CHAPTER 4
Investigating Fiscal and Social Costs of Recovery Policy

4.1 Introduction

Asia and the Pacific is the most natural hazard prone region owing to its geological environment and rapid urbanization (Davis, 2014). Taiwan is one of the most vulnerable areas among many that are prone to natural disasters, especially earthquakes. It is a small island of 36,000 km^2 with 23 million people and hosts world-leading industrial sectors, such as semiconductors and electronic equipment. They are located in many factories in the Hsinchu Science Park in the northern area close to the capital, Taipei City. This area has two risk factors of disasters. First, the Shan-jiao fault runs through the semiconductor complex area. The second risk factor is nuclear power stations, which are located at coastal areas within 30 km from the capital. As showed by the catastrophic impact of the Great East Japan Earthquake (GEJE) in 2011, a destructive tsunami caused by a huge earthquake can trigger a nuclear disaster and a power crisis, which could be termed a "compound disaster" (McEntire, 2006; Kawata, 2011). Electricity is indispensable for modern industries, especially the semiconductor industrial sector. On September 21, 1999, an ML 7.3 earthquake hit northern Taiwan, causing serious damage to communities and facilities, including the power network, and disrupting industrial activities for two weeks. The disaster incurred costs as high as 14 billion USD or 3.3% of Taiwan's gross domestic product (GDP) (Prater and Wu, 2002). The loss of semiconductor and electronic equipment manufacturing in the Hsinchu Science Park exceeded 10 billion TWD (Hsinchu Science Park, 2011). Taiwan has achieved further high growth after the earthquake and, thus, could lose more from another compound disaster.

Some impact assessments of actual and potential disasters have been made for Taiwan. Mai et al. (1999) quantified the macroeconomic impacts of the 921 Earthquake. Tsai and Chen (2011) conducted risk analysis of various disasters for Taiwan's tourism industry from an engineering viewpoint by using a geographic information system. Huang and Hosoe (2014) assessed the economic impact of an ML 7.5 earthquake and a power crisis hitting the manufacturing sectors of northern Taiwan by using a static computable general equilibrium

(CGE) model. They found that the semiconductor, chemical, and pottery sectors, which are capital and/or energy intensive, would be affected most severely, the machinery and transportation equipment sectors would be affected much less, and the power crisis would push up power prices by 27% to add up to an additional 17% of losses caused by the assumed earthquake alone. These estimates of damages and losses by disasters are useful for researchers to develop disaster impact mitigation plans and to quantify their investment values. However, no matter how deeply and precisely the impact of a disaster is quantified, it cannot be prevented and, thus, would have some negative impacts on the economy. Given the occurrence of a disaster, it is critically important to develop a recovery plan by studying recovery processes and policies that can minimize the disaster-induced losses and/or achieve a recovery goal at minimum cost. After the 921 Earthquake, the Taiwanese government set up a 2-year recovery plan with a special budget of 200 billion TWD (Shieh, 2004). In a future disaster case, a similar amount would be requested. The impact assessment is essential to foresee what would happen in a recovery process after a disaster and what would need to be done for a better recovery. That is, the study questions what type of policy could achieve a recovery, how much fiscal costs would be needed, and how much social costs an economy would bear in the recovery process.

On top of these questions, there is another issue about the timeframe for the recovery program. While people often prefer intensive and, thus, quick recovery, additional funds may be needed. In the case of the GEJE, a large portion of the special recovery budget was prepared after the event; the Board of Audit of Japan (2013) reported that about 10% of the budget for the first 2 years was misused or abused. In addition, inefficiency would result from interventions for recovery and an intensive recovery program would bring about even larger distortions. Therefore, finally, the study addresses the question of how long recovery program duration should be.

Studies on recovery process and policies *after* a disaster are scant for Taiwan although it potentially faces risks of various and serious disasters. Chen (2013) simulated a no-nuclear situation (but without considering any disasters) with a dynamic CGE model for Taiwan. Huang and Min (2002) investigated a recovery of inbound tourist flows after the 921 Earthquake. While no economy-wide study for these questions exists for Taiwan's disaster and recovery, the GEJE strongly motivated researchers to study recovery processes and policies for Japan. Okiyama, Tokunaga, and Akune (2014) used an SCGE model to simulate the GEJE and studied efficient financing measures of reconstruction funds. Akune, Okiyama, and Tokunaga (2013) used a dynamic CGE model to predict recovery time needed for the fishery and marine products industries, which were severely affected by the GEJE-induced compound disaster. However, the long-run effects of recovery program duration were not considered in these studies.

To answer these questions, the study develops a dynamic CGE model for Taiwan and simulates a huge earthquake that causes losses in capital and labor as well as a nuclear power shutdown in a compound disaster. To examine the costs and effectiveness of recovery policies, the study considers two types of subsidies—a production subsidy and a capital-use subsidy—that are aimed at achieving a recovery of output levels in a few major industries in 10 years. The study evaluates these policy interventions by measuring their fiscal and social costs by varying program duration. Subsection 4.2 describes the dynamic CGE model for Taiwan. Subsection 4.3 explains the simulation scenarios and simulation results. Subsection 4.4 summarizes the findings and their implications for a better recovery policy.

4.2 Dynamic Computable General Equilibrium Model and Simulation Method

4.2.1 Intratemporal Model Structure

We use a recursive dynamic CGE model for Taiwan that is developed on the basis of the static model by Huang and Hosoe (2014). As extensions made for recursive dynamics are described in detail in the Annex of Hosoe (2014), only its major features are shown below. The model distinguishes 22 sectors (Table 4.2.1). It describes activities *within* a period with nested-constant elasticity of substitution/transformation (CES/CET) functions (function 4.2.1). They describe (1) substitution between capital and labor, (2) intermediate input and composite factor input with an energy composite input for a production function of gross output, (3) transformation for domestic goods supply and exports, and (4) substitution between the domestic goods and imports, à la Armington (1969). (5) The Armington composite goods are used by a representative household and the government as well as for investment and intermediate input. (6) The household utility depends on consumption of various nonenergy goods and an energy composite.

Table 4.2.1: *Sectors and their Estimated Loss of Capital Stock and Total Labor Endowment*

Sector and its Abbreviation		Damages on Factor Endowments in Period 0
Capital Loss		
Agriculture	AGR	−1.3%
Crude Oil and Natural Gas[a,b]	PAG	−4.2%
Mining	MIN	−1.9%
Coal[a]	COA	−5.7%
Food	FOD	−3.9%
Textiles and apparel	TXA	−7.1%
Wood and paper	WPP	−9.6%
Petroleum[a,b]	PET	−4.9%
Chemical	CHM	−7.4%
Pottery	POT	−6.3%
Steel	STL	−5.8%
Metal products	MET	−6.4%
Semiconductors	SEC	−11.6%
Electronic equipment	EEQ	−11.0%
Machinery	MCH	−6.1%
Transportation equipment	TEQ	−4.1%
Manufacturing	MAN	−5.6%
Electricity[a,b]	ELY	−16.3%[c]
Town gas[a,b]	TWG	−5.8%
Construction	CON	−6.8%
Transportation	TRS	−13.5%
Services	SRV	−8.2%
Labor Loss[d]		−7.4%

Note. Calculated by Huang and Hosoe (2014).
[a] Energy sectors whose energy input is determined by fixed coefficients. In addition, their output is used for the production of energy composite goods for industries
[b] Energy goods used for energy composite goods for households
[c] This loss consists of the direct loss by the earthquake and the loss reflecting the nuclear power shutdown.
[d] The labor loss is assumed to recover gradually in five periods.

