How to Use Carbon Tax Revenues Well: Implications from Taiwan

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Abstract

Carbon pricing is one of the main policies for improving energy efficiency and achieving carbon reduction. This study has aimed to investigate how to use carbon pricing revenues well to mitigate negative effects on the economy. Relying only on carbon pricing policies can result in high economic costs; in particular, the energy-intensive industrial sectors suffer greater impacts. We propose that providing subsidies to sectors based on their respective carbon pricing payments could mitigate the negative effects on the GDP better than the other examined scenarios of providing the carbon pricing revenues to the fiscal budget or providing subsidies to sectors based on their respective contributions to emission reductions. Thus, proper design of the use of carbon pricing revenues could mitigate the negative economic effects of carbon pricing.

Key words: carbon pricing, economic impacts, supportive measures

1. Introduction

Carbon pricing is a useful policy measure for achieving carbon emission targets. When a carbon price is imposed on carbon emissions, emitters have to bear the corresponding costs for the use of fossil energy. In face of carbon prices, industries and households are motivated to re-optimize their production and consumption decisions according to the carbon prices. This provides incentives for the use of clean energy, motivating industries and households to reduce their use of high-emission energy. In the literature, numerous studies have investigated the importance of carbon pricing for achieving emission targets. Wu et al. (2019) investigated the effects of Taiwan's carbon trading system for achieving reduction targets. Springer (2003) reviewed 25 models, proposing that restricting the permit supply can increase carbon price revenues. Springer and Varilek (2004) argued that a modest change of carbon price would have large effects on consumers and investors. Zhang and Wei (2010) summarized the operating mechanism and economic effects of Europe's carbon trading system. Wang et al. (2016) proposed that a market-based abatement policy had been more efficient than a command and control policy for China. Fan et al. (2016) showed that a national carbon market could reduce regional economic disparities and macroeconomic costs for the whole nation. Zhou et al. (2013) suggested that China's interprovincial emission trading could reduce total abatement costs by 40 percent. Zhang et al. (2017) demonstrated that integration of emission trading schemes would optimize the allocation of emission permits, providing economic welfare gains to countries that adopt permits. Wang et al. (2009) proposed that emission limits similar to those of the Kyoto Protocol would seriously impede future economic growth in China. Wang et al. (2015) elaborated that the emission trading system could reduce the economic costs of achieving the Copenhagen commitment for China. Wu et al. (2016) showed that the economic effects of the carbon trading system in China depended on carbon allowance allocation and renewable energy development.

The Taiwanese government intends to launch a carbon trading system in the future under the Greenhouse Gas Reduction and Management Act. Various carbon pricing plans have been proposed by researchers and scholars in Taiwan, including propositions for the use of carbon pricing revenues. Yang (2014), for instance, proposed that carbon pricing revenues could be used to improve energy efficiency, enhancing the effectiveness of carbon reduction. Shaw et al. (2020) showed the design of four carbon tax recycling schemes under the principle of unchanged government total tax revenue, proposing that the implementation of a carbon tax could have significant energy efficiency and carbon reduction effects. In addition, there are numerous papers in the literature investigating the issue of recycling carbon pricing revenues. For example, Zhao et al. (2022) proposed that carbon pricing increased income inequality. Imposing the same tax return rate on all income groups would widen the income gap while distributing higher tax returns to lower income groups would narrow the income gap. Pradhan and Ghosh (2022) suggested that coal tax revenues could be useful for promoting research and development in new energy technologies in India. Mayer et al. (2021) argued that carbon pricing in Austria increased public goods provision, improving the welfare of low-income households. Carattini et al. (2019) studied how to use carbon pricing revenue to maximize public support.

This study has aimed to investigate how to use carbon pricing revenues well to mitigate negative economic effects. The funding that a government raises through the carbon pricing may be provided to the fiscal budget or used to promote renewable energy development or to improve energy efficiency. Each of the aforementioned measures could have various economic effects. Therefore, supportive measures need to be designed to reduce the negative impacts on the economy and industrial sectors.

