Carbon Tax Accompanied by a Revenue Recycling Increases Australia's GDP: A Dynamic Recursive CGE Approach

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1. Introduction

Carbon tax has been proven to be the most cost-effective policy in reducing carbon emissions, while redirecting the accumulated tax revenue back into the economy brings economic benefits (Linnenluecke and Smith, 2019; Balezentis et al., 2019; Rajabi, 2022a). Australia applied a carbon tax policy in 2012 but the policy was repealed just two years after its imposition due to the negative impact of a carbon tax policy on prices and economy (Meng, 2014)

To find out how the carbon tax affect prices and Australian economy years after a carbon tax policy starts, this study employs the dynamic recursive Computable General Equilibrium (CGE) approach to evaluate the variations in the economic variables during 2020 to 2035 due to the policy implementation. Classifying the economy into eight industries and starting the policy in 2023, this study finds that the imposition of a carbon tax on fossil fuels accompanied by a revenue recycling approach increases Australia's GDP during thirteen years after the implementation of the policy. Moreover, this study finds that the introduction of a carbon tax is effective in reducing Australia's carbon emissions.

In this study, two policy scenarios are designed, both starting with a levy of 23 Australian Dollars per tons of carbon emissions (A$23/t CO2) on all fossil fuels consumed in the industry sector in 2023, rising with a constant rate up to 2030 and staying at that level up to 2035. As the uniform tax rate is more effective than the differentiated tax rate among industries (Hoel, 1996), in both policy scenarios a uniform tax rate is levied on all fossil fuels consumed by industries. The influence of carbon tax imposition in both policy scenarios on production cost, fossil fuels price, producer price, consumer price, inflation, GDP, and total emissions is compared to a business as usual (BAU) scenario in which no carbon tax is levied. In the BAU scenario, Australia's economic growth equals its average growth rate in the second decade of this century.

In the first scenario (SIM1), the carbon tax rate rises by A$4.5 annually to reach A$53 (US$37) in 2030, which is the average carbon tax price in the OECD[1] countries. In the second scenario (SIM2), the carbon tax rate rises by A$7 annually to reach A$70 (US$50) in 2030 and stays at the same level afterwards. This is the tax rate calculated and suggested by the US Government to combat climate change.

In both policy scenarios, the price paid by the three big coal-consuming industries (mining, manufacturing, and aggregated electricity, gas, water, waste) to secure fossil fuels for the production process rises at a higher rate when compared to other industries, due to the higher carbon content of coal. As the aggregated electricity, gas, water, and waste sector is the biggest coal consumer in Australia while paying the lowest price to secure coal -due to the government subsidy- (Meng et al., 2013), the highest carbon tax would be paid by this industry and the composite price of fossil fuels employed by this industry during the production process rises significantly.

Implementing a carbon tax increases the price of intermediate inputs and the producers' price of fossil fuel consumer industries, while, regardless of the amount of fuel consumption, the final price of all commodities in the market rises substantially, leading to an increase in inflation. In the first scenario, inflation rises by 0.05 percent in 2023, then to 1.06 percent in 2030. In the second policy scenario, carbon tax-related inflation starts from 0.5 percent in 2023, rises to 1.21 percent in 2026 and reaches 1.52 percent in 2030.

This study finds that if a revenue recycling approach is not adopted, the negligible, negative effect of the carbon tax exacerbates during the first six years after implementing the carbon tax but this negative impact declines afterwards. Evaluating different revenue recycling approaches for Australia's economy shows that redirecting tax revenue back into the economy through reducing individual income taxes while investing in research and development (R&D) offsets the negative effect of the carbon tax on the economy and leads to a rise in GDP. Compensating for the loss of purchasing power while investing in R&D causes a 0.095 percent rise in Australia's GDP compared to BAU in 2023, which finally reaches 0.217 percent in 2030 in the first policy scenario. In the second policy scenario the real value of GDP increases at a higher rate to finally reach 0.286 percent higher than BAU in 2030. This study contributes to

[1] Organization for Economic Cooperation and Development.