To describe substitution between electricity with other energy sources, which can be crucial in a power crisis induced by the nuclear power shutdown, (7) the energy composite assumed for nonenergy sectors is developed from the five energy goods indicated in Table 4.2.1, while assuming conventional Leontief's fixed coefficient technology for the five energy sectors. (8) In the energy composite for the household, petroleum, natural gas, electricity, and town gas (without coal) are used. The model is calibrated to Taiwan's input–output (IO) table for 2006 (DGBAS, 2011a) with parameters summarized in Table 4.2.2.[6]

[6] The sensitivity analysis is conducted with respect to these assumed parameters to examine robustness of the results. Details are shown in the Appendix.

Table 4.2.2: *Assumed Parameters*

Parameter	Value	Source
Rate of return of capital (*ror*)	5%	Hosoe (2014)
Depreciation rate (*dep*)	4%	Chow and Lin (2002); Chang and Kuan (2005)
Population growth rate (*pop*)	1%	DGBAS (2007)
Armington elasticity parameters (σ, ψ)	0.90–7.35	GTAP Database version 8.1 (Hertel, 1997)
Elasticity of substitution among energy sources (σ^e)	1.1	Author's assumption
Elasticity parameter in the investment function (4.2.1) (ζ)	1.0	Hosoe (2014)

4.2.2 Intertemporal Model Equation

We depart from the earlier study with a static model by Huang and Hosoe (2014) by installing recursive dynamics in that model, which link economic activities *between* periods. In the *t*-th period, private savings S_t^p, which are generated with a constant saving propensity, and foreign savings in the foreign currency S_t^f, converted to the local currency with an exchange rate ε_t, are spent purchasing investment goods. These savings are allocated to purchase goods for sectoral investment in the *i*-th sector $II_{i,t}$ according to its expected relative profitability among sectors in the next period.

$$p_t^k II_{i,t} = \frac{{p_{CAP,i,t+1}^f}^{\zeta} F_{CAP,i,t+1}}{\sum_j {p_{CAP,j,t+1}^f}^{\zeta} F_{CAP,j,t+1}} \left(S_t^p + \varepsilon_t S_t^f\right) \qquad \text{(equation 4.2.1)}$$

where $p_{i,t}^q$ denotes the price of composite investment goods, $p_{CAP,i,t+1}^f$ and $F_{CAP,i,t+1}$ denote the price and the amount of capital service in the *i*-th sector in the next period, respectively. The last two variables can be replaced with the *t*-th period variables $p_{CAP,i,t}^f$ and $(1+pop)F_{CAP,j,t}$, where *pop* denotes population growth rate, by assuming a myopic expectation. ζ is an elasticity parameter that determines sensitivity of sectoral investment allocation to a gap of sectoral rate of returns. As the putty-clay type capital is assumed, the capital cannot move from one sector to another instantaneously but moves sluggishly through capital accumulation. By contrast, labor is assumed to be mobile among sectors, as assumed in many CGE models.

4.2.3 Growth Paths

Through calibration to the IO table data and parameters that are summarized in Table 4.2.2, the model generates a path that is constantly growing at the population growth rate *pop* (Figure 4.2.2). Hereafter, this path is called the business-as-usual (BAU) path, which experiences no exogenous shocks or policies (Figure 4.2.2). It is assumed that the first period (period 0) experiences an ML 7.5 earthquake with a nuclear power shutdown, which Huang and Hosoe (2014) assumed to quantify their short-run impacts with a static CGE model. By running the model recursively from period 0 to 30, the long-run consequence of the compound disaster could be described without any policies for recovery as the "base run." After computing the base run path, the growth paths could be computed under counterfactual scenarios with various policy interventions for recovery of some major sectors in Taiwan. Finally, these counterfactual growth paths are compared with the base run path to evaluate these policies.

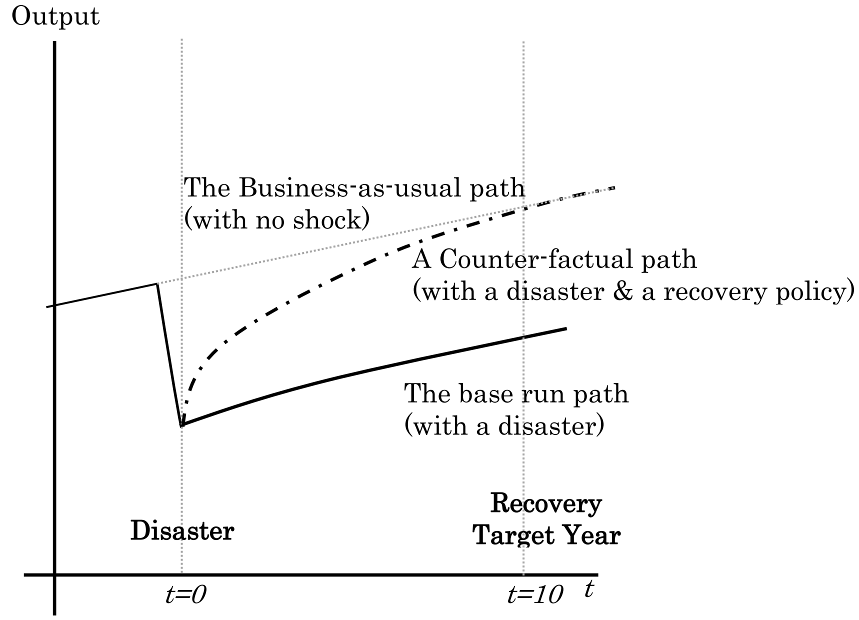

Figure 4.2.2: Three Growth Paths for Comparative Dynamics

4.2.4 Disaster Shocks: Earthquake and Nuclear Power Shutdown

The hypothetical earthquake at the Shan-jao fault is assumed to cause destruction of capital stock and unavailability of labor force. The study uses the estimates of their losses made by Huang and Hosoe (2014) for period 0. They estimated the capital losses based on the regional building collapse estimated by Taiwan Seismic Scenario Database (TSSD) with regional concentration data of affected industries (DGBAS, 2011b).[7] The capital losses are assumed to occur exogenously only once in period 0 and can be recovered through endogenously-determined investment from period 1, as described by the sectoral investment equation (4.2.1). The loss rates differ among sectors because capital intensity and spatial distribution differ by sector (Table 4.2.1).

