Resolving Taiwan's Nuclear Puzzle: The Economic Impacts of Terminating the Fourth Nuclear Power Plant

Ping-Cheng Li and Shih-Hsun Hsu*

Abstract

The continuing struggle between the ruling DPP and the opposition alliance over the fate of the controversial Fourth Nuclear Power Plant has been a major policy issue in Taiwan since the new anti-nuclear power government took office on May 20, 2000.

The purpose of this paper is to evaluate the economic impacts of the termination of the Fourth Nuclear Power Plant under different alternative policy proposals. The proposals considered in this research are 1) the termination of the Fourth Nuclear Power Plant without any alternative undertaken, 2) overall energy efficiency improvement as an alternative policy, 3) thermal efficiency improvement in coal-fired power plant as an alternative power source, and 4) thermal efficiency improvement in natural gas-fired power generation facilities as an alternative power source.

The analysis in this paper is based on simulation results from TAIGEM-D (TAIwan General Equilibrium Model-Dynamic), a dynamic, multisectoral, applied general equilibrium model of the Taiwan's economy, developed specifically to analyze energy and climate change response issues.

The findings of this research clearly demonstrated that the Fourth Nuclear Power Plant is not as necessary as is alleged by Taiwan Power Company. Under the worst scenario when no alternative tactics are available, the termination of the Fourth Nuclear Power Plant will only cause medium to small impacts on the Taiwan economy. If the actions of energy efficiency improvement and retrofitting of the existing power plants are undertaken, the Taiwan economy will be better off even though the termination of the project may lead to a shortage of electricity. Moreover, policy simulation results also indicate that the Fourth Nuclear Power Plant shows no supremacy over the power plant retrofitting options when CO_2 emissions are a concern.

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Resolving Taiwan's Nuclear Puzzle:
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Ping-Cheng Li*

1. Introduction

Whether the fourth nuclear power plant should be built in Taiwan has been disputed ever since the project was initiated by the state-run Taiwan Power Company (Taipower) under the Kuomintang (KMT) administration. Over time this issue has developed into a heated controversy between the KMT and Democratic Progressive Party (DPP), and the debate has become even severe in the period of president campaign since the DPP platform clearly affirms the opposition of nuclear power. After the victory of DPP in the president-elect, the Chen Shui-bian administration immediately faces the situation of making a prudent decision on the fourth nuclear power plant under construction.

To resolve this controversy, the new government organized a committee comprised of scholars, specialists, legislators, and government officers to re-evaluate the fourth nuclear power plant project. Within 12 weekly meetings of the Re-evaluation Committee, issues related to nuclear safety, nuclear waste treatment, decommissioning of nuclear power plants, costs of nuclear power generation, social costs and environmental protection, and power generation alternatives to substitute the fourth nuclear power plant were discussed thoroughly. Supporters of nuclear power asserted that northern Taiwan would be confronted with a shortage of electric power by 2004 if this project were scrapped. Despite the risks of nuclear power accidents, they proposed the use of nuclear power as a feasible method to mitigate CO_2 emissions. On the other hand, the dissenters of nuclear power reminds people of the Chernobyl nuclear power plant accident in 1986 and the trouble of disposing of the radioactive waste from Taiwan's existing nuclear power plants. They insisted that alternative sources of electric power could be developed economically by retrofitting existing power generation facilities and by resorting to renewable energies. They also suggested energy efficiency improvement tactics as the best policy to curb the possible electricity shortage problems.

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On the other hand, the most important issue that most people and businessmen care about is the possibility of huge sunk cost of project termination and the resultant economic downturn if a shortage of electricity did occur. With respect to this concern, the re-evaluation committee did not reach any consensus, either. Based on the published statistical data, the dissenters of nuclear power asserted that the spinning reserve in 2007 would be higher than those of the past ten years even if the fourth nuclear power plant is terminated, and a shortage of electricity is, therefore, unlikely to happen in Taiwan. It is true that the economic concern may ultimately play the most crucial role in policy decision-making for the fourth nuclear power plant project. However, the economic impacts of project termination will depend on the possibility of a shortage of electricity and the development of alternative economic sources of electric power. Without a full understanding of the possible consequences, it is difficult to make a right decision on this nuclear power controversy.