the literature by identifying the economic effect of a carbon tax on the Australian economy through the adaptation of a dynamic recursive CGE model. This study clarifies the effect of a carbon tax on producers' prices, consumers' prices, inflation, consumption, real GDP over a 13-year period. It also identifies the effect of the carbon tax on total CO_2 emissions and examines the impact of three revenue-recycling approaches on Australia's economy. Illustrating the effect of the carbon tax on prices and economic variables during 13 years after the introduction of the policy in Australia, this research helps policymakers in constructing a better and more constructive environmental policy and provides a baseline for future research in this field. This paper is structured as follows: Section 2 reviews the literature while Section 3 outlines the methodology and the details of the CGE model adopted in this study. Section 4 presents the result of the simulations. The effect of three different revenue recycling approaches on the economy is presented in Section 5 and Section 6 outlines the sensitivity analysis. Section 7 concludes the research and provides policy implications.

2. Literature Review

In assessing the impact of a carbon tax on the economy, the CGE approach has been proven to be an effective tool as it provides an illustration of the direct and indirect impact of a policy on economic variables. The static CGE model shows the effect of the policy at a point in time while the dynamic CGE model shows the variations of the economic variables due to the implementation of the policy over time. Applying the static CGE approach, Meng et al. (2013) estimates the effect of a A$23/t$CO_2$ tax on the Australian economy without an accompanied revenue recycling policy, finding that the policy can lead to a 0.5 percent reduction in the real GDP of Australia while the nominal value of GDP continued to rise. Siriwardana et al. (2014) finds the implementation of a carbon tax decreases Australia's real GDP by 0.68 percent but leads to a 0.75 percent rise in inflation. Meng (2014) estimates the effect of a carbon tax on Australia's electricity sector and finds its implementation in 2012 caused the wholesale price of electricity to rise by 80 percent, while the retailer price increased by 25 percent. Just focusing on the impact of the policy implementation on one year, these studies evaluated the impact of the carbon tax policy that was offered by the government without offering any scenarios. In this policy the carbon tax was imposed on big carbon emitters not all the industries and a share of tax revenue was allocated to transfer to low-income families.

In similar studies, Orlov and Grethe (2012) find the introduction of a carbon tax increases the cost of producing fossil fuels but recycling tax revenue by reducing the income tax cancels out the negative impact of the policy on Russia's GDP. Allan et al. (2014) apply the static CGE approach to estimate the effect of imposing 50-pound (£50) carbon tax on all the fossil fuels consumed in the industry sector in Scotland accompanied by revenue-recycling through a reduction in income taxes. This research finds this carbon tax design reduces Scotland's carbon emissions by 37 percent while its GDP grows incrementally over time. Benavente (2016) estimates the effect of introducing US$ 26/t CO2 on the Chilean economy and confirms that it results in a 20 percent reduction in carbon emissions while Chilean GDP declines by 2 percent compared to a BAU scenario. This study concludes by highlighting the necessity to apply a revenue-recycling approach to obtain economic benefits through the introduction of the policy.

Turning to studies adopting a dynamic CGE approach, Lin and Jia (2018) design different policy scenarios and argue that the negative impact of carbon tax policy on China's GDP does not exceed 0.5 percent in 15 years after implementation. They use the differentiated carbon tax rate among industries. Ojha et al. (2020) employ a dynamic recursive CGE model and impose the carbon tax only on coal consuming industries and find the real value of India's GDP falls by 0.06 percent compared to a BAU scenario in 2040, while total emission falls 3.37 percent.

Freire-Gonzalez and Ho (2019) adopt the same approach and estimate the effect of three carbon tax scenarios on Spain's economy over thirty years. This study finds that by imposing a 10 Euros carbon tax (€10/t CO2) on big carbon emitter industries and recycling the carbon tax revenue into income tax, the negative impact of the carbon tax on GDP be eliminated in ten years while total emissions reduce by 10 percent during the ten years period and the reduction in carbon emissions and substitution of coal accelerates. In this research the tax is imposed only on big fossil fuel consumers in the industry sector. The dynamic CGE models constructed by Carl and Fedor (2016), Chen et al. (2017), Niu et al. (2018), and Xu and Wei (2021) show that carbon tax has a meaningful impact on the reduction of carbon emissions over time. Xie et al. (2018) and Shi et al. (2019) find carbon tax reduces total fossil fuel consumption while Zhu et al. (2019), Lin and Jia (2020), Li et al. (2020), and Mardones (2022) discuss the effectiveness of the policy on enhancing energy efficiency in the industry sector. In these studies not all the industries were impacted by the policy but the policy was imposed on a group of industries call big carbon emitters or coal consumers.

