

SHORT-TERM IMPACTS OF THE ‘TOTAL-LOAD-CONTROL’ POLICY ON CO₂ EMISSIONS: A CASE STUDY IN TAIWAN

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Abstract

Following the 1997 Kyoto Protocol, CO₂ emission control has become one of the most important issues in the debate surrounding methods of limiting greenhouse gas emissions. Whilst there are, in fact, many economic and non-economic instruments available for use in implementing the Kyoto Protocol's basic commitments on CO₂ emission control, the aim of this paper is specifically to simulate the short-term impacts of the ‘total-load-control’ policy.

The paper develops an energy/environmental computable general equilibrium (CGE) model at different periods (1991 and 1996) to simulate the effects of the ‘total-load-control’ policy on CO₂ emission control in Taiwan. Even with the adoption of a policy with a uniformly reduction rate of total CO₂ emissions for the next 20 years, the empirical evidence of this paper demonstrates that inconsistencies exist in the prospective results with regard to the short-term impacts on industries and national economy. Energy production industry and final demand sector will have seriously negative impacts compared with other energy-intensive industries. This may disappoint those engineers and policy-makers who strongly favor the idea of a ‘total-load-control’ policy, but they may not have considered the automatic adjustment effect, which is already in-built in this economy.

Keywords: CGE, Energy, CO₂ emissions, control policy

1. Introduction

Over the decades, Taiwan has placed particular stress on economic development and industrial policies but overlooked environmental protection. Along with the creation of an economic miracle, considerable destruction on the environment people have relied upon for subsistence had occurred. At the same time, huge quantities of energy have been consumed to support industrial development. This has led to worsening environmental quality (e.g., air and water pollutions) and further reliance on import of energy sources (i.e., over 95% of energies are imported). As Taiwan moves towards becoming one of the newly developed country and with growing importance on global environmental protection awareness issues, the possible impact environment and energy problems it may caused to our country can no

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longer be ignored. There is a need to look over the 3-Es (economy/energy/environment) problems as early as possible and think of a solution to maintain sustainable development.

Following the 1997 Kyoto Protocol, reduction in CO₂ emission levels has become one of the important topics for environmental protection worldwide. In considering sustainable development for Taiwan, there is a need to conduct a review on the past energy and industrial policies to respond to future reduction in CO₂ emissions. In recent years, the government has become aware of the importance of sustainable development and has made appropriate adjustments in industrial development policies. Improvements in industrial policies concerning requirements and standards for polluted emission and energy conservation have been made. However due to lack of coordination between policy design and reality of market structure, there is still a discrepancy in the development of overall energy-intensive industries. Thus, with continuous development in energy intensive industries, the government has failed the commitment for improving the energy mix structure and controlling the energy intensity in recent years (Yu et-al., 1992; Wang, 1996). This is the basic reason why general public and experts cast doubts on the timeliness of industrial policy and consistencies in energy and environmental protection policies.

The objective of this paper is to use an energy/environment computable general equilibrium (CGE) model to study the interrelationship among 3-Es and simulate the short-term effects of CO₂ 'total-load-control' policy on the economy of Taiwan. The basic research procedures are: (i) collect relevant domestic and foreign references relating to CGE analysis and tools for reducing carbon dioxide emissions; (ii) setup an energy/environment input-output (IO) database in Taiwan for the years of 1991 and 1996, use carbon dioxide emission coefficient to calculate carbon dioxide emissions generated for use of energy in various sectors; (iii) construct the CGE model by using the economic theory and simulate carbon dioxide emission total load control and its short-term impact on the economy; (iv) conduct a comparison on the short-term effects for 1991 and 1996, under the same reduction rate as well as result of relative research of carbon tax. The present paper is divided into the following sections: Introduction, Review of past studies, Model structure, Data description, Simulations, and Conclusions.

2. Review of Past Studies

As mentioned above, the topic of this paper involves interaction on issues relating to energy, environment, and economic policies. It encompassed a broad scope of disciplines that include economy, sociology, biology, engineering, and science for which numerous studies were conducted. This paper provides an overview of reference related to CGE model and economic tools to reduce CO₂ emissions as follows.

For local studies, Bor (1994) used an applied general equilibrium model to assess the impact of fluctuation of energy prices on the economy and industries. This is the very first

CGE study of Taiwan's energy problem. However, due to the government-owned and monopoly of energy market, the impact of energy price fluctuations have limited impact on the local economy.

Lin (1995) constructed a 16-sectors CGE model to analyze the impact of fuel/energy tax on the welfares of the various income level groups. After simulated several types of fuel and energy taxation instruments, the paper showed that carbon tax is the best strategic tool. However, from the perspective of household benefit, all energy taxes will increase the burden of low-income groups. The author also recommends that government should have accompanying remedial measures to maintain social equality while imposing fuel/energy tax policies.

Lee (1997) also used a CGE model to simulate impact caused by carbon tax on Taiwan's economy. It combines the energy and environmental policies. The model revealed that prevention and control of global greenhouse effect has a significant negative impact on Taiwan's economy and its energy industries.

Hsu (1997) used the GTAP model (GTAP, 1996) to review carbon-leaking problems and found out that Taiwan does not benefit, as carbon tax will cause a decline in GDP. In addition, Huang et al. (1999) used a CGE model (Dixon et al., 1993) to assess the impacts of carbon tax and the result revealed that cost of carbon tax to reduce carbon emissions is lower than the costs of other tax instruments. The basic structure of their model is more or less the same as structure of the Australian ORANI model (Dixon et al., 1993).

There are many similar CGE studies of energy/carbon tax for other counties or area, such as Boyd et al., (1995), Dessus and Bussolo (1998), Frandsen et al., (1996), Parry and Williams (1999), Robinson et al., (1993), and Winter et al., (1998) during this decade. However, among a great number of references, it was found that most of the studies of CGE models were focused on the instruments of carbon tax and quota. Almost none were focused on a 'total-load-control' policy instrument that environmental engineers strongly favored the idea. This is one of the reasons behind this study.