This study has adopted a computable general equilibrium (CGE) model to investigate the effects of carbon pricing on Taiwan's economy. Three measures for supporting carbon tax revenues were examined. In the first, the carbon pricing revenue is used as an income source for the fiscal budget. In the second, the government subsidizes sectoral industries according to their respective contributions to emission reductions. In the third, the government subsidizes sectoral industries according to their respective carbon pricing payments. We ran simulations to determine which of these three measures would result in the least economic disruption. It must be noted that Taiwan has a small open economy. Based on this economic structure, we have constructed a CGE model for Taiwan that includes industry, households, government departments and foreign import and export trade, using a small open economy framework. Since the energy sector is a key component in determining future carbon emission pathways, this model also specifies a detailed design for the power supply sector, which is one of the main sources of carbon emissions in Taiwan.

The contributions of this study are as follows: First, we have compared the three scenarios for the use of carbon tax revenues, in which (1) The carbon pricing revenue is used as an income source for the fiscal budget; (2) The government subsidizes sectoral industries according to their respective contributions to emission reductions; and (3) The government subsidizes sectoral industries according to their respective carbon pricing payments. We have found out that the third scenario–subsidizing industrial sectors according to their respective carbon pricing payments–results in the lowest losses in gross domestic production (GDP). This indicates that to minimize GDP losses, the industrial sectors that pay higher carbon prices could get more support from the government. Thus, this refund policy for carbon pricing revenues could have less of a negative effect on the economy.

Second, we have simulated the effects of carbon pricing on sectoral output values. The sectoral industries that pay higher carbon prices will suffer from higher output value losses. Moreover, industries that produce upstream products or services may suffer higher losses of output value. Thus, correlation coefficients between carbon pricing payments and output value losses are relatively high when we consider upstream industrial sectors.

The structure of this report is organized as follows: The second section describes the scenarios and model designs, the third section presents the simulation results and the last section summarizes the conclusions.

2. Scenarios and Model Designs

This section describes how the business as usual (BAU) scenario, emission reduction targets, carbon pricing revenue support measures and model designs for the CGE model were set up.

2.1 Scenarios

Figure 1 shows the BAU scenario of CO_2 emissions from fuel combustion and emission targets. No policy measures have been implemented in the BAU scenario, and a high share of electricity is generated by fossil fuel. Thus, CO_2 emissions continue to rise. In 2035, fuel combustion emissions approach 380 million tonnes. The official emission target for fuel combustion emissions declines to about 190 million tonnes of CO_2 in 2035. This study analyzes the impact of the carbon pricing

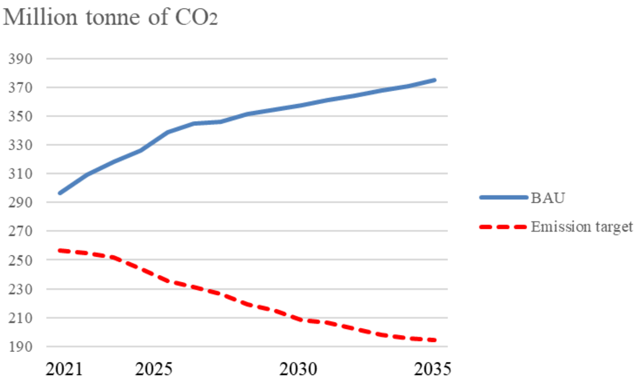


Fig. 1 CO_2 emissions in the BAU scenario and the reduction target.

mechanism on the industrial sectors and economy. We will elaborate the effects of carbon pricing on the achievement of the emission target.

In 2019 the fuel combustion emissions of the industrial sectors constitute the majority, accounting for 49% of total emissions. The other main sources of carbon emissions are the energy sector for personal use (15%), transportation (14%), residential (11%), the service sector (10%), and agriculture (1%). Thus, the industrial sector is the main source of emissions in Taiwan.