Summing up the existing literature, the following deficiencies can be found: 1) There is no simulation for the Australian economy to find out how a carbon tax shock would affect prices, economic variables, and total emissions over time and how the negative impact of a carbon tax on inflation and consumption should be offset? 2) There is no study that evaluates the impact of using a uniform carbon tax rate covering the whole industry sector on the economy. 3) Among different revenue recycling policies proposed by scholars, there is no study to determine which approach is appropriate for the Australian economy and offsets the impact of a carbon tax on purchasing power of families and consumption.

This study fills the gap in the literature by simulating the Australian economy for 16 years, from 2020 to 2035, and investigating the impact of a carbon tax shock on prices, GDP and total carbon emissions over this period. Using the dynamic recursive CGE model to simulate the impact of two carbon tax policy scenarios in Australia, this study contributes to the literature by examining the impact of two different carbon tax scenarios on the Australian economy, both following a uniform carbon tax policy and covering the whole industries in the country. Most of the previous studies selected a group of carbon emitter industries and evaluated the impact of a carbon tax imposition on this specific group of industries on the whole economy and total carbon emissions, but in this study, we evaluate the impact of a full coverage of the policy in the industry sector as it provides an incentive to industries to transition to low carbon technologies. Proposing different revenue recycling policies, this study clarifies which revenue recycling policy is more powerful in offsetting the negative impacts of a carbon tax on the Australian economy and consumption. Answering the concern of politicians regarding the economic effect of a carbon tax in Australia, this research can provide a baseline for better policy-making in the country and help the country accelerate its transition to a low-carbon economy. The details of the methodology adopted for this study are outlined in the next section.

3. Methodology

3.1. Dynamic CGE Model

To evaluate the economic effect of the carbon tax on Australia's economy, this paper constructs a computable general equilibrium model based on the market clearing assumption and factor flow. This energy-environment-CGE model is a dynamic recursive model of a small open economy suitable for analyzing policy measures. In this study, we focus only on CO2 emissions from energy consumption in the industry sector and evaluate the impact of the policy imposition on economic variables specifically prices, overall CO_2 emissions, and Australian's GDP. Although the main assumption of the model is aligned with standard CGE models, for this study the model is modified to be able to use it for analyzing a carbon tax policy. The modifications are as follows:

1- In the standard CGE models, there is no subdivision for energy commodities. As this study aims to estimate the effect of the carbon tax policy based on energy consumption in each industry, the energy elements in the commodity account are subdivided and are considered as a specific section in the intermediate commodities used in the production process of each industry sector.
2- Three energy sources in this study are coal, oil, and natural gas. These fossil fuels are the main sources of CO_2 emissions produced in the mining sector. So, the mining commodity in the commodity account is subdivided into four sections namely coal, oil, natural gas, and other minerals. Coal, oil, and natural gas are the intermediate commodities used as energy sources in different industries.
3- As a uniform carbon tax rate is confirmed as the most effective approach to reduce carbon emissions, in this study the carbon tax is levied on all the fossil fuels consumed in the industry sector based on the carbon content of each fossil fuel.

The construction of the CGE models can be described as a system of simultaneous equations in which all the actors maximize their utility through maximizing their profit or minimizing their cost (Paroussos et al., 2015; Lin and Jia, 2017; Lu et al., 2017). CGE models, which are based on Walras law, simulate the behavior of social agents like households, government, enterprises, and rest of the world (He and Lin, 2017; Bohringer et al., 2017; Zhao et al., 2018). The CGE framework in this paper consists of five blocks, which are outlined in the following subsections: production block, income-expenditure block, trade block, energy policy block, and macroscopic-closure and market-clearing block. The general framework of the CGE model is illustrated in Figure1. Although the CGE model is a very powerful policy analysis tool, it still has some limitations as follows:

1- The assumption of elasticity and growth rate of labor and capital is considered as an important limitation in this model.

2- It is assumed that policy changes do not affect the level of unemployment, the competition among firms, and the rate of technological progress because there are not aligned with what happens in the real world.