The labor losses are assumed to occur in period 0 by 7.4 %, which is also estimated based on the building collapse and damage. The background assumption is that building collapse and damage render workplaces unavailable and, thus, a certain proportion of the labor force is unavailable. Note that the unavailability of the labor force does not mean only expected deaths and injuries in the earthquake, which are not high enough to cause macroeconomic impacts. Because the collapsed or damaged buildings in due course would be rebuilt or fixed, labor unavailability is assumed to be reduced gradually in the following five periods (i.e., by 25% every year).

On top of these two factor losses, a nuclear power shutdown is assumed in the compound disaster. By this assumption, it could be interpreted either that the earthquake and/or an earthquake-induced tsunami hit and destroy the nuclear power plants or that the earthquake makes Taiwanese people concerned about a nuclear accident, causing them to call for the suspension or abolition of the nuclear power plants. The nuclear power shutdown implies two impacts. One is further losses/unavailability of the capital stock of the nuclear power plants in the electric power sector. The assumed capital losses in the electric power industry in Table 4.2.1 have been increased 16.3%. The other impact is increased fossil fuel uses to make up the losses of nuclear power generation, just as Japan has experienced after the GEJE.[8] In the experiments, it was assumed that 138% more petroleum, 15% more coal, and 27% more natural gas are used to produce a unit of electricity. This is implemented in the simulations by adjusting their Leontief input coefficients in the electric power sector by that magnitude.

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[7] http://teles.ncree.org.tw/tssd/

[8] Details about these loss estimates in capital, labor, and nuclear power are provided in Huang and Hosoe (2014).

4.2.5 Recovery Policy Scenarios

After a disaster, people often call for various measures of recovery for housing, food supply, medical services, employment and industrial activities, energy supply, and so on. In the macroeconomic simulations, the study focuses on the recovery of economic activities. Indeed, as standard macroeconomic growth theory shows, aggregate output cannot recover perfectly from a shock in endowments and/or technological changes. Instead, in the multisectoral setup, we investigate policies that can achieve a recovery of output in some of the major sectors for Taiwan, such as semiconductors, electronic equipment, and chemicals. In addition, the study investigates the possibility of recovery in the electric power sector, which is assumed to be hit seriously by a compound disaster.

Two types of subsidies are examined in the experiments. One is a production subsidy, which is expected to stimulate sectoral output to the desired level directly. The second type is a capital-use subsidy. As the investment good allocation function (4.2.1) shows, the capital-use subsidy raises remuneration of capital and, thus, attracts more investment in the target sector for quicker recovery. It is assumed that these subsidies are financed by lump-sum direct taxes.

We set the recovery target year at period 10. While many periods are needed for recovery, the duration of recovery programs tends to be rather short. In Taiwan's case, the recovery budget is prepared only for the first 3 years, including the year when the earthquake occurred. Three variations for the program duration are assumed: 3, 5, and 7 years. The government is assumed to provide a production subsidy or a capital-use subsidy for one of the target industries in these periods after the earthquake. For simplicity, their subsidy rates are assumed to be constant during the recovery program periods and are set high enough to achieve output recovery in each target sector at period 10 (Table 4.2.3). As the study focuses on the recovery of the four sectors from the compound disaster by means of the two types of subsidies with the three different types of recovery program duration, 24 different experiments are conducted in the simulations.

Table 4.2.3: *Subsidy Rates Required for Recovery at Period 10*

	Production Subsidy Rate	Capital-Use Subsidy Rate
3-year Recovery Program		
Semiconductor	12.0%	46.5%
Electronic Equipment	0.4%	4.5%
Chemical	6.0%	47.9%
Electricity	93.1%	98.8%
5-year Recovery Program		
Semiconductor	7.4%	33.1%
Electronic Equipment	0.2%	2.6%
Chemical	3.8%	34.5%
Electricity	84.3%	97.6%
7-year Recovery Program		
Semiconductor	5.3%	25.6%
Electronic Equipment	0.1%	1.8%
Chemical	2.7%	26.7%
Electricity	76.6%	95.8%

4.3 Simulation Results on Recovery Policies

4.3.1 The Base Run: Impacts of Compound Disaster

We use a multisectoral model and, thus, can see the impacts of disasters and the effects of policies not just on the target sector but also on other sectors. In Figure 4.3.1, thick lines show the paths of sectoral output in the base run (i.e., only a compound disaster) in terms of deviations from their BAU paths (i.e., no shocks). Output would decline in all the sectors except PET in period 0, as Huang and Hosoe (2014) predicted with a static CGE model. The study investigates what would occur in the subsequent periods with the dynamic CGE model.