The purpose of this paper is to evaluate the economic impacts of the termination of the fourth nuclear power plant under different policy proposals. The proposals considered in this research are 1) the termination of the fourth nuclear power plant without any alternative undertaken, 2) overall energy efficiency improvement as an alternative policy, 3) thermal efficiency improvement in coal-fired power plant as an alternative power source, and 4) thermal efficiency improvement in natural gas-fired power generation facilities as an alternative power source. I used the TAIGEM© dynamic general equilibrium model to perform such policy simulations.

2. An Overview of TAIGEM© Dynamic General Equilibrium Model

TAIGEM©-D is a dynamic computable general equilibrium (CGE) model of the Taiwan economy. It is descended from the TAIGEM© model, a multipurpose model suitable for analyzing climate change issues (such as baseline forecasting and climate change response policies), environmental protection problems, domestic labor economic policies, and private and government investment projects. The core of TAIGEM©'s model structure is modified from ORANI (Dixon, Parmenter, Sutton and Vincent, 1982). The TAIGEM© database was compiled from the 150-sector by 569-commodity Use table of the 1994 Taiwan Input-Output tables. With its electricity sector further disaggregated into 11 sectors and its commodities suitably aggregated, TAIGEM© has 160 sectors, 170 commodities, 6 types of labor, and 8 types of margins. Like most static CGE models, TAIGEM© was designed for comparative-statics, i.e., for simulating 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 produced annual projections of the Taiwan CO_2 emission, GDP growth rate, and other economic variables.

Dynamic mechanism of TAIGEM©-D

Dixon and Parmenter (1996) classified dynamic mechanisms of dynamic CGE models 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 optimization investment behavior.

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, where 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. A dynamic model such as TAIGEM©-D is beneficial when analyzing the fourth nuclear power plant project since the timing of policy implementation and the adjustment path an economy follows are highly relevant in the policy debate.

Structure of Production: Non-Electricity Sectors

In TAIGEM©-D, each industry is allowed to produce several commodities, using as inputs domestic and imported goods, 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. This multi-input, multi-output production specification is kept manageable by a series of weak separability assumptions.

The production specification of the non-electricity sectors in TAIGEM©-D model is illustrated by the nested structure shown in Figure 1. The input demand of production is formulated by a five-level nesting, and the production decision-making of each level is kept independent. With the assumption of cost minimization and technology constraint at each level of production, producers choose optimal input demand. At the top level, commodity composites and a primary-factor composite are combined using a Leontief function. Consequently, they are demanded in fixed proportion to the industry activity. At the second level, each commodity composite is a CES (constant elasticity of substitution) aggregation of domestic goods and the imported equivalent (the Armington assumption). Energy and primary-factor composites are a CES aggregation of energy composite and primary-factor composite.