3.1.1. Production Block

The production block contains all the industries responsible for producing different commodities in the country. This block consists of value-added and energy (VAE) and intermediate input following a Leontief function. The VAE bundle consists of value added and energy following a constant elasticity of substitution (CES) function. In the next level VA bundle and energy bundle both follow a CES function.

In the VA bundle one representative of capital and one type of labor exists and the energy bundle contains two levels, both following a CES function. In the first level, coal and O-G (oil and gas) are considered as the main energy sources and in the second level O-G is divided as oil and gas input in the production process. As Australia's electricity sector is heavily dependent on fossil fuels, we follow Meng et al. (2013) and Meng (2014), Siriwardana et al. (2014), and Lin and Jia (2018) to consider the fossil fuels as the main energy sources in the study and focus on the imposition of the tax on these fuels. The electricity sector is categorized as one of the consumers of fossil fuels and affects the prices through its share in each sector's intermediate consumption.

Energy is a subdivision of intermediate commodities in the model and the intermediate bundle consists of all the commodities used in the production process except energy inputs. The whole economy is distributed into eight industries, which are used to construct the production block and produce eight commodities. To extract out the energy commodities, the intermediate commodities generated by the mining industry are divided into four commodities namely coal, oil, natural gas and other mining commodities. The classification of industries and commodities in this study is shown in Table 1. We assume each sector produces multiple products.

Table 1: Description of the sector classification in the CGE model

Production block (Sector name in the model)	**Commodities (Sector name in the model)**
Agriculture, forestry, and fishing (AGR)	Agriculture, forestry, and fishing (AGR)
Mining (MIN)	Coal (COAL)
	Oil (OIL)
	Natural gas (NG)
	Other minerals (OTHMIN)
Manufacturing (MAN)	Manufacturing (MAN)
Electricity, gas, water, and waste services (ELEC)	Electricity, gas, water, and waste services (ELEC)

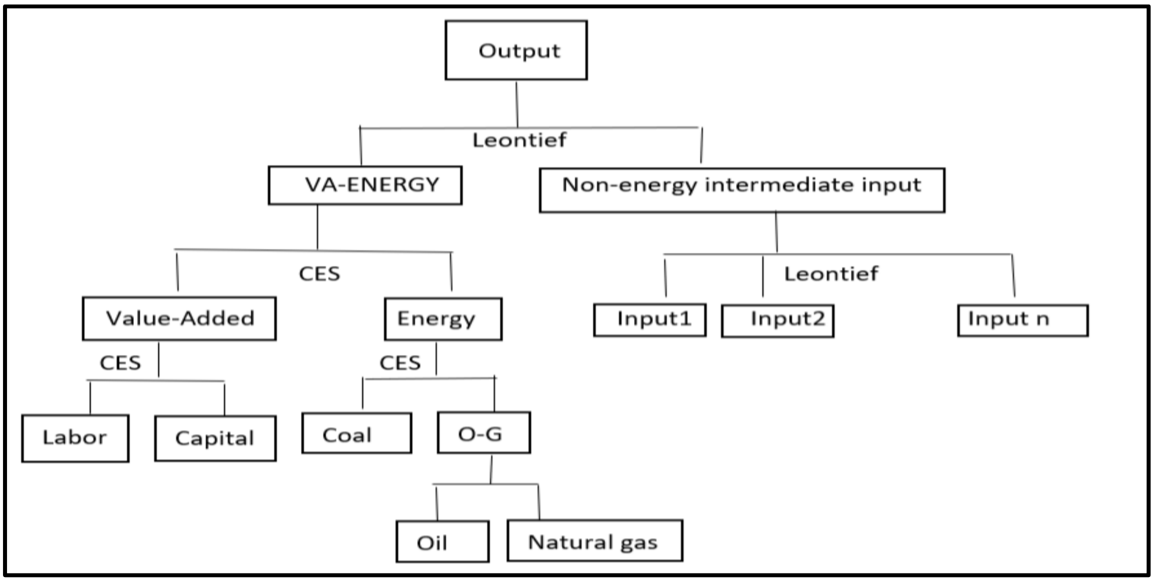
Construction (CON)	Construction (CON)
Transport, postal and warehousing (TRAN)	Transport, postal and warehousing (TRAN)
Financial and insurance services (FIN)	Financial and insurance services (FIN)
Commercial and wholesale (COM)	Commercial and wholesale (COM)

The whole economy is classified into eight industries. By disaggregating the mining sector to extract the fossil fuel sectors, eleven commodities are considered in this study.