Table 1 elaborates the three scenarios for the use of carbon pricing revenues. The first scenario specifies the carbon tax system. In it, the carbon pricing revenues are transferred as an income source to the fiscal budget. The fiscal income could be used for government spending, government saving and/or government investment in foreign countries. The CGE model determines the recipient of government income while balancing the fiscal budget.

In the second scenario, the carbon price revenue is recycled back to sectoral industries according to their respective carbon-reduction contributions. To distribute the carbon tax revenue, the CGE model simulates the effect of carbon pricing on sectoral emission reductions. By calculating the carbon emission reduction of each sector, we can evaluate the sectoral share of contribution to emission reduction. Finally, each industrial sector obtains a carbon pricing subsidy according to its carbon-reduction contributions.

In the third scenario, each industrial sector receives a subsidy according to its respective-carbon-pricing payments. The CGE model simulates the carbon pricing payments of each sectoral industry. This way, we can evaluate the share of carbon pricing payments from each sectoral industry. Finally, the subsidy is distributed according to carbon pricing payment share.

2.2 Model Designs

The CGE model can be used to simulate the complete range of interaction and feedback between representative agents in an economic system. Such a model framework has been widely used to assess the economic and environmental impacts of various climate policies. Böhringer and Löschel (2005) and Fujimori et al. (2014) applied the CGE framework to global issues. Zhang (1996) and Wang et al. (2009) performed CGE studies on a national level.

We collected economic data from multiple sources. The 2016 input–output (IO) table was obtained from the Directorate-General of Budget, Accounting and Statistics, Executive Yuan in Taiwan. Official population, GDP growth and sectoral future trend projections were obtained from the National Development Council in Taiwan.

Figure 2 illustrates the nesting structure of the CGE

Table 1 Supportive measures for the use of carbon pricing revenues.

Scenario	Description
Carbon pricing revenues are used as an income source for the fiscal budget	Carbon pricing revenues are transferred as an income source to the fiscal budget. The CGE specifications determine how such revenues are used endogenously while balancing the fiscal budget.
The government subsidizes sectoral industries according to their respective contribution to emission reductions	(1) We simulate emission reductions of each sector following the launch of carbon pricing. (2) We calculate the contribution of each sector to total emission reduction. (3) The carbon pricing revenue is returned according to the share each sector contributed.
The government subsidizes sectoral industries according to their respective payments for carbon pricing	(1) We simulate the carbon pricing payments of each industrial sector. (2) We calculate the payments of each sector to the total carbon pricing revenues. (3) The carbon pricing revenues are returned according to the share paid by each sector.