3. Model Structure

Basically, the structure of this model is similar to the structure of ORANI model (Dixon et al., 1982) and Bor (1996). In order to suit the research objective, it has been modified to conduct the 'total-load-control' of CO₂ emissions. Like the ORANI model and most of the CGE studies, this model used the Johansen (1960) method to find the solutions of general equilibrium model. Equations of a typical Johansen style model can be divided into 5 groups: (i) final demand sectors, (ii) production sectors, (iii) zero pure profit conditions, (iv) market clearing conditions, and (v) other useful equations. Please refer to Figure 1 and 2 for a basic idea of the model structure and refer to Dixon et al., (1982) and Bor (1996) for the detailed specification of all key mathematical equations.

In this model, it was assumed that labor and capital are the only two primary inputs.

For production sectors, there were 13 industries (see next Section), of which petroleum industry provided 4 kinds of sub-products (gasoline, diesel, fuel oil, and other oil products), and the remaining industries produced only one product. With respect to the petroleum industry, consideration should not only be given on how to allocate various input and factors of production but also consider the allocation of the consumption of its products.

There are several special characteristics of that this CGE model as follows. First, In terms of calculating the CO₂ emissions from the demand side of final energy products and intermediate energy inputs, this model has perspectively divided the energy products into 7 kinds of energies: coal, natural gas, electricity and the above 4 oil products. This differed with most of other studies conducted by Lin (1995), Lee (1997), Hsu (1997), and Huang (1999). They have tried to calculate CO₂ emissions from the supply side of primary energies (e.g., steam or coking coal and crude oil). Both methods are notable by the Intergovernmental Panel of Climate Change (IPCC, 1996); however, the demand side calculation is more precise and needs detailed data preparation requirements. On the other hand, the supply side calculation from primary energies is much easier than calculation from demand side and is simple in comparison between counties because not every country has complete energy balance table or sufficient data. Actually, the primary energy data is usually not consistent with the flow of IO tables. Thus, it needs to setup a supplementary primary energy table to calculate the CO₂ emissions, and this will cause miss-specification problems in combining with the IO tables for CGE models. Second, this asymmetrical CGE model (16 by 13) includes 7 major energy products and 4 major energy-intensive industries that are quite sufficient for a small open economy as Taiwan. The consumption of gasoline, diesel, and fuel oil together occupy the share of over 62% out of total consumption of petroleum products. In addition, the energy consumption of four major energy-intensive industries (i.e., textiles, chemical products, nonmetallic mineral products, and basic metal products) have the share of over 83% out of total energy consumption of industrial sector. In terms of industrial classification, can largely be divided into energy industry, energy-intensive industries, and other non-energy-intensive industries, add to that final demand sectors. Third, this model has a comparatively detailed design in terms of final demand sectors for energy consumption (see Figure 2). Moreover, the model itself adopts very simple equations to describe the interaction between variables, such as Leontief and Cobb-Douglas functional forms (see Figures 1 and 2); thus, a large section of the coefficient can be automatically generated. Unlike previously mentioned other domestic CGE model studies (Hsu 1997 and Huang et al. 1999), where a large portion of parameters followed assumptions made by foreign models and considerably lose its reality. Finally, as Taiwan is a small open economy, approximately 95% energy supply is mostly reliant upon imports, thus Taiwan virtually has no influence on international (energy) market (see Table 1 for an intuitive observation). Practically and theoretically, a single-country model will be adequate to search for a large portion of the possible impact of CO₂ emission reduction policy.

4. Data Description

4.1 Input Output Data

The empirical data used in this paper was mostly IO tables in Taiwan for year 1991 (150 sectors) and 1996 (160 sectors) published by Directorate-General of Budgets, Accounting, and Statistics (DGBAS 1991 and 1996). Data for year 1996 were the latest IO table that can be obtained during the research period, followed by data for year 1991. The three major sub-tables needed for this paper include Transactions Table at Producers' Price (Excluding Net Import Duties), Transactions Table of Domestic Goods and Services, Transactions Table of Import Goods and Services (C.I.F. + Net Import Duties). The following provides a brief description of methods for combining and adjusting the IO tables:

1. Combining IO Tables

Industries are classified into 13 sectors (see Table2): agriculture, Mining and primary energy, textiles, chemical products, nonmetallic and mineral products, basic metal products, other industries, coal industries, petroleum products, natural gas, electricity, transportation and services. Petroleum products can be divided into four sub-categories: gasoline, diesel, fuel oil, and other petroleum products. A total of 16 product categories have been subjected to analysis. In subdividing petroleum products, we adopted 4 kinds of sub-products (i.e., gasoline, diesel, fuel oil and other petroleum products) out of the IO tables of the 569 sectors (1991) and the 596 sectors (1996). The reason for adopting subdivided petroleum products is for demand side analysis of energy consumption. First, combine the tables of the 150 sectors (1991) and the 160 sectors (1996) into 13 sectors tables separately. There is only a need to add the elements of corresponding rows and columns of sectors that will be combined.

2. Adjustment of IO Table

By combining industrial sectors as mentioned above, the present paper obtained its fundamental database. Some adjustments were made to meet model requirements. First, territorial exports and non- territorial exports in Transactions Table of Domestic Goods and Services combined as exports. Fixed capital formation and inventory changes in Transactions Table at Producers' Price and Transactions Table of Import Goods and Services were combined as domestic investment. In addition, operating surplus and depreciation in Transactions Table at Producers' Price were combined as capital. Then the IO database was ready for solving at the software of GEMPACK (Impact Project and KPSOFT 1993). An adjusted IO database was compiled as shown in Table 1.

4.2 Data on Carbon Dioxide Emissions

As the objective of this paper lies in reviewing the effects of 'total-load-control' instrument on reduction of carbon dioxide emission, thus in addition to IO tables, there is still a need for data on carbon dioxide emission levels. In this paper, carbon dioxide emission

levels produced by each industry is obtained by multiplying consumption quantity of energy products of each industry with corresponding carbon dioxide emission coefficients. Thus, for simplicity, the carbon dioxide emission coefficients of other commodities except for energy products have been set at zero. In this way, the present paper is focus on the carbon dioxide emission from energy products only (note that it is about 95% of total carbon dioxide emission in Taiwan). Carbon dioxide coefficients of each energy products are obtained by referring to EnFore-C model (see below and Bor et al. 2000).