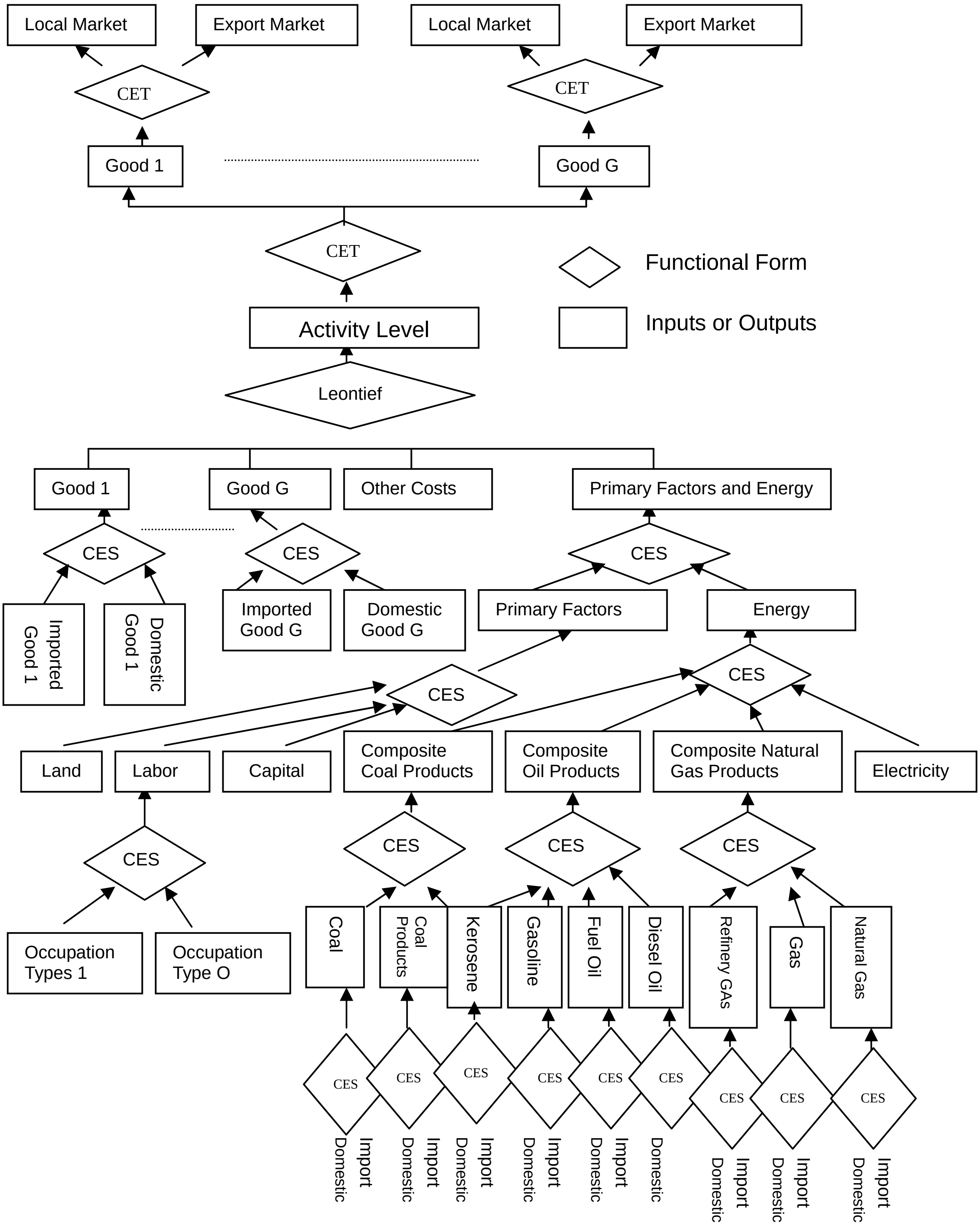

Figure 1. Structure of Production: Non-Electricity Sectors

At the third level, the primary-factor composite is a CES aggregation of labor, land, and capital, while 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 energy products and their imported equivalents.

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

Technology Bundle in Electricity Sector

In TAIGEM©-D, production in the electricity sector is modeled using the "technology bundle" approach derived from the Australia ORANI-E model and MEGABARE (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 electricity sector 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, 10 known technologies are used to generate electricity, namely hydro, steam turbine-oil, steam turbine-coal, steam 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. Since nuclear power is a separate sector in this technology bundle approach, it is possible to simulate the termination of the fourth nuclear power plant project.