Figure 1 depicts the framework of the production module in this study. Energy is a subdivision of intermediate inputs in the industry sector so intermediate inputs are all the non-energy commodities used during the production of various commodities. In the first level of energy subdivision coal and O-G (oil and gas) are two main energy sources and in the second level O-G is divided into oil and natural gas. Among eight industries considered in this model, manufacturing, commercial and wholesale are consumers of oil, but this subdivision is vital to clarify the impact of the carbon tax on the cost of production and variations in the prices as well as GDP.

We follow the ORANI model for substitution elasticity at both levels of energy subdivision. At the top level, the elasticity of substitution is considered to be low, and the assigned value is 0.6, while at the bottom level, the substitution elasticity between oil and natural gas is lower and the assigned value is 0.5 (Meng et al., 2013; Guo et al., 2014; Siriwardana et al., 2014; Lin and Jia, 2018; Sun et al., 2020; Ojha et al., 2020; Zhang et al., 2022; O'Ryan et al., 2023).

Figure 1: Framework of the production module



3.1.2. Income-expenditure block

Four agents in this study are household, government, firms, and the rest of the world. There is a representative household agent and enterprise agent in this study and the federal government is the representative government. In the social accounting matrix, which is the data framework adopted for CGE studies, the balance and relationship of the four agents are pictured. The government gains its fiscal revenue through direct tax, indirect tax, tariffs, and carbon tax. Although the carbon tax rate in the BAU scenario is zero, in the proposed scenarios the tax rate has increased and becomes another source of income for the government. All the revenue collected by the government is used to transfer payments, consumption and saving. Firm income comes from consumption of households, other firms, government and the rest of the world and the revenue is either paid to government as direct tax, transferred to other agents or saved. Households gain their income from labour income, capital income and transfer from government and it is equal to their consumption, direct tax, and savings.

3.1.3. Trade block

In the CGE model the local production of a commodity and the imported commodity are homogenous and this assumption results in export and import for the same product not taking place at the same time, which is contradictory to what is happening in the real world. To overcome this problem, CES and CET (constant elasticity of transformation) functions are introduced into the model to simulate import and export. In the literature, this is called the Armington assumption (Hosoe, 2014; Lin and Jia, 2018; Rajabi, 2022b).

3.1.4. Energy policy block

By the start of 2022, there were 27 countries in the world that had applied carbon tax policy, mostly members of OECD. Finland, Denmark, and the Netherlands imposed a carbon tax in the early 1990s and now have a comprehensive policy. Other European countries have joined this group in a quest to reduce carbon emissions, and the number of carbon tax countries have grown to 27. However, many of these, such as Poland, Portugal and Ukraine, have applied low and inadequate carbon tax rates, so that the imposition of the policy has had no the amount of CO2 emissions in these countries nor on climate change.

In all the carbon tax adopter countries, carbon taxes are applied on the consumption of fossil fuels and based on their carbon content and the translated CO2 emissions factor. The carbon tax rate multiplied by the amount of CO2 emissions in each industry depicts the whole carbon tax cost of each industry and summing across the industries covered by the policy generates total carbon tax revenue of government (Baranzini et al., 2000; Lu et al., 2010; Lin and Jia, 2018; Ojha et al., 2020). As the uniform tax rate and full coverage of industries under the policy is the best carbon tax design, this study evaluates the effect of imposing the carbon tax on all fossil fuels used in the industry sector based on their carbon content (Hoel, 1996; Bye and Nyborg, 2003; Metcalf and Weisbach, 2009; Nurdianto and Resosudarmo, 2016). This block can be expressed by the following equations:

$$EM_{j,t} = COAL_{j,t} \times \gamma^{COAL} + OIL_{j,t} \times \gamma^{OIL} + NG_{j,t} \times \gamma^{NG} \quad (1)$$