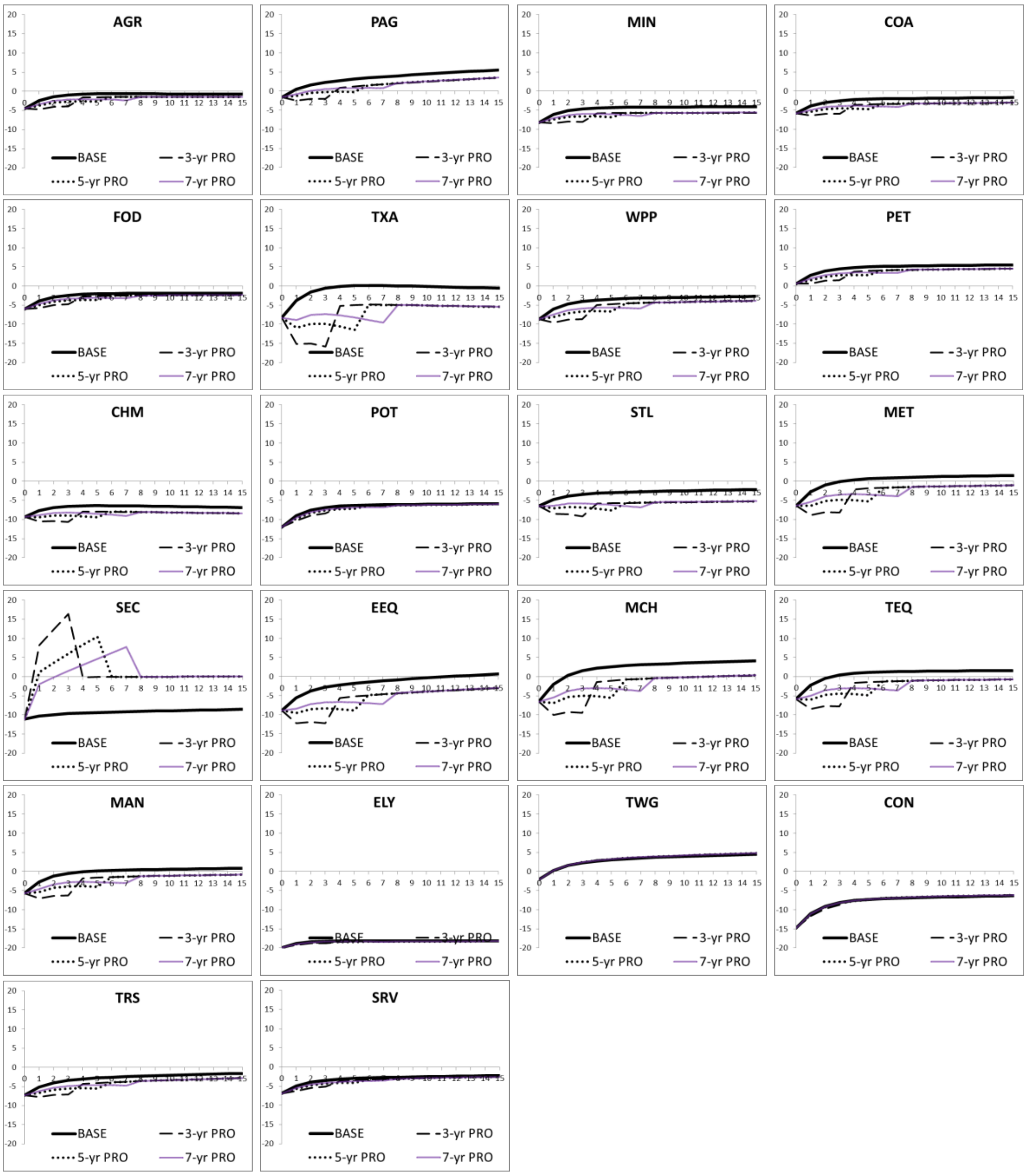

Figure 4.3.1: Sectoral Output with and without Production Subsidies for Semiconductor Sector [Unit: deviations from the BAU, %]

The semiconductor sector (SEC), among many others, would suffer a very severe decline of more than 10% in period 0 and even after period 10 (i.e., the target year). Similarly, the chemical (CHM), pottery (POT), and electric power sectors (ELY) would suffer in the long run. In contrast, the textiles and apparel (TXA), metal (MET), electronic equipment (EEQ), machinery (MCH), transportation equipment (TEQ), and other manufacturing (MAN) sectors would recover in due course without any policy interventions. The petroleum sector (PET) alone would gain throughout the simulation periods owing to increased fossil fuel demand from the nuclear power shutdown. From a macroeconomic viewpoint, the social losses, measured with Hicksian equivalent variations, would reach 565 billion TWD in period 0 and 2,677 billion TWD in periods 1–10, which are comparable to 4.9% and 2.7% of the BAU GDP, respectively.

4.3.2 Sectoral Impacts

4.3.2.1 Impacts of Recovery Program for Semiconductor Sector

Considering the importance of SEC in Taiwan, citizens could well call for policies that would help or accelerate the sector's recovery. The production subsidy would achieve a recovery quickly, with conspicuous overshooting of its output level compared with the BAU path (the panel in the far left of the fourth row of Figure 4.3.1). The shorter the recovery program duration is, the more marked its overshooting would be during the recovery program. After the program finishes, the SEC output level would fall sharply and become stable at the BAU level. These interventions would affect other sectors negatively, especially TXA, STL, EEQ, and MCH. This is because recovery of one sector could be achieved only by mobilizing resources, that is, investment goods and the labor force, from other sectors. Direct taxes, which are raised to finance subsidies, would decrease household consumption as a whole. TXA has a significant share of household consumption and, thus, would also suffer through this channel. Such drastic fluctuations may be regarded as the side effects of the recovery policy.

Alternatively, when a capital-use subsidy is used for the SEC, its recovery paths would be smooth without any overshooting (the panel in the far left of the fourth row in Figure 4.3.2). The impact of this on other sectors would also be negative but smaller. As the capital-use subsidy can recover lost capital through the investment mechanism function (4.2.1) directly, it works more efficiently than the production subsidy.

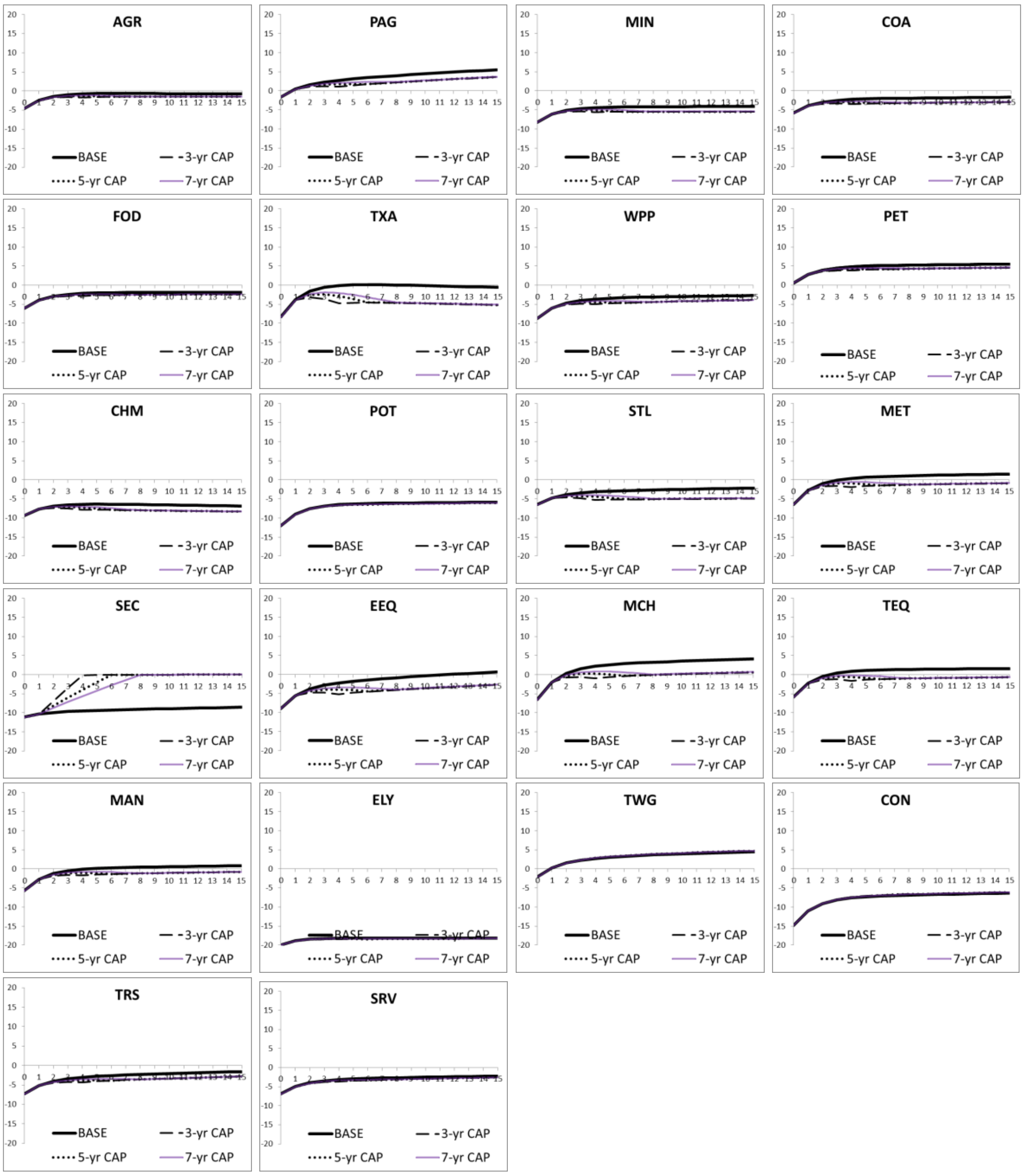

Figure 4.3.2: Sectoral Output with and without Capital Use Subsidies for Semiconductor Sector [Unit: deviations from the BAU, %]