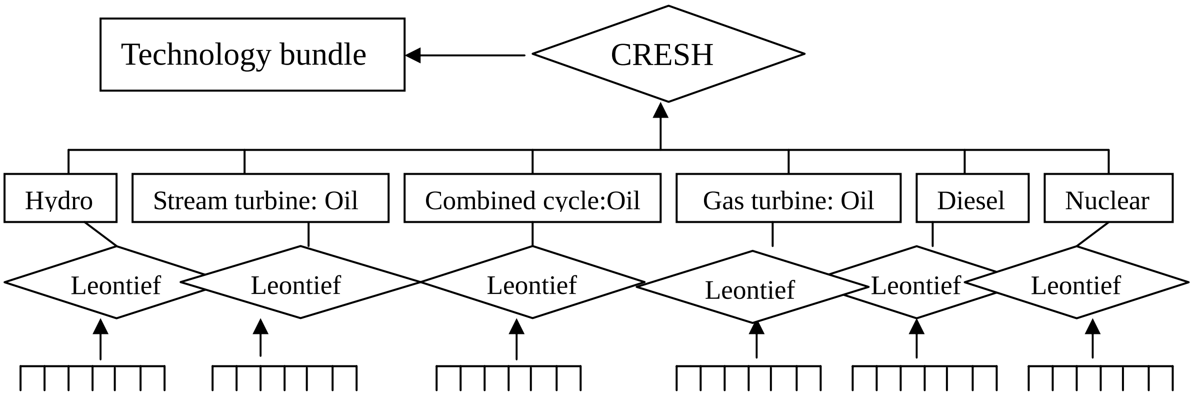

Figure 2. Technology Bundle of TAIGEM©-D Model: Electricity Sector

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 I use to generate up-to-date data for the 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. By using observed historical macroeconomic and microeconomic data to calibrate model parameters, the accuracy of TAIGEM©-D can be significantly improved. Moreover, through the historical simulations, I can calibrate detailed patterns of changes in technology and household tastes over the historical period. This information is used later in forecasting simulation.

The second is forecasting simulation that is designed to incorporate into the forecasts as much specialist information as is available. This allows the modeler 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., the termination of the fourth nuclear power plant project in this research).

The first two types of simulation comprise of what is called the baseline scenario, a reference case for comparison before policy simulations. In the baseline scenario of this research, I assume that the fourth nuclear power plant will be built according to the old policy that was made by the KMT government. To successfully derive the baseline, two different closures (selections of exogenous variables) of the model are adopted. 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 that 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 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) 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 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 expenditure, government consumption, exports and imports are determined in the model.

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%. We also assume that productivity growth rate of primary factors will increase at an annual rate of 3% from 1998 up on and CPI growth rate 2%.

The most important macroeconomic indices for evaluating the fourth nuclear power plant project is the real GDP and CO_2 emissions, since some members in the Re-evaluation Committee used the contribution of the fourth nuclear power plant on GDP growth and CO_2 emission reduction to judge its value. Therefore, it is important to generate these two baselines. The baseline projection result of real GDP growth for Taiwan is shown in Table 1 and Figure 3. 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. In the forecasting simulation from 1999 to 2020, the growth rates are taken from Economics Institute, Academia Sinica. The simulation results show that the real GDP is 8,134 billion NT$ in 2000, and 19,898 billion NT$ in 2020. The baseline projection of CO_2 emissions is illustrated in Table 2 and Figure 4. In 2000, the total CO_2 emissions in Taiwan is estimated to be 224 million tons, while in 2020, the estimation was 531 million tons.

4. Policy Simulation of the Project Termination

Policy Simulation Design

To resolve the controversy of the fourth nuclear power plant project, suitable scenarios of the project termination have to be designed to evaluate its economic impacts. In this research, four scenarios are proposed:

1. Case I: In this policy simulation, the fourth nuclear power plant is assumed to be scraped without any alternative action undertaken. This is the so called the "no-alternative scenario".
2. Case II: In this policy simulation, the fourth nuclear power plant is terminated, and the government will adopt the energy efficiency improvement tactics as an alternative policy to compensate the possible power shortage. The energy intensity improvement is increased each year after year 2000 from a historical average of 0.6% to a new level of 1.2%.
3. Case III: In this policy simulation, the fourth nuclear power plant project is stopped immediately, and the government will order the state-run Taipower Company to repower its existing coal-fired power plant so that the thermal efficiency can be increased to curb the possible power shortage. The average thermal efficiency will be increased from the current average of 35% to 39% within the next four years.
4. Case IV: In this policy simulation, the fourth nuclear power plant project is stopped immediately, and the government will order the state-run Taipower Company to repower its existing natural gas-fired power plant so that the thermal efficiency can be increased to curb the possible power shortage. The average thermal efficiency will be increased from the current average of 37% to 57% from year 2007 to 2010 (this represent the possibility of late reaction of the Taipower Company).

Policy Simulation Results

Although it is very likely that the termination of the fourth nuclear power plant may not cause any electricity shortage problem, in TAIGEM©-D, I assumed that the electricity generated would be decreased to represent the worst situation that Taiwan may encounter in the future.