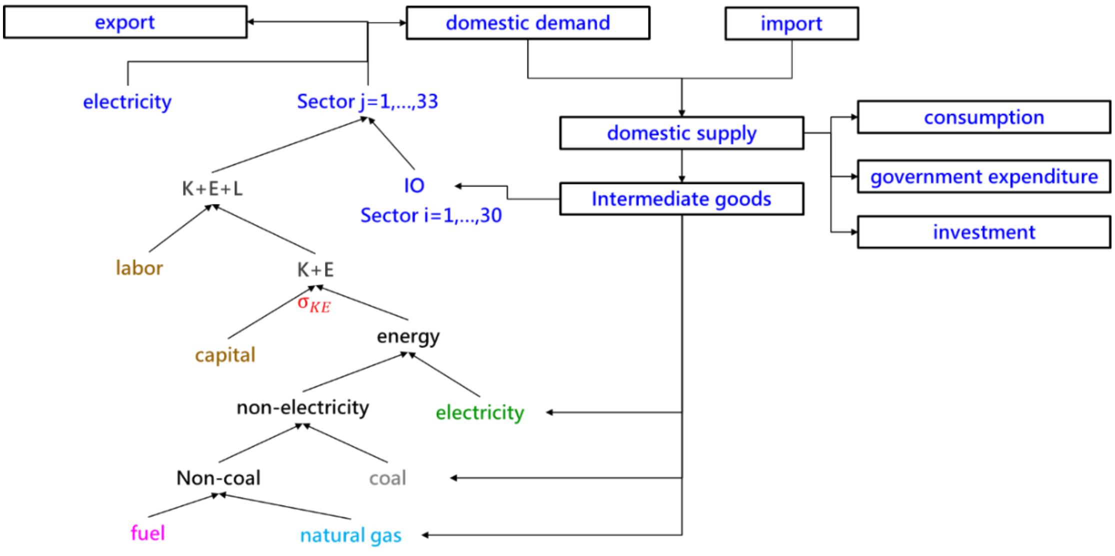


Fig. 2 Nesting structure of the CGE model.

model used in this study. Detailed specifications as well as industrial classifications are available in an appendix upon request. The market structure follows the specifications of the Asia-Pacific Integrated Model/ Computable General Equilibrium (AIM/CGE). AIM/CGE was developed by the National Institute for Environmental Studies (NIES), with an emphasis on specifying energy substitution. Natural gas and fuel oil are mainly used for combustion, providing heat energy for production. Therefore, there is a substitution relationship between fuel oil and natural gas. Moreover, coal also generates heat energy. In practice, it is easier to maintain temperatures using combustion of fuel oil and natural gas, compared with that of coal. Fuel oil and natural gas are combined to produce non-coal goods, which are then combined with coal to form non-electric composite goods. Electricity can be used for power provision and heat generation, and is more widely applied in industries than other fossil energy. Non-electric energy is combined with electricity to produce energy composite goods.

As an input, efficient capital stock can generate the same output using less energy. Capital stock can combine with energy, generating capital-energy composite goods. Moreover, capital stock and labor are key components for industrial added value. Each industry combines labor and capital-energy composite goods as capital-labor-energy composite goods. Non-energy intermediate goods are combined with capital-labor-energy composite goods, producing gross outputs. Figure 2 indicates 33 production sectors, including agriculture, industry and services. The electricity sector has unique specifications, different from AIM/CGE.

We specified our CGE model as a small open economy. Thus the gross outputs are sold either as export goods to foreign countries or as domestic goods domestically. Moreover, the domestic goods are combined with import goods to produce the domestic supply. Producers and consumers in the domestic market purchase commodities–including for consumption, or as government expenditure, investment and intermediate goods. The intermediate goods are adopted by firms as production inputs.

In this study we have designed a specific production structure for the electricity sector to facilitate subsequent analysis of the impact of Taiwan's future electricity policy. Since the electricity sector is Taiwan's main source of fuel combustion emissions, it is necessary to elaborate its structure. Taiwan's power generation is disassembled into fossil fuel power, renewable power, nuclear power generation and the transmission and distribution sectors.

Figure 3 depicts the nesting structure of the electricity sector. Fossil fuel power generation is Taiwan's main source of power generation, consisting of fuel oil, coal and natural gas as the main inputs. The aforementioned energy is combined to formulate fuel energy. Moreover, electricity is also one production input, combined with fuel energy as energy composite goods. The new capital for electricity generation is more efficient, generating the same output using less energy. Capital stocks and the energy composite are combined as capital-energy composite goods. The labor supply and capital-energy composite goods are combined to generate capital-energy-labor composite goods. Finally, the composite goods and the other non-energy intermediate inputs are used to generate fossil energy power.

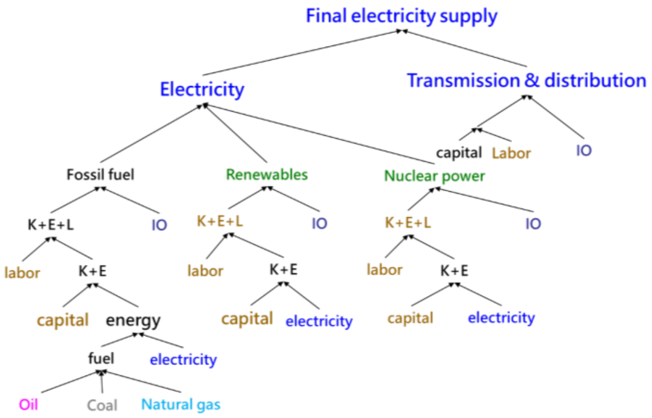


Fig. 3 Nesting structure of electricity sector in the CGE model.