The EnFore (Energy Forecast) system (Bor et al., 2000) was developed since 1995 for the Energy Commission, Taiwan. The basic function of EnFore system is to provide short-term (12 months), medium-term (8 seasons), and long-term (25 years) energy demand and supply forecasts. It is a hybrid and computerized system of econometrics, statistics, and engineering models. One of the emphases of EnFore system structure is its ability of estimating and providing the emission level of CO_2 for both supply- and demand-sides.

With respect to CO_2 emitted by the electricity, the system hold on to the “polluter pays principle (PPP)” which believed that end user of each sectors shall share carbon dioxide emissions generated by the power generation based on the power mix of different fuels. By referring to IPCC (1996) energy consumption basis, the system developed the EnFore-C (Carbon) method. A brief description of the method is as follows:

1. Establish database of calorific values, carbon emission fractions, carbon oxidation fractions, and carbon-stored rates of each energy.
2. Refer to IPCC computation method for CO_2 , calculate historical level of CO_2 emission of each industry based on carbon dioxide emission fractions of energies (according to the classification of Energy Balances in Taiwan (EC 2000).
3. Fuels for power generation also obtained from Energy Balances in Taiwan, and based on carbon emission fraction of each kinds of fuel, calculate CO_2 emission of electricity. Then based on final consumption of electricity in each industry, CO_2 emission levels can be measured.
4. The method for estimating CO_2 emission level of co-generation is similar to the power generation.
5. Add up CO_2 emission levels under items (3) and (4) will be the total emission level for power generation.
6. Industrial CO_2 emission levels can be calculated based on the energy consumption of coal, oil, gas, and electricity.

The computation result of above method is as shown in Table 1.

Based on EnFore-C estimation, the total emission of CO_2 is about 226.548 million tons in year 2000 (see Figure 3). Of which, the industrial sector holds the largest bulk of total emission level at 49.3%, followed by transportation sector 17.5%. Next in line are household sector 12.4%, energy sector 6.4%, business sector 6.0%, and other sectors 6.2%. Agricultural sector only holds 1.6% of total emissions and the remaining is non-energy use at

0.6%.

Among industrial sector, iron and steel industry tops the list by holding 16.0% of total emission volume. Other industries hold second at 13.0%, chemical material industry at 10.0%, ratio of which is very high, others such as textile industry hold 4.2% of total emissions, cement industry 3.8%, and paper and printing industries 2.3%.

If divided by energy, CO₂ emission levels of electricity are highest at 45.6% in year 2000.

Petroleum products placed second at 34.1%, followed by coal at 17.5%, natural gas 2.7%.

While electricity is a clean energy at end user, however, based on PPP, EnFore-C calculate CO₂ emission levels based on fuel consumption during the power generation process. This is the reason that electricity generates emission level tops the list in CO₂ emission structure.

4.3 Reciprocals of the Export Demand Elasticity

Since this model treats the rest of the world as a big unknown sector, there is a need to estimate the foreign elasticity of demand for each commodity. Bor (1996) has estimated these export demand elasticity for the above 16 commodities (see Table 1), with the assumption that within the short term, there is not much change in Taiwan's international trading structure. Actually, from Table 1, it reveals that Taiwan has very little influence to world market for most of the commodities. Again, this support that Taiwan is basically a small open economy. A single-country CGE study would have pretty much enough solutions for most of interested CO₂ emission control problems as one in this paper. The figures in Table 1 represent the ratio of value of domestic products' export on total value of similar products around the world. Meanwhile, export of electricity sector refers to labor services output of power generation industry.

5. Simulations

In this section, the software of GEMPACK (Impact Project and KPOFT 1993) has been used to solve the simulations. Before that, like most of the standard CGE studies, this model have more variables (1,343) than equations (1,215), thus 128 exogenous variables have to be selected from the model in order to solve the system. The principle of selecting exogenous variables or interested policy variables is as follows and the result is shown in Table 2.

5.1 Principle for Setting Policy Variables

The major focus of this paper is concerning the effect of 'total-load-control' instrument on reduction of CO₂ emission levels, thus total CO₂ emission was selected as a key exogenous variable. Meanwhile, as mentioned above, Taiwan is a small open economy and She has no control power on the prices of imported products ($P_{(i,j,2)}^*$), thus, it was assumed as exogenous variables. In addition, indirect taxes paid by each sectors (T_q), import tariffs ($V_{(i,j,2)}$), export

subsidies ($V_{(i,j,1)}$), and real consumption of household sector (C_R), are often used by the government as policy tools, thus they have been selected as exogenous variable. Export demand shift variables ($F_{(i,j,1)17}$) represent the change of the demand of world market that is something Taiwan cannot control, thus they have been assumed as exogenous variables. This paper has set the wage shift variable ($F_{(14,14,1)}$) as an exogenous variable to look at the change of real wage rate. This model choose exchange rate Φ as a numeraire and exogenous variable. Of course other price variables (e.g., rate labor wage rate ($P_{(14,14,1)}$) or consumer price index (CPI)) could also be chosen as numeraire according to the needs of researchers. Since the model is not a dynamic CGE model that emphasizes the behavior of investment, thus, capital of each industry (K_q) and domestic investment ($X_{(i,j,k)16}$) are assumed as exogenous variables.

5.2 Policy Analysis

After selection of adequate exogenous or policy variables in the above section, the model can conduct a policy simulation to study the impact of implementation of ‘total-load-control’ CO₂ emission in Taiwan.

According to the forecast of EnFore system (Bor et al., 2000) the total CO₂ emission in year 2020 will be 427.667 million tons due to the consumption of energy. Suppose there is a ‘total-load-control’ policy that demands CO₂ emission has to be reduced back to year 2000 levels within the next 20 years. That is, government will not allow further CO₂ emission by admitting to the reality of status quo. By this way, it can reduce the political conflicts between government and industries to the lowest situation. The average annual reduction rate in ‘total-load-control’ of carbon dioxide is about 3.497%. Under this design of policy impact, the above CGE model was used to solve short-term effects for 1991 and 1996. Results are shown in Table 3. The basic reasons for the cross-period (1991 and 1996) comparative checking are: (i) to observe the differences of economic structure changes in two points in time; and (ii) to verify the stability and reliability of the model.