By comparing costs of these different recovery programs, the efficiency of these programs can be seen (the left panel of Figure 4.3.3). A recovery program with longer duration, which requires lower subsidy rates, costs less. When the program duration is extended with production subsidies and capital-use subsidies from 3 years to 5 years, its fiscal burden could be reduced by 10% and 7%, respectively. The saved fiscal costs of production subsidies (139 billion TWD) and capital-use subsidies (113 billion TWD) by extending the program duration from 3 years to 5 years are comparable to 0.1% of the BAU GDP in periods 1–10. Another extension of the program duration from 5 years to 7 years would cut the fiscal costs further in a similar magnitude.

The capital-use subsidy would cost 10, 8, and 7% less than the production subsidy in the 3-, 5-, and 7-year programs, respectively. Finally, it should be noted that the total fiscal burden for this single sector of SEC would exceed 1,000 billion TWD while the annual government budget is 1900 billion TWD in the years without large-scale disaster.

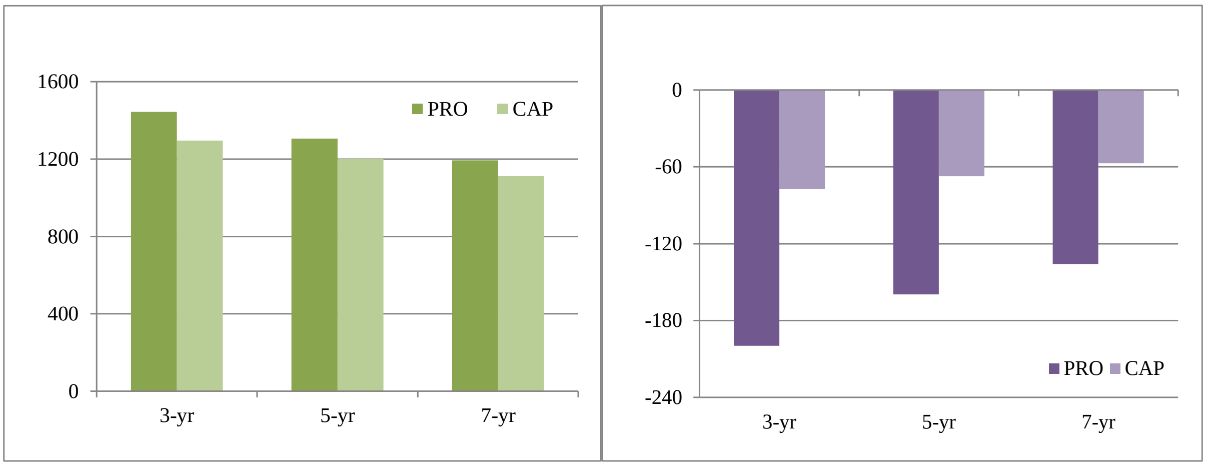

Figure 4.3.3: Total Fiscal (Left Panel) and Social Costs (Right Panel) of Recovery Programs for Semiconductor Sector (unit: billion TWD)
Source: Author's calculation.
Note: The total fiscal costs and social costs measured by the Hicksian equivalent variations in Periods 1–10 discounted at a rate of 4%.

The higher subsidy rates in the shorter recovery programs cause larger distortions in resource allocation and, therefore, incur additional social costs on top of those in the base run, that is, with a compound disaster but without any subsidies for recovery (the right panel of Figure 4.3.3). These subsidy programs would increase social losses by more than 5%.

4.3.2.2 Impacts of Recovery Programs for Three Other Sectors

The output paths indicates that EEQ would achieve a recovery in period 11 (i.e., one period after the target period) without subsidies and, thus, would require only a little acceleration of its recovery by subsidies (Figures 4.3.4 and 4.3.5). The impact of subsidies for EEQ are found to be qualitatively similar to that discussed in the previous section for SEC. The smaller policy interventions would incur smaller fiscal and social costs (Figure 4.3.6).