The electricity generated by renewables does not involve the use of coal, fuel oil no natural gas; however, the renewables still need electricity for power generation. Capital and electricity are combined to generate capital-energy composite goods for renewables. Moreover, such composite goods are combined with the labor supply to generate capital-energy-labor composite goods. In the last nest, the other non-energy intermediate goods and the aforementioned inputs are combined for the production of renewable electricity. Nuclear power generation does not involve the use of fossil energy; thus, its production nest is the same as that of renewable energy.

Electricity consists of fossil fuel power, renewable energy power, and nuclear power. The electricity transmission and distribution sector is essential for the transmission of the electricity to households and industries. This sector consists of capital and labor. These two inputs are combined with other intermediate goods for the transmission and distribution of electricity. Electricity is combined with the transmission and distribution sector, providing the final electricity supply to the market.

3. Simulation Results

This section presents the results of simulating the use of carbon pricing to achieve carbon reduction targets. We demonstrate the impacts on the industrial sectors and GDP, investigating the effects of supportive measures for carbon pricing revenues.

3.1 Carbon Pricing to Achieve Targets

As shown in Fig. 1, a reduction of approximately 40 million tonnes was needed in 2021 and around 180 million tonnes will be needed in 2035 to achieve Taiwan's emission target.

Figure 4 shows the simulated carbon prices for achieving these emission reduction targets. The government collects carbon pricing revenue as income for its fiscal budget. To achieve Taiwan's carbon reduction target in 2025, a carbon price of around 150 U.S. dollar per tonne (USD/tonne) will be needed. Moreover, the carbon price has to be set to around 440 USD/tonne for the large emission reduction required in 2035. Therefore, a high carbon price is necessary for achieving emission targets without launching other government measures.

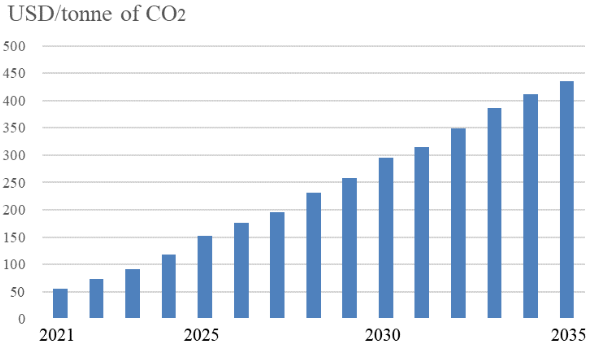


Fig. 4 Carbon prices necessary for achieving emission targets.