Among the 1,215 endogenous variables, this paper selected 4 directions to analyze the simulation result: (i) general macroeconomic variables such as total domestic product (TDP), gross domestic product (GDP), imports (IM), exports (EX), household income ($\bar{C}$), tax revenues ($\bar{T}$), and labor demand (L); (ii) domestic price variables such as consumer price index (CPI), wholesale price index (WPI), and energy price index (EPI); (iii) changes in

industrial labor demand; and (iv) changes in CO₂ emissions of industries.

1. Impact on Macroeconomic Variables

Simulation results obtained from data of year 1991 and Year 1996 revealed that it has similarly negative short-term effects on the economy of Taiwan, and the impacts are relatively greater for year 1991 than the impacts for 1996 (see Table 3). Take the GDP as example, the impact of year 1991 is -1.139% and the impact of year 1996 is -0.330%. This revealed that policy of 'total-load-control' CO₂ emission would hurt the economy badly in production, income, tax revenue, and international trade. Fortunately, due to the change of economic structure (e.g., emphasize with the development of high-tech and low-pollution industry and services sector and encourage the use of low-carbon fuel, liquefied natural gas), the negative impact has considerably decreased. The later economy is not so fragile compared to old economy. The only positive result is the total demand of labor. They have increased slightly 0.078% in 1991 and 0.051% in 1996. First, the present CGE model adopts a non full-employment assumption. Since labor is the only endogenous variable of two primary inputs (i.e., capital has been chosen as a exogenous variable), it represents the endowment of social resources in this model. Once the policy of 'total-load-control' CO₂ emission has executed, the resource (labor) will flow out from those uncompetitive (i.e., high labor cost) sectors to those relatively competitive (low labor cost) sectors. In this case, the total demand of labor increases in both the cases of 1991 and 1996 (see following section for further analysis).

2. Impact on Domestic Price Levels

From Table 3, reduction of a 3.497% in total CO₂ emission control for years 1991 and 1996 have mostly led to decline in domestic price levels, such as CPI, WPI, and EPI. For example, in 1996, CPI decreases in -0.025%, WPI decreases in -0.140%, and EPI declines for -0.139%. Thus, it shows that the major source of the fall of price levels is coming from the decline in energy products, such as coal, oil, gas, and electricity. This phenomenon reflects the bleak conditions of energy industries after being subject to direct control. This situation does not conform to the general conclusion of above carbon tax studies that it will lead to full-scale increase in energy prices. This can be expected because the functional setting of the carbon-tax CGE models. By largely increase the energy prices (i.e., add up a carbon tax) so as to decrease the profit of industries and reach the purpose of controlling CO₂ emission. Empirical analysis revealed that it was evident 'total-load-control' and 'carbon tax' tools have the same objective as policy for controlling CO₂ emissions. However, their economic impacts are not the same.

3. Impact on Labor Demand

First, following the basic reason as mentioned above, the total demand of labor increases slightly. For details, Table 3 also shows the flow of labor force between industries. In 1991, the major flow of labor demand transfers from petroleum products, natural gas, and electricity

industries to all other industries, of which mainly are the chemical products industry and other industry and agricultural, transportation, and services sectors. Nevertheless, in 1996, the labor demand flows out from every energy and energy-intensive industries to other industry and agricultural, transportation, and services sectors. This result shows that low carbon-intensive industries or sectors increase labor inputs to substitute energy inputs due to the control of CO₂ emissions. This would serve to be a driving force to increase total demand of labor employment. Of course, this is the condition under non full-employment assumption of this model.

4. Impact of CO₂ emissions of industries

In order to reach the reduction target of 3.497% in total CO₂ emissions, each industry or sector has to adjust the combination of inputs used for its production and consumption according to the market conditions (e.g., prices, incomes, and substitution and income effects). The situation becomes more complicated. In 1991, the target is achieved mainly because of the reduction of petroleum products and electricity industries and the final demand sectors (i.e., household and government). In 1996, most of the energy and energy-intensive industries are all being forced to restrict their emission of CO₂ except the agriculture sector, other industries, transportation sector, services sector, and coal products industries. For natural gas industry, the time of year 1991 is highly crucial because after 1991 Taiwan has dramatically increase the use of liquefied natural gas (from 855.629 million M³ to 2,070.447 million M³ at that year) for household and power generation. For 1996, the consumption of liquefied natural gas has already up to 3,435.516 million M³. Although the CO₂ emission fraction of natural gas is less than the emission fractions of coal and oil products (see Table 1), under the pressure of cutting down of total CO₂ emissions, the effects of natural gas industry has changed from positive in 1991 to negative in 1996. The story of coal products industry is quite different. On the other hand, coal have the highest CO₂ emission fractions among all the energy products (see Table 1), however, the price (cost) of coal is also the lowest one compared to other energies (i.e., about 59% of oil and 44% of gas). From the empirical result of Table 3, the impacts of coal products industry are positive for both 1991 and 1996, that is, it relatively creates more CO₂ emission. This result implies it is very hard to replace the demand of coal because of the substitution effect among energies. For final demand sectors, there is no way out but to cut down the CO₂ emission due to the control policy because they consume a lot of oil, gas, and electricity products.

In the end, the policy of ‘total-load-control’ on CO₂ emission has caused relatively bigger effects on energy industries, especially on the petroleum products and natural gas industries, and final demand sectors but do not necessarily have expected large impacts on energy-intensive industries. If the government adopted the ‘total-load-control’ policy, it needs to understand the empirical evidence of the present study and the fact of comparative advantage competition among industries that does not necessary produce consistent results as

originally monotone planning and prospect.