$$CTAX_{ENE,j,t} = EM_{ENE,j,t} \times R_{ENE,j,t} \quad (2)$$

$$TCTAX_t = \sum_{ENE,j} CTAX_{ENE,j,t} \quad (3)$$

Where the subscript "J" represents all the industries in the model and the subscript "ENE" represents the energy type. "$EM_{j,t}$" is the emissions by sector "J" at time "t", "$COAL_{j,t}$" is the consumption of coal, "$OIL_{j,t}$" is the consumption of oil and "$NG_{j,t}$" is the consumption of natural gas in sector "J" at time "t". $\gamma^{COAL}, \gamma^{OIL}, \gamma^{NG}$ denote CO2 emission factors based on recent Australian National Greenhouse Accounts Factors[2] and depicted in Table 2. "$CTAX_{ENE,j,t}$" is the carbon tax paid by industries covered by the carbon tax policy and "$TCTAX_t$" is the total carbon tax revenue of the government at time "t".

Table 2: Fossil fuels emission factor

Fossil fuel	Emission factor (tones of CO2 e per Tera Joule)
Coal (black and brown coal)	92500
Crude oil	69300
Natural Gas	51400

Emission factors are estimated in the national greenhouse accounts factors report published by the Australian Government in August 2021.

In the BAU scenario, the carbon tax is fixed at zero and there is no carbon tax revenue for government and carbon tax cost for production sector. By imposing the tax policy and increasing the rate, the production cost function of industries should be modified as imposing

[2] https://www.dcceew.gov.au/sites/default/files/documents/national-greenhouse-accounts-factors-2021.pdf

the carbon tax results in soaring energy prices, increasing the cost of production as well as generating another source of income for the government. Note that we focus only on CO_2 emissions due to the consumption of fossil fuels in the industry sector and emission of other polluters is not taken into account.

3.1.5 Macroscopic-closure and market-clearing block

The principles of market closure in this model are government budget balance, foreign trade balance, and investment-saving balance. The government budget balance is the equation of government revenue with government expenditures. In the CGE model, it is assumed that all the savings are used for investment and results in the investment- saving balance. In the market clearing section, the first assumption is that there is no unemployment in the economy and labor moves between industries freely. This is called factor market clearing. This model also assumes that all the commodities are used for consumption of households, government, and intermediate input used in industries and finally saving. This is called the market clearing of the Armington composite commodity and is the other closure considered in this model.

3.2. Social Accounting Matrix

The social accounting matrix constructed for this study is based on Australia's input–output tables for year 2019–2020. Australia's national accounts are used to collect the required data for agents' account including households, government, firms and rest of the world. To link the social accounting matrix to environmental policies, the energy inputs, which are on monetary basis, should be linked to physical energy inputs and this important step is done by employing Australia's energy balance. We made this link by introducing an industry-specific price coefficient and multiplying this coefficient to monetary energy data to generate the amount of CO_2 emitted in each industry per million dollars spent on each fuel in various industries. The accumulation of CO_2 emissions in all the industries covered by a carbon tax is multiplied by the carbon tax rate gives the total amount of carbon tax revenue in each year.

3.3. Model Dynamics

The model constructed for this study is a dynamic recursive, single country, multi-period model for Australia, which is an open economy. The dynamic recursive model is solved as a sequence of static single-year CGE models, after updating sectoral capital stocks each year. The capital stock in the first year is exogenous but in the following years it is estimated endogenously by considering the capital depreciation rate and the sectoral investment undertaken in the previous period. To be more specific, the capital stocks at the start of year t are estimated by adding the investment in that sector, net of depreciation, plus the capital stocks at the beginning of year $t-1$. This relationship is depicted in equation (5) in which $KD_{J,t}, KD_{J,t-1}$ are the capital stocks of industry J at time t and $t-1$ respectively. δ_J is the depreciation rate of capital in each industry and $INV_{J,t-1}$ is the amount of investment made by each industry in the previous period.

$$KD_{J,t} = KD_{J,t-1}\left(1-\delta_J\right) + INV_{J,t-1} \quad (5)$$

3.4 Revenue Recycling Approaches

The model follows a revenue-neutral policy, and the accumulated carbon tax revenue should be redirected back into the economy to offset the negative effect of the tax. Investing in R&D projects leads to developing new technologies and facilitating the transition to a low carbon economy via employing clean energies. This investment affects the economy through the generation of new jobs. In addition to investment, the accumulated tax revenue should be used to support consumption either through reduction in individual income taxes, reducing firm's income taxes or transition to low-income families.