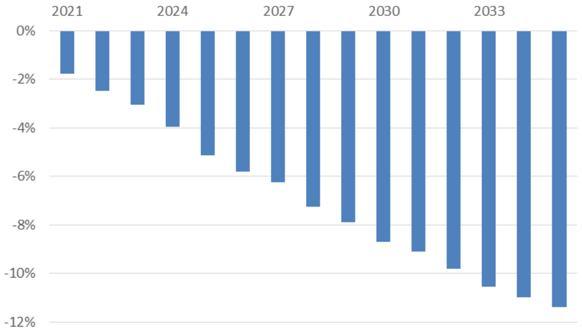


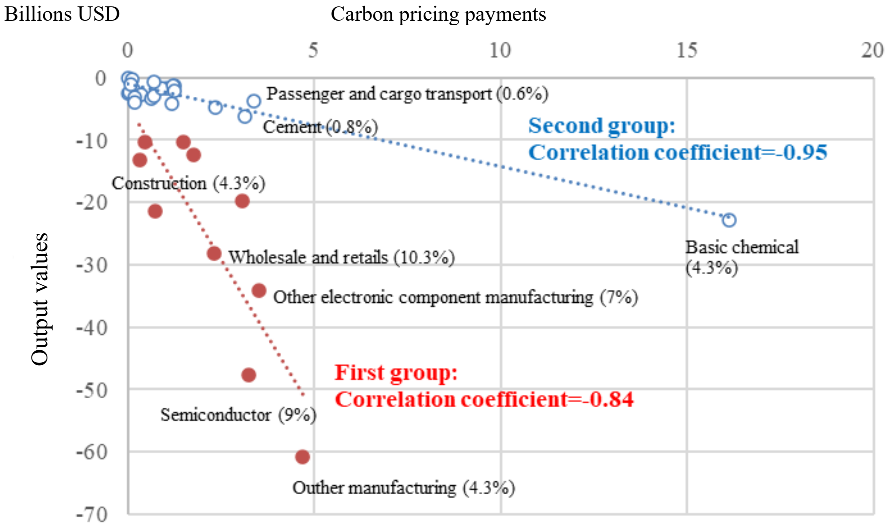
Fig. 5 Impact of carbon prices on the GDP.

3.2 Impacts of Carbon Pricing on the GDP

Figure 5 presents the impacts of carbon pricing on the GDP for achieving emission reduction targets. Assuming other conditions remain unchanged, the launch of carbon pricing will decrease the GDP by about 5% in 2025 compared with BAU, and this pricing system will reduce the GDP by 11% in 2035. Therefore, carbon pricing alone has substantial negative effects on the GDP.

3.3 Impacts of Carbon Pricing on the Industrial Sectors

Figure 6 shows the effects of carbon pricing on sectoral output values. Carbon pricing payments are depicted on the horizontal axis and losses to industrial output value, on the vertical axis. The supportive measure uses the carbon pricing revenues as fiscal budget income. We have divided the industrial sectors into two groups to investigate the effects of carbon pricing on output values. The first group is represented by solid red circles and the second group, by blue circles. The numbers in parentheses denote output value share of the *j* th sector to the aggregate output value of all sectors. The first group has an output value share higher than 4.3% while the second group's is lower than that threshold value. A higher value indicates that the sector in question is more closely connected to other sectors. The launch of carbon pricing would not only have negative effects on production in this sector but also reduce its demand for production inputs. Therefore, interconnection of the production chain



Note: Carbon pricing payments are depicted on the horizontal axis and losses of industrial output value, on the vertical axis. We have divided the industrial sectors into two groups to investigate the effects of carbon pricing on output values. The numbers in parentheses denote the output-value share of the *j*th sector to the aggregate output value of all sectors. The supportive measure uses the carbon pricing revenues as fiscal budget income.

Fig. 6 Impacts of carbon pricing on output values.

amplifies the negative effects of a carbon tax on the large industrial sector.

The correlation coefficient between carbon price payments and output values regarding the first group is −0.84. This group includes industrial sectors such as other manufacturing, semiconductors, other electronic component manufacturing, wholesale and retail, power, and construction. Regarding the second group, the correlation coefficient is −0.95. This group consists of basic chemicals, cement, passenger and cargo transport, steel products, and iron and crude steel. The respective correlation coefficients of these two groups indicate that the higher the carbon price paid by the industrial sector, the larger the negative effects on its output value.

Industrial sectors in the first group tend to produce upstream products or services, such as power and semiconductors These sectors have higher energy intensity compared with those in the second group. Moreover, these sectors have large market shares, enlarging the negative effects of carbon pricing. Thus, the launch of carbon pricing could exacerbate the negative effects on sectors in the first group compared with those in the second group, given the same level of carbon emissions. We need to distinguish between these two groups in order clearly to identify the negative relationship between carbon pricing payments and output value losses.