The policy simulation results are illustrated in Table 1, Table 2, Figure 3, and Figure 4. From Table 1 and Figure 3, it is clear that the termination of the fourth nuclear power plant may negatively impact the Taiwan economy if no alternative policy action is undertaken (Simulation I). Especially in 2005 and 2006, the Taiwan

Table 1. Real GDP Growth of Taiwan under different policy simulations for the fourth nuclear power plant project
(Unit: billion NT$)

	Baseline (1)	Case I (2)	(2)-(1)	Case II (3)	(3)-(1)	Case III (4)	(4)-(1)	Case IV (5)	(5)-(1)
1994	5817	5817	0	5817	0	5817	0	5817	0
1995	6168	6168	0	6168	0	6168	0	6168	0
1996	6518	6518	0	6518	0	6518	0	6518	0
1997	6959	6959	0	6959	0	6959	0	6959	0
1998	7295	7295	0	7295	0	7295	0	7295	0
1999	7702	7702	0	7702	0	7702	0	7702	0
2000	8134	8140	7	8140	6	8140	7	8140	7
2001	8540	8559	18	8552	12	8559	18	8559	18
2002	8967	8997	29	8985	18	8997	29	8997	29
2003	9416	9454	38	9441	25	9454	38	9454	38
2004	9887	9933	46	9921	34	9933	46	9932	46
2005	10381	10336	-45	10427	46	10336	-45	10334	-47
2006	10869	10797	-72	10927	58	10824	-45	10794	-75
2007	11380	11302	-77	11453	73	11326	-53	11323	-56
2008	11915	11825	-90	12002	88	11846	-68	11869	-45
2009	12475	12367	-107	12580	105	12387	-87	12439	-36
2010	13061	12933	-128	13185	124	12952	-109	13037	-24
2011	13635	13488	-147	13780	144	13506	-129	13599	-36
2012	14235	14067	-169	14401	166	14084	-151	14186	-49
2013	14862	14671	-190	15051	189	14688	-174	14802	-59
2014	15516	15304	-212	15729	214	15321	-195	15451	-65
2015	16198	15965	-234	16439	241	15981	-217	16133	-66
2016	16879	16625	-254	17149	270	16642	-237	16818	-61
2017	17588	17310	-277	17890	302	17329	-259	17531	-56
2018	18326	18021	-305	18666	339	18043	-283	18274	-52
2019	19096	18760	-336	19516	420	18786	-310	19091	-5
2020	19898	19539	-360	20362	464	19568	-330	19907	8