5. Conclusions

In summary, the policy of ‘total-load-control’ of carbon dioxide emissions has a considerably harmful impact on the overall economy in short-term, and it will re-allocate the resources as a result of free competition among industries as shown in this paper. However, ‘total-load-control’ policy is a fairly simple, strong, and yet effective control strategy for government and environmental engineering. It would be proper for the government to consider adopting an evenly progressive control strategy for CO₂ emission control for avoiding a crush down of the economy. From the CGE model, we could understand that that reducing CO₂ emissions in a very large amount or zero-emission policy is illogical and does not conform to actual conditions of the real world. Although the economic structure changes gradually in according to the growing demand of environmental protection, industry itself has the limit to withstand the huge shock in the short-term (i.e., system has break down).

In the long term, the question on whether reduction of the same level of carbon dioxide emissions each year under ‘total-load-control’ policy would be able to continuously duplicate short-term effects has be confirmed by further development of a dynamic CGE model. However, the task is not easy for a large numerical model. Often, it will end-up with no solution when the variables of model involved are too many and too complex (e.g., nonlinear system). In the future, we hope it will have a breakthrough in both the theorem and application.

6. References

- Bor, Yunchang Jeffrey (1994), A Study on the Impact of Energy Price Changes on Taiwan’s Economy, Energy Commission, Taipei.
- Bor, Yunchang Jeffrey (1996), "The Impact of Energy Pricing Policy on Taiwan’s Small Open Economy", *Asian Economic Journal* 10(1), pp.61-81.
- Bor, Yunchang Jeffrey, Shi-Ming Liu, Hsiao-Chi Chen (2000), Energy Forecasting (EnFore) System for Taiwan, ROC: Supply Side Modeling, Energy Commission, Taipei.
- Boyd, R, K Krutilla, and W.K. Viscusi (1995), " Energy Taxation as a Policy Instrument to Reduce CO₂ Emissions - A Net Benefit Analysis ", *Journal of Environmental Economics and Management*, Vol 29, Iss 1, pp 1-24.
- Brendemoen, A. and H. Vennemo (1994), “A Climate Treaty and the Norwegian Economy - A Cge Assessment”, *Energy Journal*, Vol 15, Iss 1, pp 77-93.
- Dessus, S., and M. Bussolo (1998), "Is there a Trade-Off Between Trade Liberalization and Pollution-Abatement - A Computable General Equilibrium Assessment Applied to Costa-Rica", *Journal of Policy Modeling*, Vol 20, Iss 1, pp 11-31.
- DGBAS (1991), 1991 Input-Output Tables – Taiwan Area, R.O.C., Directorate-General of Budget, Accounting, and Statistic, Taipei.

- DGBAS (1996), 1996 Input-Output Tables – Taiwan Area, R.O.C., Directorate-General of Budget, Accounting, and Statistics, Taipei.
- Dixon, P.B., B.R. Parmenter, J. Sutton, and D.P. Vincent (1982), ORANI: A Multisectoral Model of the Australian Economy, Contributions to Economic Analysis, Vol. 142, North-Holland, Amsterdam.
- EC (2000), 2000 Energy Balance Table – Taiwan Area, R.O.C., Energy Commission, Taipei.
- Frandsen-SE, J.V. Hansen, and P. Trier (1996), "The Computable General Equilibrium-Model Gesmec and Its Application to Quantifying the Macroeconomic Impacts of a CO₂-Tax", *Nationaløkonomisk Tidsskrift*, Vol 134, Iss 3, pp 272-289.
- Gottinger, H. W. (1998), "Greenhouse-Gas Economics and Computable General Equilibrium", *Journal Of Policy Modeling*, Vol 20, Iss 5, pp 537-580.
- Hertel, Thomas W. (1997), *Global Trade Analysis: Modeling and Applications*, Cambridge University Press: Cambridge.
- Hsu, Shih-Hsun (1997), "A Review of the Cost-Benefit Analysis of Carbon Tax", proceedings, the Conference of Economic Tools and their Impacts on Global Warming Effect, The Center of Sustainable Development, National Tsing-Hua University: Hisn-Chu, Taiwan.
- Huang, Chung-Huang, Ping-Cheng Li, Shih-Hsun Hsu, et-al. (1999), The Cost-Benefit Analysis of Greenhouse Gas Reduction: The TAIGEM Model and its Economic Assessment, The Center of Sustainable Development, National Tsing-Hua University: Hisn-Chu, Taiwan.
- Impact Project and KPSOFT (1993), *Gempack User Documentation*, Center of Policy Studies, Monash University, Australia.
- IPCC (1996), *Greenhouse Gas Inventory Reporting Instructions*, Intergovernmental Panel on Climate Change, United Nations, Washington D.C.
- Jaffe, Adam B and Robert N. Stavins (1995), "Dynamic Incentives of Environmental Regulations: The Effects of Alternative Policy Instruments on Technology Diffusion..", *Journal of Environmental Economics & Management*. Vol. 29 (3). p S43-63. Part 2.
- Jahanson, L. (1960), *A Multisectoral Study of Economic growth*, North-Holland, Amsterdam.
- Jorgenson, D. W. and P. J. Wilcoxon (1993), "Reducing U.S. Carbon Dioxide Emission: An Assessment of Different Instruments", *Journal of Policy Modeling* 15(5&6), pp.491-520.
- Kokoski, Mary F. and V. Kerry Smith (1987), "A General Equilibrium Analysis of Partial-Equilibrium Welfare Measures: The Case of Climate Change", *American Economic Review*, 77:3, pp.331-341.
- Koutstaal, Paul (1997), "Economic policy and climate change: Tradable permits for reducing carbon emissions", *New Horizons in Environmental Economics series*. Cheltenham, U.K. and Lyme, N.H.: Elgar; distributed by American International Distribution Corporation, Williston, Vt. p viii, 184.