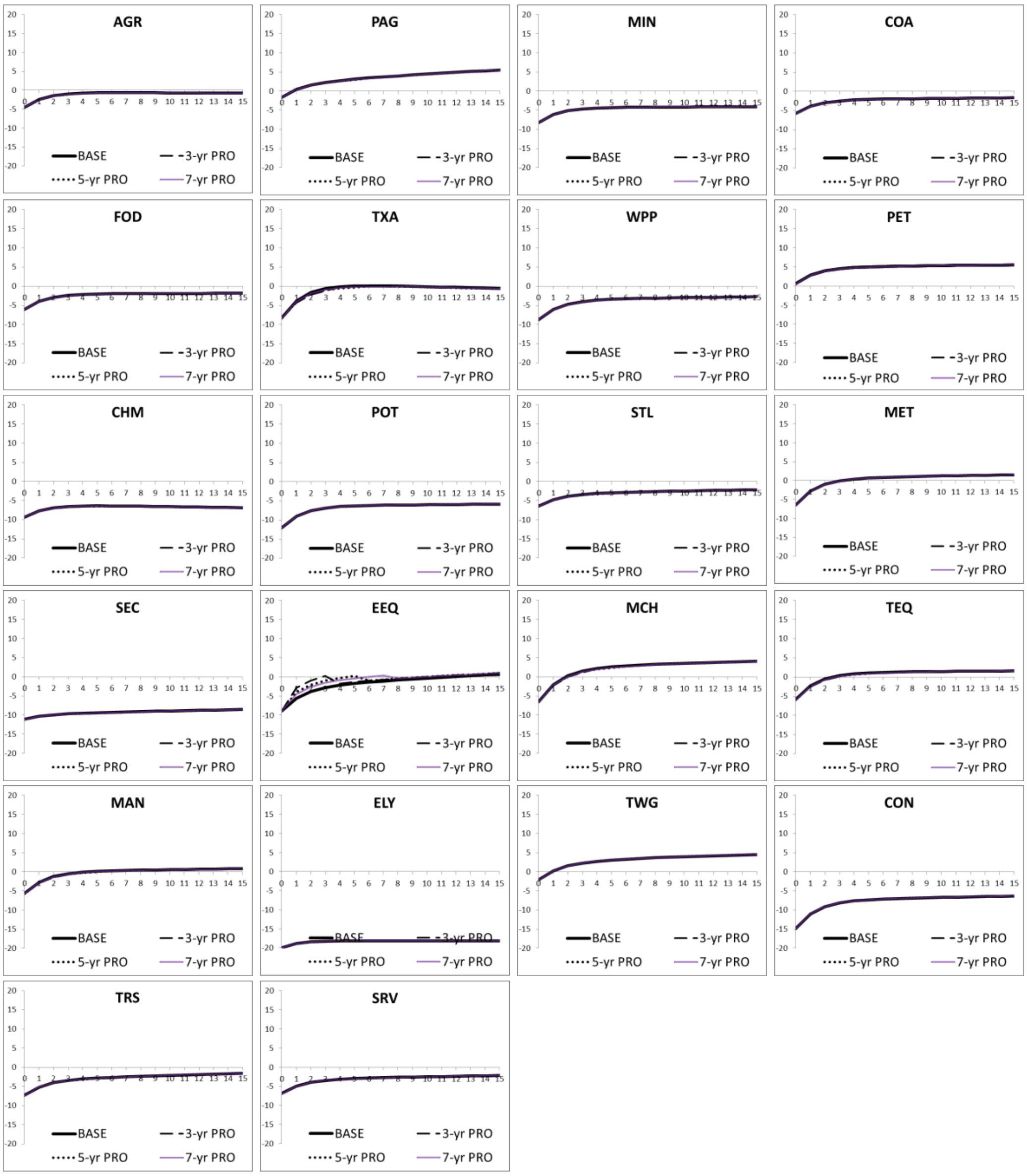

Figure 4.3.4: Sectoral Output with and without Production Subsidies for Electronic Equipment Sector

[Unit: deviations from the BAU, %]

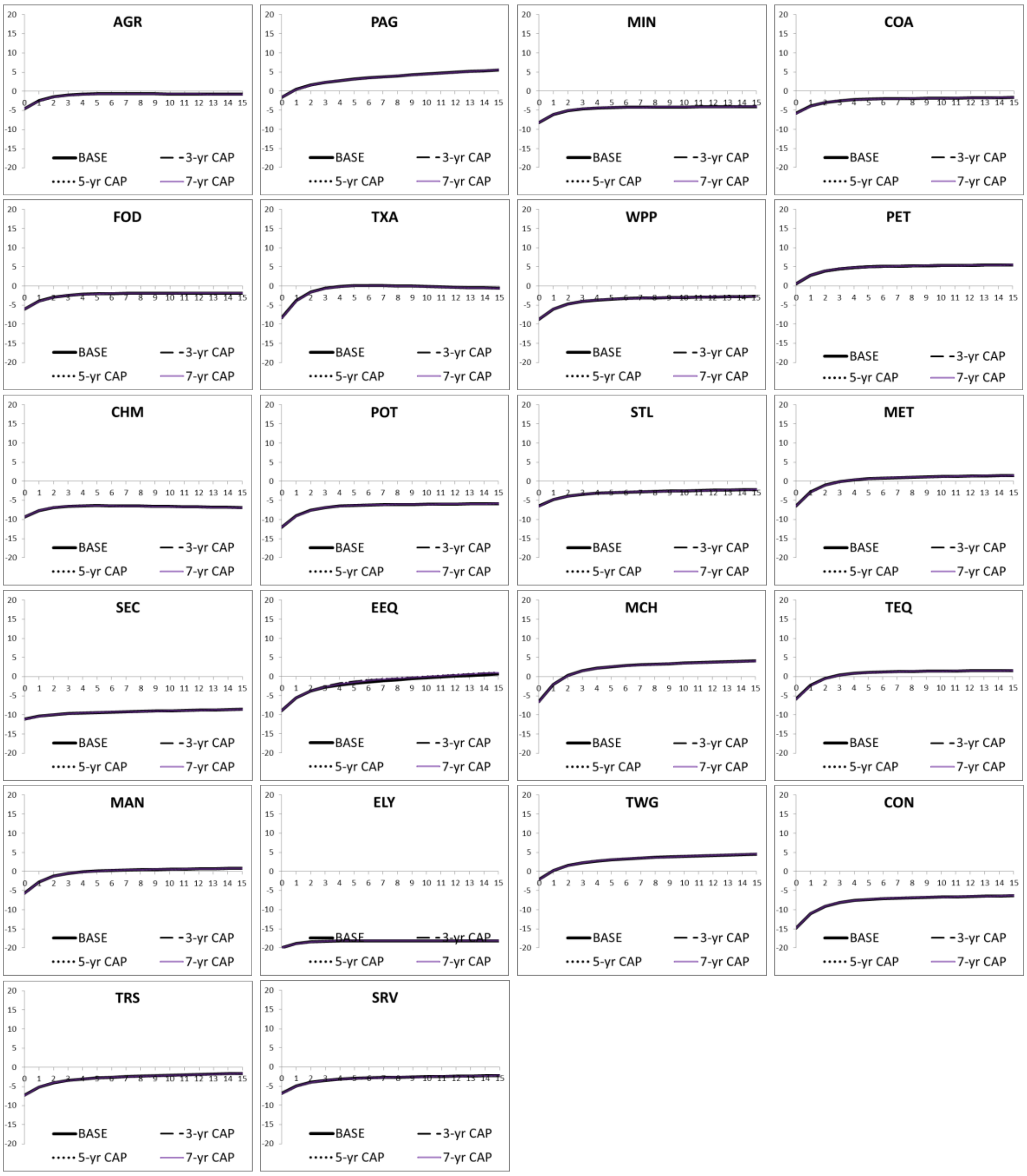

Figure 4.3.5: Sectoral Output with and without Capital Use Subsidies for Electronic Equipment Sector

[Unit: deviations from the BAU, %]