3.4 Uses of Carbon Pricing Revenues

Figure 7 shows the effects on the GDP of the uses of carbon pricing revenues. In the first scenario using the carbon pricing revenues as an income source for the fiscal budget, the carbon prices have the largest negative effect on the GDP. Compared with the BAU scenario, the negative effects on the GDP reach 5% in 2025, 9% in 2030, and 11% in 2035. In the second scenario, using the carbon price revenues for subsidies according to contribution to emission reductions, the negative effects on the GDP are −3% in 2025, −5% in 2030, and −8% in 2035. In the third scenario, subsidizing industrial sectors according to carbon pricing payments, the negative effects on the GDP are −2% in 2025, −5% in 2030, and −6% in 2035. Thus, the largest negative effects on the GDP occur in the scenario of using carbon pricing revenues as an income source for the fiscal budget–the CGE model determines how a government uses such revenues endogenously. Moreover, providing subsidies according to sectoral carbon price payments can effectively mitigate the negative effects of carbon pricing.

Figure 8 shows the carbon price necessary for achieving the emission target for each of the three supportive measures. The negative effects on the GDP are the largest in the first scenario of using carbon tax revenues as income for the fiscal budget. The reduced economic activity results not only in lower energy use but also in lower carbon emissions. Therefore, the carbon price necessary for achieving the emission target is the lowest among three scenarios. In the third scenario, where subsidies are provided for sectoral carbon pricing payments, the government needs to impose the highest carbon prices in the face of the smallest negative effects on the GDP. In the second scenario where subsidies are provided for sectoral contributions to emission reductions, both the carbon prices and their negative effects on the GDP range between those of the two aforementioned scenarios. Thus, the supportive measures for carbon pricing revenues affect both the carbon pricing and its negative effects on the GDP.

Table 2 shows the sectoral effects of carbon pricing in the case of each of the three supportive measures. Regarding the scenario of treating revenue as income for the fiscal budget, the first column corresponds to its sectoral effects as shown in Fig. 6. The second column corresponds to subsidies regarding emission reduction while the third column corresponds to subsidies regarding carbon pricing payments. The carbon pricing policy has the largest effects on the “other manufacturing” sector. The recycling of carbon pricing revenue according to emission reduction or carbon pricing payments mitigates the negative effects of carbon pricing on that sector. The former recycling scheme mitigates the negative effects to a large extent compared with the latter one. The semiconductors sector ranks as the second hardest affected sector in the three scenarios. The sasic chemicals sector ranks in third place (−27 billion USD) in the second scenario, while the electronics sector is number three (−26 billion USD) in the case of the third scenario.

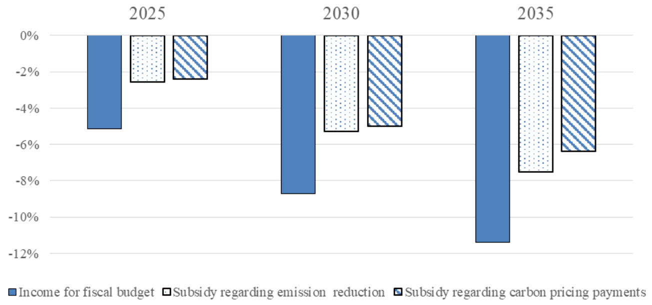


Fig. 7 Effects of supportive measures for carbon pricing on the GDP.

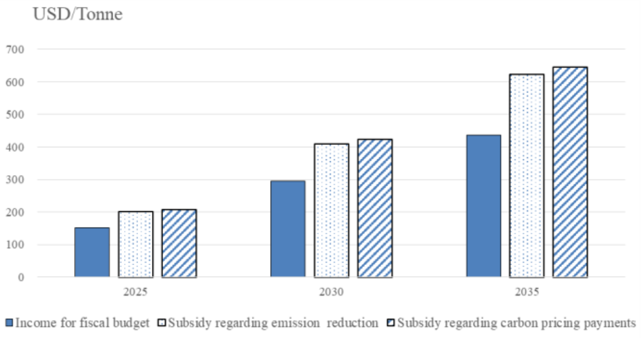


Fig. 8 Carbon prices necessary for achieving the emission target in the case of each alternative supportive measure.