- Lee, Ping-Cheng (1997), "The Policy of Mitigation of Greenhouse Gas and Its Economic Impact on Taiwan", proceedings, the Conference of Economic Tools and their Impacts on Global Warming Effect, The Center of Sustainable Development, National Tsing-Hua University: Hisn-Chu, Taiwan.
- Lin, Shih-Mo (1995), "Fuel Taxes in Taiwan: Welfare Impacts on Region and Socioeconomic Groups", Department of International Trade, Chung-Yuan Christian University: *Working Paper*.
- Nestor, D.V. and C. A., Pasurka (1995), "Cge Model of Pollution-Abatement Processes for Assessing the Economic-Effects of Environmental-Policy", *Economic Modelling*, Vol 12, Iss 1, pp 53-59.
- Parry, Ian W.H., Williams, R.C.(1999), "A Second-Best Evaluation of Eight Policy Instruments to Reduce Carbon Emissions", *Resource and Energy Economics*, 21, pp.347-73.
- Robinson, Sherman, Subramanian, Shankar, and Geoghegan, Jacqueline(1993)," A Regional, Environmental, Computable General Equilibrium Model of the Los Angeles Basin", University of California at Berkeley Department of Agricultural and Resource Economics Working Paper: 646. p 22.
- Wang, Kimmie K. M. (1996), A Study of Energy Consumption in Taiwan's Energy-Intensive Industries, Energy Commission, Taipei.
- Winters, P., R. Murgai, E. Sadoulet, A. Dejanvry, and G. Frisvold (1998), " Economic and Welfare Impacts of Climate-Change on Developing-Countries ", *Environmental & Resource Economics*, Vol 12, Iss 1, pp 1-24.
- Yu, Tzong-Shian, George J. Y. Hsu, Li-Ming Xui (1992), A Study of Energy-Intensity in Taiwan, Energy Commission, Taipei.

Table 1. CO₂ emission fractions & reciprocals of the export demand elasticity

Number	Commodities	COEF _(i,j)	$\gamma_{(i,j)}$
1	Agriculture	0	0.00435
2	Mining & primary energy	0	0.00081
3	Textiles	0	0.10137
4	Chemical products	0	0.03083
5	Nonmetallic mineral products	0	0.02059
6	Basic metal products	0	0.00484
7	Other industries	0	0.02349
8	Coal products	3.8483	0.00109
9 ₁	Gasoline	2.5851	0.0001
9 ₂	Diesel	2.7629	0.00198
9 ₃	Fuel oil	2.8862	0.01314
9 ₄	Other petroleum products	1.6928	0.00628
10	Natural gas	1.9841	0.0001
11	Electricity	2.3456	0.00086
12	Transportation	0	0.0001
13	Services	0	0.0001

Note: CO₂ emission fractions (COEF_(i,j)); reciprocals of the export demand elasticity ($\gamma_{(i,j)}$)

Table 2. Exogenous variables

Variables	Domain	Numbers	Description
CO_2		1	Total carbon dioxide Emissions
$P_{(i,j,2)}^*$	$i = j = 1, \dots, 8, 10, \dots, 13,$ $i = 9, j = 9_1, \dots, 9_4.$	16	Prices of imported commodities (foreign currency)
T_q	$q = 1, \dots, 17.$	17	Indirect tax
$V_{(i,j,2)}$	$i = j = 1, \dots, 8, 10, \dots, 13,$ $i = 9, j = 9_1, \dots, 9_4.$	16	1 plus ad valorem rate of tariff
$F_{(i,j,1)17}$	$i = j = 1, \dots, 8, 10, \dots, 13,$ $i = 9, j = 9_1, \dots, 9_4.$	16	Export demand shift variable
$F_{(14,14,1)}$		1	Wage shift variable
C_R		1	Real consumption of household sector
Φ		1	Exchange rate of currency
$X_{(i,j,k)16}$	$i = j = 1, \dots, 8, 10, \dots, 13,$ $i = 9, j = 9_1, \dots, 9_4; k = 1, 2.$	32	Domestic investment
K_q	$q = 1, \dots, 13.$	13	Capital
$V_{(i,j,1)}$	$i = j = 1, \dots, 8, 11, \dots, 13,$ $i = 9, j = 9_2, \dots, 9_4.$	14	1 plus ad valorem rate of subsidy
Total = 128			

Note: The ad valorem rate of export subsidies is zero.

Table 3. Impacts of ‘total-load-control’ CO₂ emissions in year 1991 and 1996

						(%)	
1. Macroeconomic variables:		1991	1996	3. Labor demands:		1991	1996
TDP	Total domestic product	-0.950	-0.598	X _{(14,14,1)1}	Agriculture	0.120	0.038
GDP	Gross domestic product	-1.139	-0.330	X _{(14,14,1)2}	Mining and primary energy	0.107	-0.196
IM	Imports	-2.672	-1.472	X _{(14,14,1)3}	Textiles	0.101	-0.077
EX	Exports	-2.502	-1.073	X _{(14,14,1)4}	Chemical product	0.270	-0.065
$\bar{C}$	Total household income	-0.189	-0.025	X _{(14,14,1)5}	Nonmetallic mineral product	0.071	-0.081
$\bar{T}$	Tax revenue	-4.408	-1.684	X _{(14,14,1)6}	Basic metal product	0.029	-0.082
L	Labor demand	0.078	0.051	X _{(14,14,1)7}	Other industries	0.228	0.082
CPI	Consumer price index	-0.189	-0.025	X _{(14,14,1)8}	Coal product	0.657	0.883
WPI	Wholesale price index	-0.267	-0.140	X _{(14,14,1)9}	Petroleum product	-49.196	-25.741
EPI	Energy price index	-0.265	-0.139	X _{(14,14,1)10}	Natural gas	-51.888	-61.203
2. CO ₂ emissions:				X _{(14,14,1)11}	Electricity	-3.978	-3.487
XTCO _{2,1}	Agriculture	0.089	0.024	X _{(14,14,1)12}	Transportation	0.936	1.445
XTCO _{2,2}	Mining and primary energy	0.069	-0.129	X _{(14,14,1)13}	Services	0.537	0.217
XTCO _{2,3}	Textiles	0.073	-0.053				
XTCO _{2,4}	Chemical product	0.160	-0.039				
XTCO _{2,5}	Nonmetallic mineral product	0.060	-0.048				
XTCO _{2,6}	Basic metal product	0.019	-0.043				
XTCO _{2,7}	Other industries	0.172	0.062				
XTCO _{2,8}	Coal product	0.129	0.273				
XTCO _{2,9}	Petroleum product	-56.474	-36.582				
XTCO _{2,10}	Natural gas	19.427	-10.211				
XTCO _{2,11}	Electricity	-1.101	-0.937				
XTCO _{2,12}	Transportation	1.584	1.702				
XTCO _{2,13}	Services	0.353	0.131				
XTCO _{2,14}	Household	-16.900	-15.550				
XTCO _{2,15}	Government	-3.394	-0.712				

Note : The shock of simulation is : 3.497%.