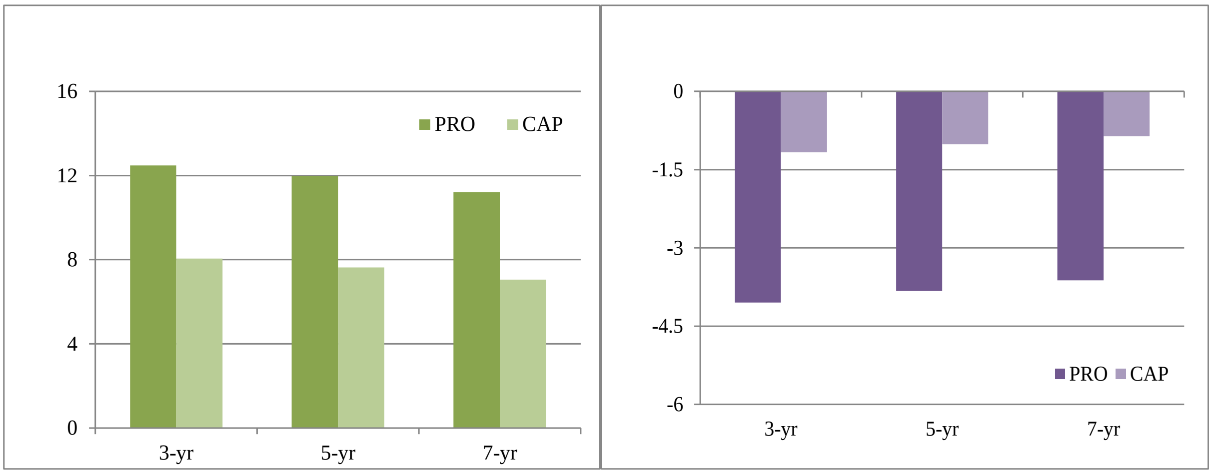

Figure 4.3.6: Total Fiscal (Left Panel) and Social Costs (Right Panel) of Recovery Programs for Electronic Equipment Sector (unit: billion TWD)
Source: Author's calculation.

In contrast to these two sectors, which could successfully recover by the subsidies, the chemical sector (CHM) could not achieve any sustainable recovery (the panel on the far left of the third row of Figures 4.3.7 and 4.3.8). That is, CHM indeed could recover its output level owing to heavy subsidies only temporally in period 10 but its output level in the following periods would be below the BAU output level. This contrast is because CHM is heavily dependent on PET input, which is used more intensively for power generation owing to its nuclear power shutdown. This input shortage blocks sustainable recovery of CHM.[9]

[9] Even if a very high subsidy rate is assumed, the output level could not be maintained above the BAU level in and after period 10 because, as Figures 4.3.7 and 4.3.8 indicate, the output growth paths converge to the base run level consistently.

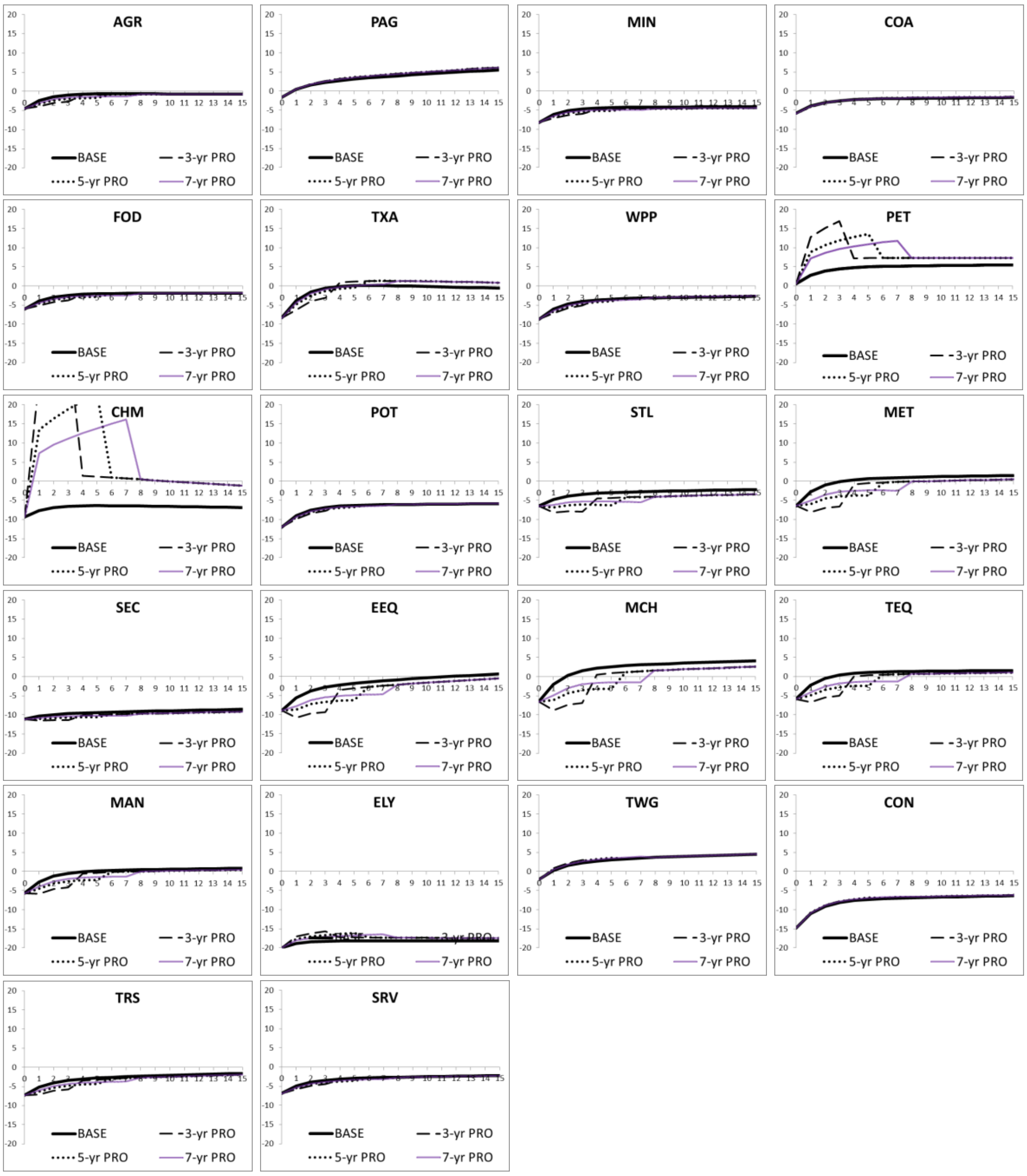

Figure 4.3.7: Sectoral Output with and without Production Subsidies for Chemical Sector

[Unit: deviations from the BAU, %]