Table 2 Sectoral effects with respect to the three supportive measures.

Unit: Billion USD

(1) Income for the fiscal budget		(2) Subsidy with regard to emission reduction		(3) Subsidy with regard to carbon pricing payments	
Other manufacturing	−61	Other manufacturing	−40	Other manufacturing	−42
Semiconductors	−48	Semiconductors	−35	Semiconductors	−37
Other electronics	−34	Basic chemicals	−27	Other electronics	−26
Wholesale and retail	−28	Other electronics	−25	Basic chemicals	−22
Basic chemicals	−23	Power	−22	Power	−22
Construction	−21	Wholesale and retail	−21	Wholesale and retail	−22
Power	−20	Construction	−11	Construction	−12
Machines and equipment	−13	Financial and insurance services	−10	Financial and insurance services	−9
Crude steel	−12	Crude steel	−9	Crude steel	−9
Other services	−10	Other services	−8	Other services	−8
Financial and insurance services	−10	Cement	−7	Cement	−6
Cement	−6	Machines and equipment	−6	Machines and equipment	−6
Steel products and iron	−5	Passenger and cargo transport	−5	Steel products and iron	−5
Chemical products	−4	Steel products and iron	−5	Passenger and cargo transport	−5
Residential services	−4	Fuel	−4	Fuel	−4

The wholesale and retail sector, other electronics, and basic chemicals sectors experience losses of 28, 25 and 22 billion USD, respectively, in each scenario.

As a consequence, recommending a best policy which could minimize negative effects on industrial sectors is not easy. The policy recommendation would depend on the target at hand. For instance, semiconductors constitute one of the most important industrial sectors in Taiwan. When the government sets up a target to minimize the negative effects of carbon pricing on such a sector, the subsidy should be provided according to sectoral emission reduction (−35 billion USD). However, regarding the goal to minimize the losses of the basic chemicals sector, the government should recycle the carbon revenue according to carbon pricing payments (−22 billion USD), instead of subsidizing with regard to emission reduction (−27 billion USD). Carbon pricing is a single policy which affects various sectors. We should not propose one scheme for recycling revenues to industrial sectors that would dominate over the other schemes, with respect to sectoral effects. Regarding the sectoral effects of carbon pricing, any revenue recycling scheme will involve distribution issues which are beyond the scope of our study. However, these two scenarios in which carbon revenues are recycled to industrial sectors would mitigate the negative effects to a large extent compared with using the revenue as income for the fiscal budget. Therefore, the proper design for the use of carbon pricing revenues will depend on the target at hand.

4. Conclusions

This study has aimed to investigate how to use carbon pricing revenues well to mitigate the negative effects on the economy. We find that relying solely on a carbon pricing policy could induce high economic costs. For instance, relying on carbon pricing reduces the GDP by 11% relative to the BAU scenario in 2035. Such a negative effect would be more severe than in carbon pricing scenarios in which subsidies are provided according to contributions to emission reductions (−8% of GDP in 2035) or carbon pricing payments (−6% of GDP in 2035). In particular, the energy-intensive industrial sectors suffer from greater impacts. Regarding GDP losses, we recommend a scheme for recycling the revenue according to individual carbon pricing payments.

Recommending a best policy that would minimize the negative effects on all industrial sectors is not easy. When the government sets up a target to minimize the negative effects of carbon pricing on semiconductors, the subsidy should be provided according to sectoral emission reduction. However, if the goal is minimizing losses for the basic chemicals sector, the government should recycle the carbon revenue according to carbon price payments. With respect to the sectoral effects of carbon pricing, any revenue-recycling scheme will involve distribution issues that are beyond the scope of our study.

We can extend this study by considering other policy measures for reducing carbon emissions. For example, the government could promote renewable energy investment, with positive effects on the economy. Moreover, the private sectors might be willing to invest in energy efficiency improvement in the face of high carbon prices. The producers could achieve the same output using less energy through improved energy efficiency, mitigating carbon emissions. We leave these issues for future research.

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