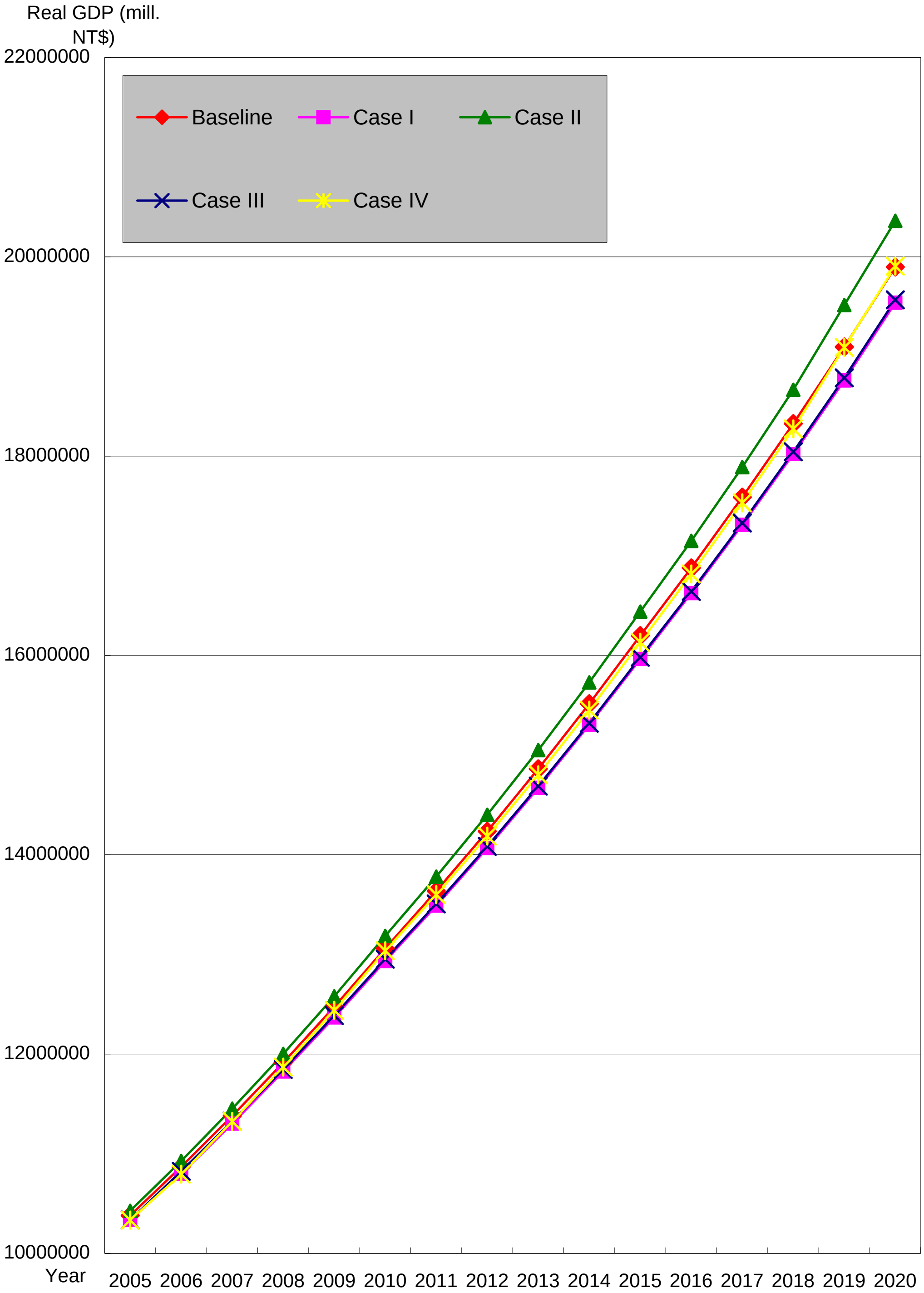

Figure 3. Projection of Real GDP of Taiwan under different policy simulations for the fourth nuclear power plant project

Table 2. Taiwan's CO_2 emissions under different policy simulations
for the fourth nuclear power plant project

CO_2 Emissions (million tons)					
	Baseline	Case I	Case II	Case III	Case IV
1994	167.140	167.140	167.140	167.140	167.140
1995	176.123	176.123	176.123	176.123	176.123
1996	184.142	184.142	184.142	184.142	184.142
1997	199.388	199.388	199.388	199.388	199.388
1998	208.079	208.079	208.079	208.079	208.079
1999	224.108	224.108	224.108	224.108	224.108
2000	235.820	236.025	234.332	236.025	236.025
2001	246.324	246.998	243.437	246.998	246.998
2002	257.370	258.484	252.941	258.484	258.484
2003	269.315	270.769	262.978	270.769	270.769
2004	282.257	284.025	273.606	284.025	283.995
2005	289.673	295.144	284.773	295.144	295.065
2006	298.291	307.986	295.424	302.792	307.846
2007	312.143	321.994	306.412	316.291	320.789
2008	326.474	336.273	317.645	330.107	333.652
2009	341.225	350.892	329.160	344.279	346.707
2010	356.445	365.965	340.938	358.896	360.139
2011	371.040	380.459	351.844	372.938	374.268
2012	386.154	395.470	362.974	387.469	388.844
2013	401.853	411.119	374.369	402.607	404.044
2014	418.197	427.486	386.076	418.445	420.094
2015	435.225	444.552	398.103	435.002	437.101
2016	451.925	461.377	409.604	451.397	454.101
2017	469.225	478.718	421.366	468.408	471.736
2018	487.119	496.549	433.495	486.007	489.904
2019	512.408	522.880	452.549	512.137	516.356
2020	531.461	542.537	464.404	531.652	536.129