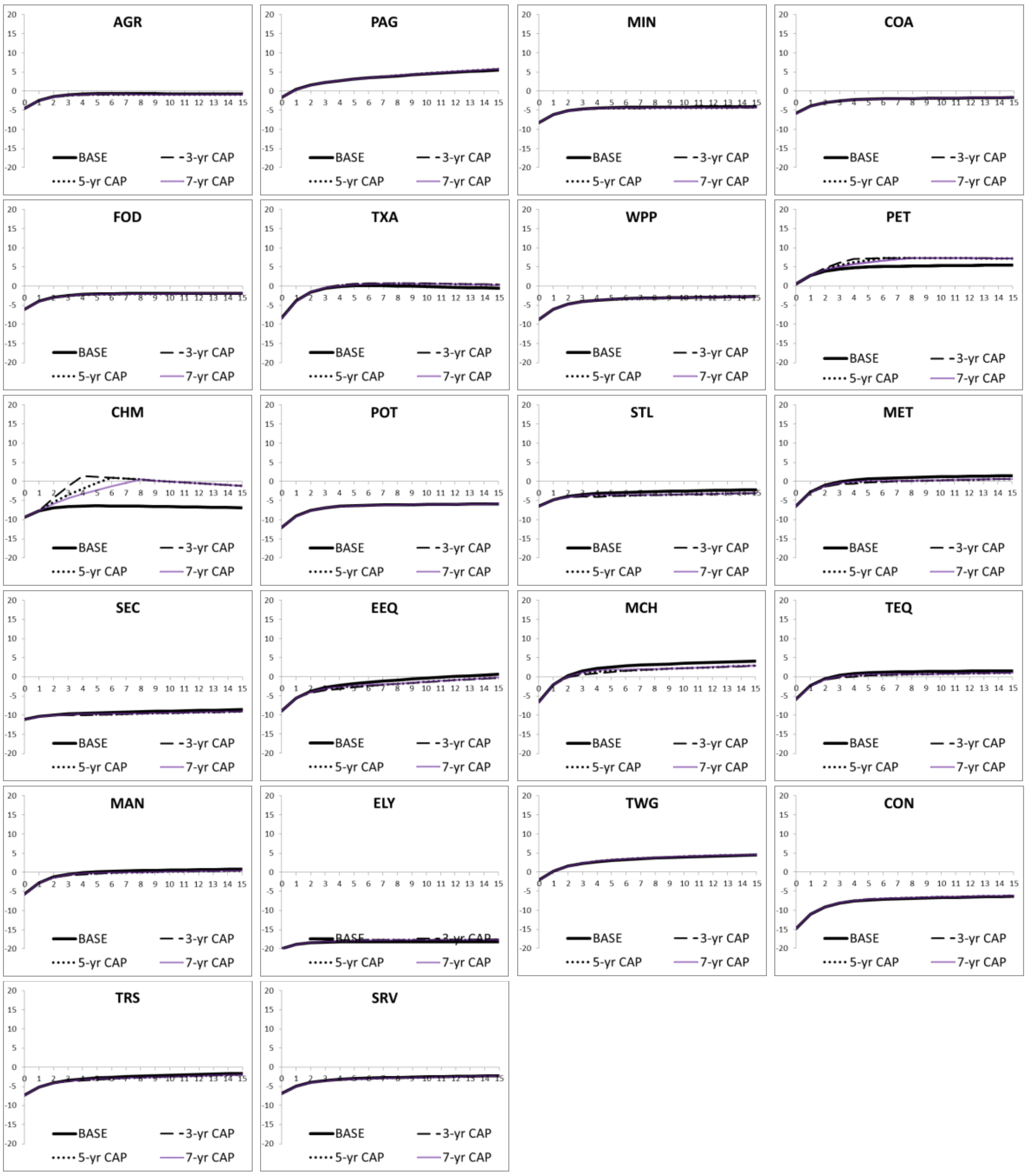

Figure 4.3.8: Sectoral Output with and without Capital Use Subsidies for Chemical Sector

[Unit: deviations from the BAU, %]

The electric power sector (ELY) would be hit so severely by the compound disaster that it could not achieve a recovery at all, even via very heavy subsidization of its output sales or capital usage (Figure 4.3.9).

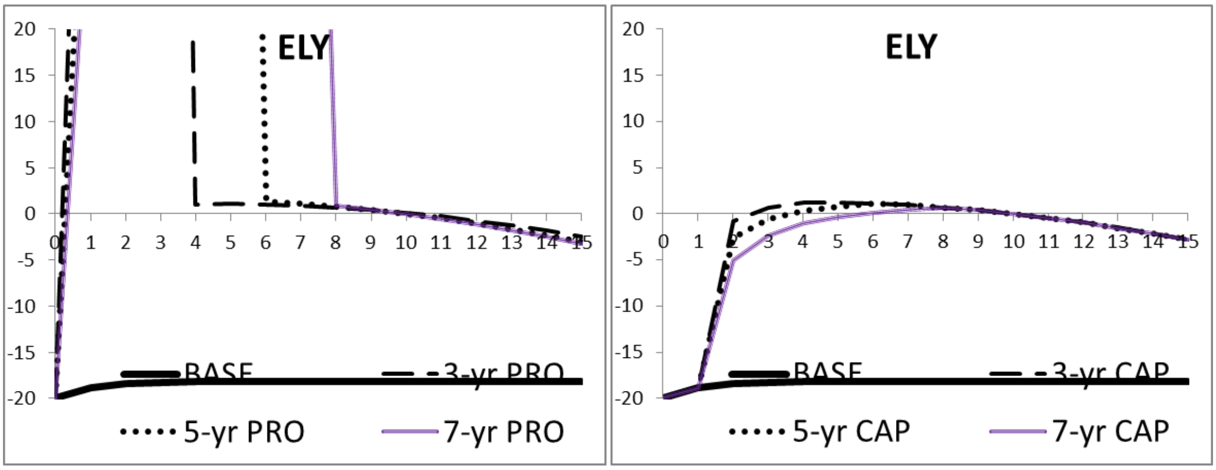

Figure 4.3.9: Sectoral Output of Electric Power Sector with and without Production Subsidies (Left Panel) and Capital-Use Subsidies (Right Panel) [Unit: deviations from the BAU, %]

4.4 Concluding Remarks

In this chapter, a compound disaster was simulated to hit northern Taiwan, where capital and major industries are located, in a dynamic CGE framework. The study focused on the recovery process of these industries and examined the effectiveness and efficiency of recovery programs with production or capital-use subsidies. Among the four sectors examined, SEC could achieve a sustainable recovery in 10 years with subsidies. However, it would need a far larger special budget than the annual budget in the years without large-scale disaster. This indicates the full recovery of SEC would be too costly to pursue; the sector may be compromised and may have to pursue a more moderate recovery target. On the other hand, EEQ could recover with only a little help of subsidies.

Regarding the recovery program schemes, capital-use subsidies would cost less than production subsidies. The latter would need high subsidy rates that cause overshooting in the recovery process and, thus, are inefficient. When the recovery program is designed to support SEC for 2 years longer with a lower subsidy rate, the fiscal costs could be lower by 7–10%. As subsidies cause distortions in resource allocation, efficiency losses would follow the recovery program. It is noteworthy to see that an additional 3% of social losses would be borne for the recovery of SEC. This is equivalent to an annual burden as high as 37,411 TWD per household or 3.4% of household income. This is solely a political issue of whether people are willing to bear such large costs for the recovery of their flagship industry.

While a recovery of these two sectors could be achieved, albeit sometimes at great cost, the energy-intensive sectors of CHM and ELY could not recover, even with extensive support by subsidies. The success or failure of their recovery would inevitably lead to the transformation of Taiwan's industrial structure after a disaster. As long as power supply is limited by a nuclear power shutdown, energy-intensive industries in the domestic economy could barely survive and would be replaced by other sectors that use less energy and/or could carry out offshoring of their production processes while maintaining their headquarters domestically. Thus, disaster-induced offshoring needs to be considered in future analysis.