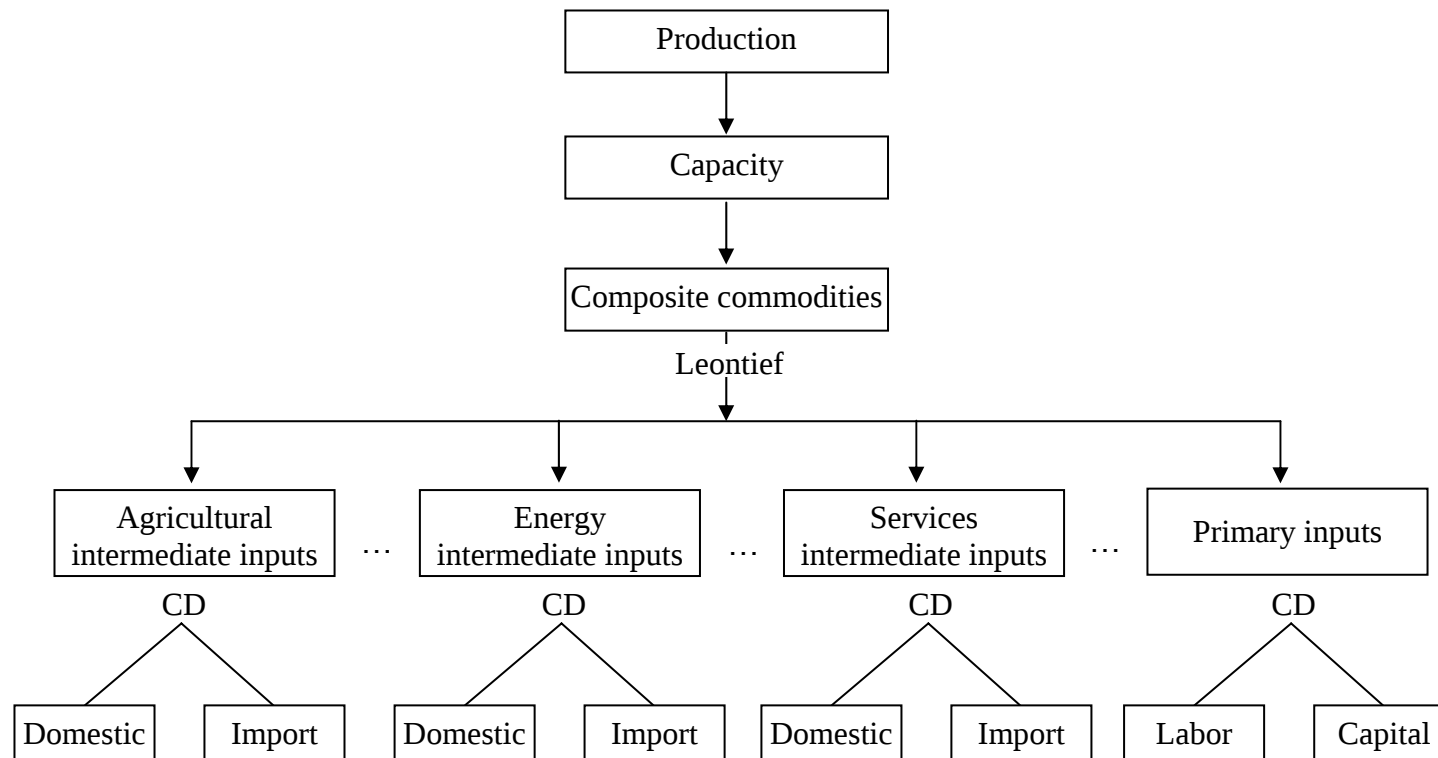


Figure 1. Production sectors

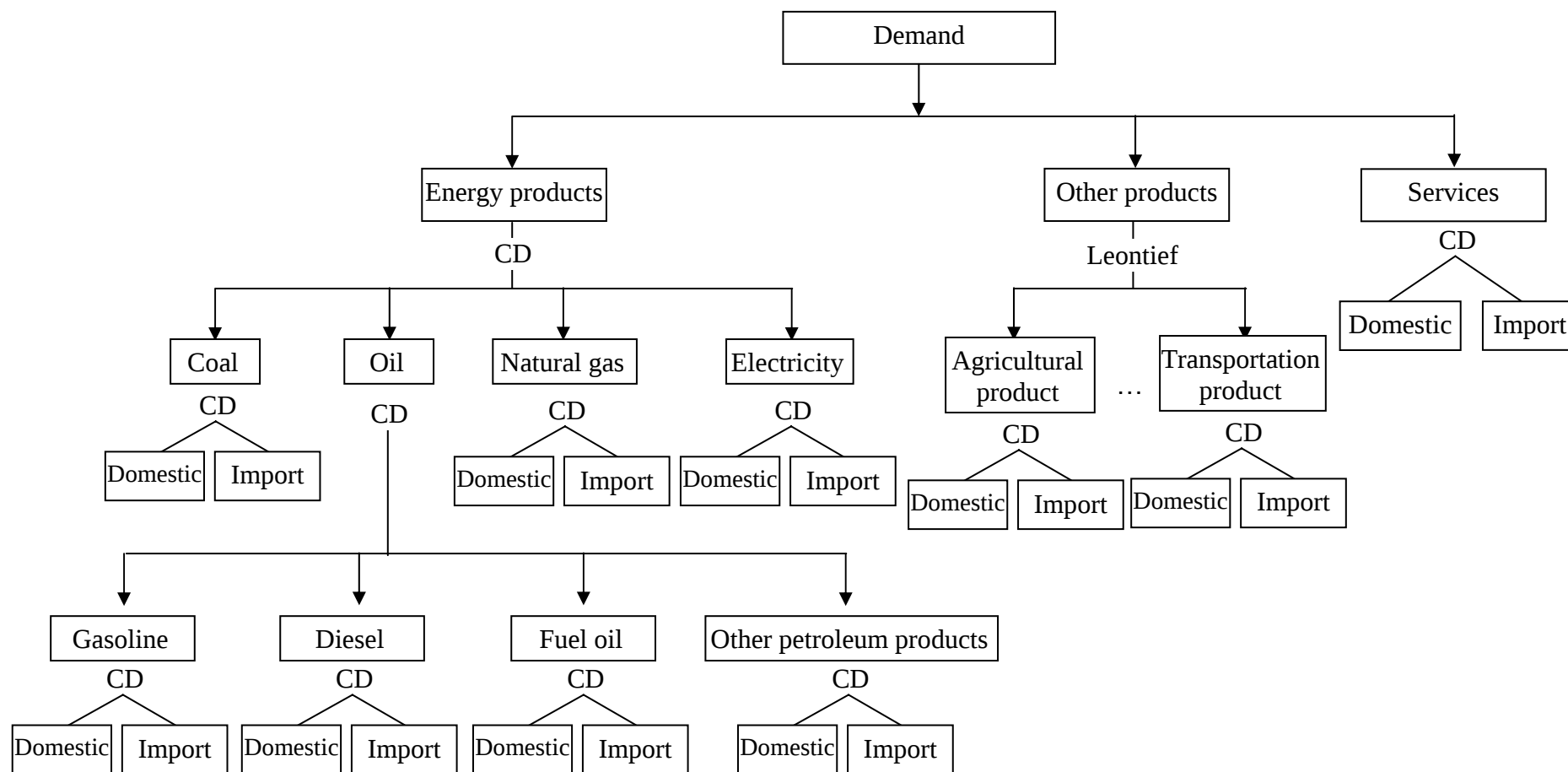


Figure 2. Final demand sectors

