | | | Nuclear | | | Hydro | | |
|------|----------|-----------------------|--------------------|----------|-----------------------|--------------------|-------------|-----------------------|--------------------|----------|-----------------------|--------------------|----------|-----------------------|--------------------|
| | Baseline | Tariff Reduc- tion | Joining the WTO | Baseline | Tariff Reduc- tion | Joining the WTO | Baseline | Tariff Reduc- tion | Joining the WTO | Baseline | Tariff Reduc- tion | Joining the WTO | Baseline | Tariff Reduc- tion | Joining the WTO |
| 1995 | 22970.3 | 22970.3 | 22970.3 | 31979.3 | 31979.3 | 31979.3 | 6574.4 | 6574.4 | 6574.4 | 8357.8 | 8357.8 | 8357.8 | 1680.2 | 1680.2 | 1680.2 |
| 1996 | 25038.9 | 25038.9 | 25038.9 | 33847.6 | 33847.6 | 33847.6 | 6985.9 | 6985.9 | 6985.9 | 9146.3 | 9146.3 | 9146.3 | 1801.6 | 1801.6 | 1801.6 |
| 1997 | 27419.8 | 27419.8 | 27419.8 | 36133.6 | 36133.6 | 36133.6 | 7572.3 | 7572.3 | 7572.3 | 10063.8 | 10063.8 | 10063.8 | 1945.2 | 1945.2 | 1945.2 |
| 1998 | 29414.7 | 29414.7 | 29414.7 | 38247.9 | 38247.9 | 38247.9 | 8114.2 | 8114.2 | 8114.2 | 10893.0 | 10893.0 | 10893.0 | 2070.8 | 2070.8 | 2070.8 |
| 1999 | 31597.0 | 31597.0 | 31597.0 | 40473.7 | 40473.7 | 40473.7 | 8728.4 | 8728.4 | 8728.4 | 11695.2 | 11695.2 | 11695.2 | 2202.8 | 2202.8 | 2202.8 |
| 2000 | 34156.1 | 34077.6 | 34096.6 | 43102.3 | 43028.0 | 43153.4 | 9444.5 | 9417.8 | 9443.0 | 12172.2 | 12172.2 | 12172.2 | 2306.1 | 2306.0 | 2306.0 |
| 2001 | 36264.0 | 36113.9 | 36103.0 | 45544.7 | 45419.8 | 45730.1 | 10049.6 | 9995.8 | 10053.8 | 12172.2 | 12172.2 | 12172.2 | 2347.4 | 2347.4 | 2347.4 |
| 2002 | 38269.0 | 38127.4 | 38066.5 | 47903.3 | 47796.9 | 48292.0 | 10632.3 | 10575.4 | 10663.9 | 12172.2 | 12172.2 | 12172.2 | 2389.6 | 2389.6 | 2389.6 |
| 2003 | 40228.9 | 40080.2 | 40017.0 | 50214.5 | 50082.8 | 50852.0 | 11212.0 | 11145.3 | 11285.9 | 12172.2 | 12172.2 | 12172.2 | 2432.6 | 2432.6 | 2432.6 |
| 2004 | 42130.8 | 41975.7 | 41891.8 | 52442.2 | 52276.3 | 53325.5 | 11798.4 | 11718.7 | 11916.7 | 12172.2 | 12172.2 | 12172.2 | 2476.3 | 2476.3 | 2476.3 |
| 2005 | 44004.4 | 43843.1 | 43719.3 | 54630.3 | 54418.5 | 55760.7 | 12413.6 | 12317.6 | 12579.9 | 12172.2 | 12172.2 | 12172.2 | 2520.9 | 2520.9 | 2520.9 |

Source: Same as Table 6.

Table 8. Sectoral Comparison of the Simulation Results on CO₂ Emissions under Different Scenarios

| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| Baseline Forecasting | | | | | | |
| CO₂ Emissions (million tons) | 233.47 (100.00) | 246.55 (100.00) | 259.04 (100.00) | 271.28 (100.00) | 283.17 (100.00) | 295.02 (100.00) |
| Share Structure (%) | | | | | | |
| Agriculture | 1.53 | 1.55 | 1.55 | 1.56 | 1.56 | 1.57 |
| Industry | 80.46 | 80.56 | 80.64 | 80.72 | 80.81 | 80.91 |
| Chemical and Petroleum products manufacturing (1) | 9.82 | 9.90 | 9.97 | 10.03 | 10.08 | 10.11 |
| Non-metallic mineral products manufacturing (2) | 1.29 | 1.28 | 1.27 | 1.24 | 1.21 | 1.19 |
| Basic metal industry (3) | 8.48 | 8.58 | 8.75 | 8.96 | 9.19 | 9.41 |
| ※High Energy-Consumption | 19.58 | 19.76 | 19.99 | 20.23 | 20.48 | 20.70 |
| Industries (1) + (2) + (3) | | | | | | |
| Services | 18.01 | 17.90 | 17.80 | 17.72 | 17.62 | 17.52 |
| Tariff Rate Reduction | | | | | | |
| CO₂ Emissions (million tons) | 233.47 (100.00) | 245.79 (100.00) | 258.44 (100.00) | 270.62 (100.00) | 282.45 (100.00) | 294.17 (100.00) |
| Share Structure (%) | | | | | | |
| Agriculture | 1.53 | 1.54 | 1.55 | 1.56 | 1.56 | 1.57 |
| Industry | 80.46 | 80.54 | 80.63 | 80.72 | 80.82 | 80.93 |
| Chemical and Petroleum products manufacturing (1) | 9.82 | 9.89 | 9.96 | 10.02 | 10.06 | 10.09 |
| Non-metallic mineral products manufacturing (2) | 1.29 | 1.28 | 1.27 | 1.24 | 1.21 | 1.19 |
| Basic metal industry (3) | 8.48 | 8.57 | 8.73 | 8.94 | 9.17 | 9.40 |
| ※High Energy-Consumption | 19.59 | 19.74 | 19.96 | 20.20 | 20.44 | 20.68 |
| Industries (1) + (2) + (3) | | | | | | |
| Services | 18.01 | 17.91 | 17.81 | 17.72 | 17.61 | 17.50 |
| Joining the WTO | | | | | | |
| CO₂ Emissions (million tons) | 233.47 (100.00) | 246.33 (100.00) | 259.14 (100.00) | 271.90 (100.00) | 284.29 (100.00) | 296.58 (100.00) |
| Share Structure (%) | | | | | | |
| Agriculture | 1.53 | 1.55 | 1.56 | 1.56 | 1.57 | 1.57 |
| Industry | 80.46 | 80.40 | 80.40 | 80.39 | 80.40 | 80.43 |
| Chemical and Petroleum products manufacturing (1) | 9.82 | 9.86 | 9.89 | 9.92 | 9.93 | 9.92 |
| Non-metallic mineral products manufacturing (2) | 1.29 | 1.27 | 1.25 | 1.22 | 1.19 | 1.16 |
| Basic metal industry (3) | 8.48 | 8.52 | 8.64 | 8.80 | 8.97 | 9.13 |
| ※High Energy-Consumption | 19.59 | 19.65 | 19.78 | 19.94 | 20.09 | 20.21 |
| Industries (1) + (2) + (3) | | | | | | |
| Services | 18.01 | 18.05 | 18.05 | 18.04 | 18.03 | 18.00 |

Source: Same as Table 6.

5. Conclusions

In this paper TAIGEM-D model is used to address mitigation policy issues. Simulation results performed in this study provide insight into how global warming mitigation policies may affect the performance of the Taiwan economy and her industries. The results of our policy simulations suggest that the energy efficiency improvement policy and the energy substitution policies together are not sufficient to reduce Taiwan's CO₂ emissions in 2020 back to the government-proposed target at 2000 level. Incentive-based mechanism like Carbon taxes or the tradable permit system has to be adopted to induce the required additional CO₂ emission reduction in 2020. Generally speaking, simulation results demonstrate that the economic impacts of these CO₂ reduction policies, especially, the imposition of carbon taxes, on the Taiwan economy are significant.

This paper investigates the potential impact of China's and Taiwan's accession to the WTO on Taiwan's international trade, industrial structure, energy demand and greenhouse gas (GHG) emission during 2001-2005. Two large applied general equilibrium models, GTAP and TAIGEM, are used in this paper to simulate China's and Taiwan's WTO accession. TAIGEM (TAIwan General Equilibrium Model), a dynamic, multisectoral, applied general equilibrium model of the Taiwan's economy is developed specifically to analyze climate change response issues. TAIGEM is derived from the ORANI model (Dixon, Parmenter, Sutton and Vincent, 1982) and the MONASH model. In this paper we use GTAP to provide the global context for the WTO accession, and TAIGEM to assess the detailed impacts on Taiwan.

It shows that the comparative advantages of China and Taiwan are in different economic sectors. In average, Taiwan's economic growth will increase yearly at 0.4% above the baseline projection for the period 2001-2005. Service sector is expected to grow. Its share of real GDP will increase from 62.97% to 64.46%. In contrast, agriculture and industry sectors are the losers. In particular, sectors related to fossil fuel, cement, and iron and steel will contract due to less international competitiveness. With reduction of coal consumption and increasing share of gas and oil consumption, CO₂ emission level is expected to be at the level of 296.6 million tons that is higher by 1.6 million tons than the baseline projection level at 295.0 million tons

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