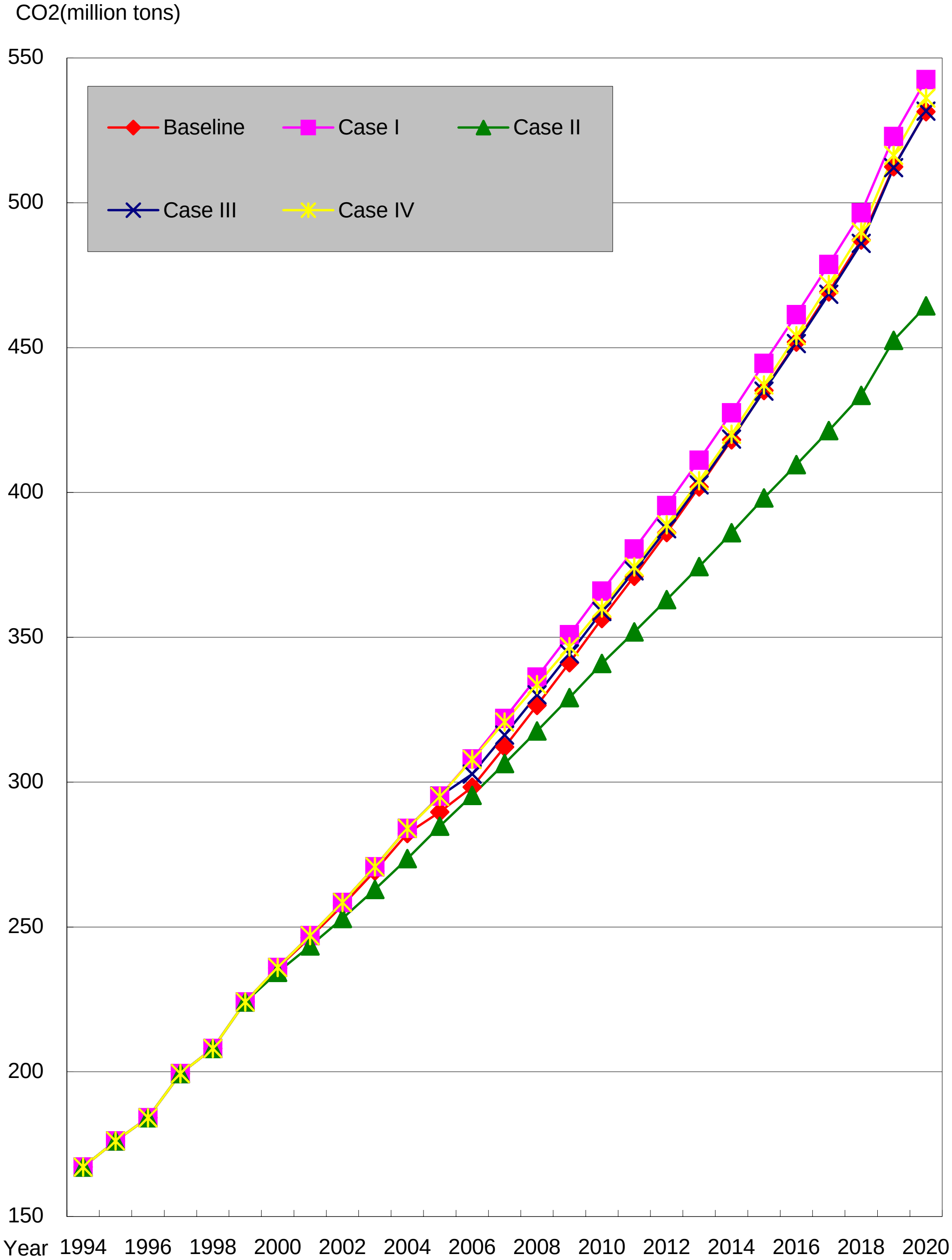

Figure 4. Projection of Taiwan's CO_2 emissions under different policy simulations for the fourth nuclear power plant project

economy is observed a medium-size negative impact of 0.88% and 0.24% GDP loss, respectively. The reason for this is because in the baseline scenario the fourth nuclear power plant is scheduled for commercial operation in 2005 and 2006, and the termination of the fourth nuclear power plant may, therefore, cause electricity shortage in those two years. However, the Taiwan economy recovers very fast in later years since the economy may adjust itself to external shocks through the market mechanism. From Table 2 and Figure 4, Simulation I indicated that case I will cause CO_2 emissions to increase. This no-alternative scenario causes CO_2 emissions to increase from a baseline level of 531 million tons to 543 million tons in year 2020.