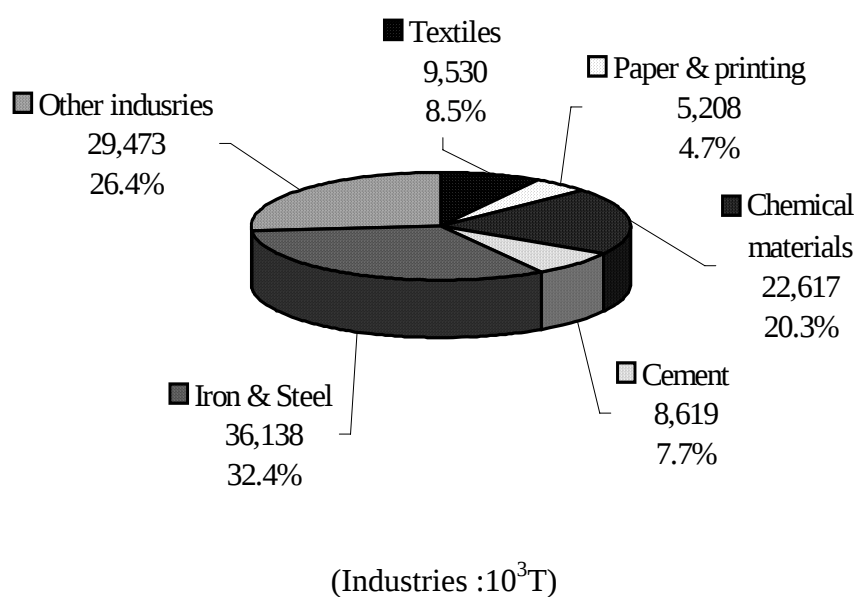
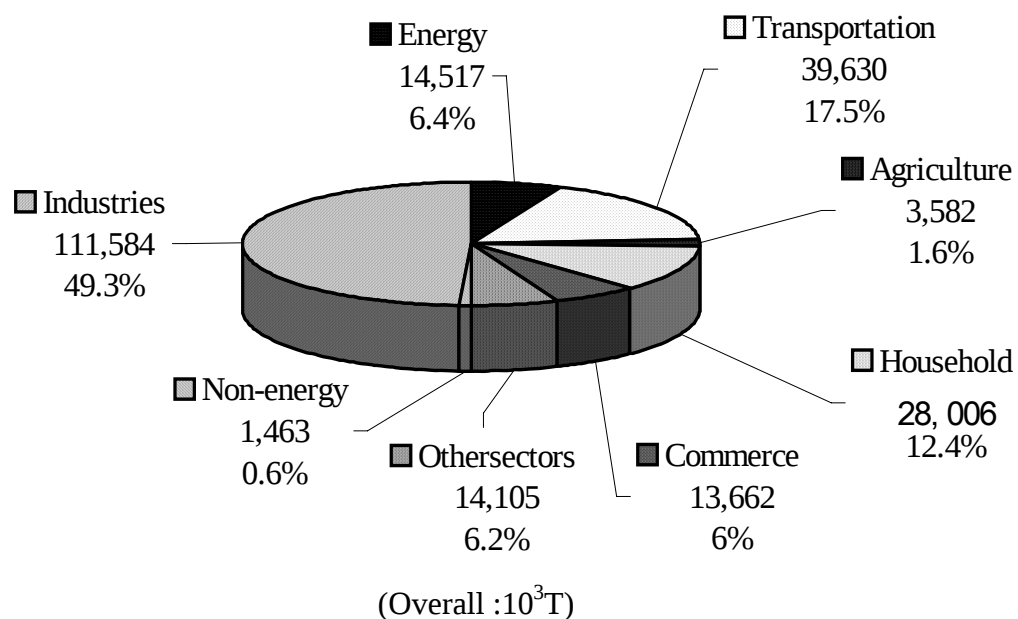


Figure 3. Carbon dioxide emissions in year 2000 (by sectors)