In Case II, the policy simulation results showed that if the energy efficiency improvement tactics are adopted along with the termination of the fourth nuclear power plant, then the Taiwan economy will be stimulated regardless of the possible negative effect of power shortage. The real GDP appears to increase from 19,898 billion NT$ to 20,362 billion NT$ in the year 2020 (Table 1). Taiwan's CO_2 emission also decreased in this case, e.g., the total CO_2 emission decreased from a baseline level of 531 million tons to 464 million tons in year 2020.

In Case III, the policy simulation results indicated that if the government orders the state-run Taipower Company to retrofit its existing coal-fired power plant so that the electricity shortage caused by the scraping of the fourth nuclear power plant can be partly resolved, then the negative impacts on the Taiwan economy can be reduced. The thermal efficiency improvement in this retrofitting Scenario means that more electricity can be generated with the same amount of coal inputs. Therefore, the energy cost of power generation in coal-fired power plant can be reduced and the price of electricity is also decreased. The only cost of this strategy is the initial capital investment of power plant retrofitting. However, this power generation option is less expensive when compared to the huge capital investment required in the fourth nuclear power plant project. As shown in Table 1, the real GDP loss in 2020 accumulates to 330 billion NT$ as compared to 360 billion NT$ in the no-alternative case. This power plant retrofitting option, therefore, represents a saving of 30 billion NT$. On the other hand, this strategy will reduce CO_2 emission to a significant extent because less coal (the most carbon intensive fossil fuel) is used to generate the same amount of electricity. In year 2020, the CO_2 emission in this case is almost the same as in the baseline case. In fact, the CO_2 emission increment due to the termination of the fourth nuclear power plant is almost completely mitigated in this policy simulation.

In Case IV, the simulation results indicated that retrofitting of the existing natural gas-fired power generation facility is both a feasible and economic strategy to fulfill the electricity shortage gap if the government decides to terminate the fourth nuclear power plant. The thermal efficiency improvement in this retrofitting scenario represents a huge saving of natural gas. If the average thermal efficiency of existing natural gas-fired power plants can be increased from 37% to 57% through repowering, then 54% more of electricity can be produced with the same amount of natural gas. This power retrofitting option will generate more electricity that is almost equivalent to the amount generated from the fourth nuclear power plant. In fact, the possible electricity shortage problem in Taiwan is the incapability of supplying sufficient electricity in peak load. Natural gas-fired power plants are more suitable than nuclear power plants to supply electricity in peak load time, since the design of gas-fired power plants allows rapid switching on and off. Like the retrofitting of the coal-fired power plant, this strategy also contributes to the reduction in the price of electricity. It is also economic in terms of the initial capital investment. Therefore, retrofitting of the existing natural gas-fired power plant is an attractive option if shortage of electricity is really a concern.

As shown in Table 1, this retrofitting strategy will cause GDP to increase. In fact, GDP started to gain in year 2020 when compared with the real GDP in the baseline case. This strategy will reduce CO_2 emission to a significant extent because less natural gas is required to generate the same amount of electricity. In year 2020, the CO_2 emission in this case is only 5 million tons more than the CO_2 emission in the baseline case.

5. Conclusion

The findings of this research clearly indicated that the fourth nuclear power plant is not as necessary as is alleged by Taipower Company. Under the worst situation when no alternative tactics are available, the termination of the fourth nuclear power plant will only cause medium to small impacts on the Taiwan economy. If the actions of energy efficiency improvement and retrofitting of the existing power plants are undertaken, the Taiwan economy will be better off even though the termination of project may lead to a shortage of electricity supply. The policy simulation results also concluded that the fourth nuclear power plant project shows no supremacy over the power plant retrofitting options when CO_2 emission issues are a concern.

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