4. Results and Simulation

4.1. Simulation Scenarios

In July 2012, the Australian government imposed a carbon tax on big fossil fuel consumers in the country. The levied carbon price per tones of CO2 emitted by consumers was A$23, aimed to increase yearly in order to reduce carbon emissions in the country. However, the policy was repealed two years later in July 2014. So, the starting point in this study is the rate that was approved in 2012 and the ultimate plan is to reach to the proposed carbon tax rate by 2030, which is a critical year in the fight against global warming (IPCC-AR6[3], 2022).

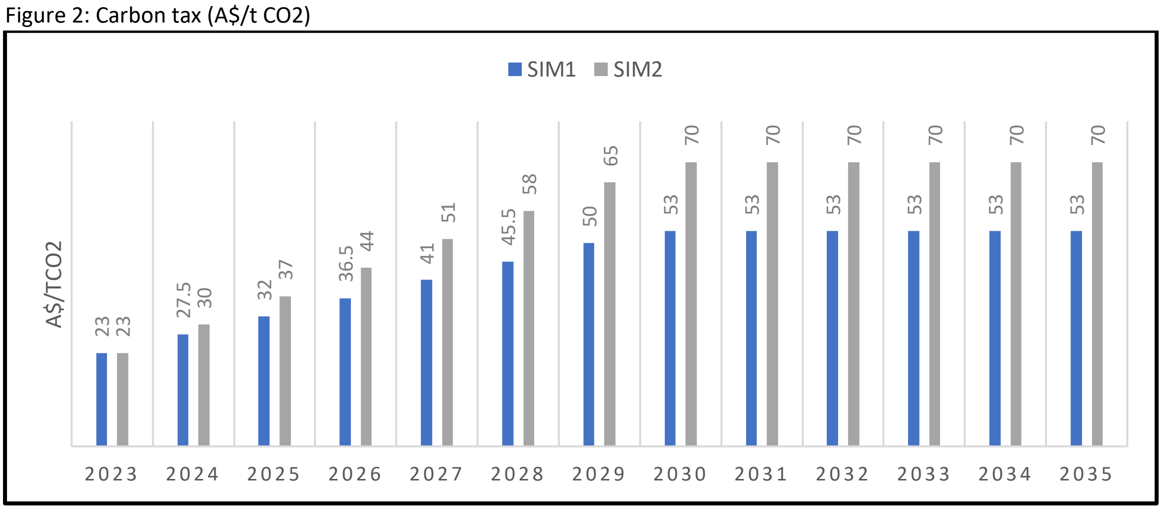
To find a reasonable policy scenario, the history of carbon tax rate around the world is reviewed. Among the carbon tax adopter countries, the highest carbon tax is levied is in Sweden, Switzerland, Uruguay, and Liechtenstein, which is more than US$130 per tones of CO2. On the other hand, some countries like Chile, Ukraine, Japan, Colombia, and Estonia the

[3] Sixth Assessment report of International Panel on Climate Change, 2022

carbon tax is less than US$5 per tones of CO2, far lower than the required rate to impact global warming or change economic variables (World Bank[4]). Not considering these extreme cases, two distinct policy scenarios are designed for Australia, and the result of implementing both scenarios on the economy is compared to a BAU scenario. In the BAU scenario, no carbon tax is levied. The simulation scenarios for this study, which is illustrated in Figure 2, are as follows:

1- The average carbon tax rate in OECD countries in 2023 is US$37, which is approximately A$53. In the first simulation the carbon tax policy starts in 2023 with A$23/t CO2 and increases by A$4.5 annually to reach A$53 in 2030 and this rate does not change afterwards (SIM1).
2- In the second scenario the ending point will be US$50 (approximately A$70). This price is offered by the US Government as the starting point to combat global warming and reduce emissions by 2030 in the US. In this scenario the policy is imposed in 2023 and each tone of CO2 emissions would cost A$23. This tax increases by A$7 annually to reach A$70 in 2030 and carbon emitters continue to pay A$70 up to 2035, which is the final year of this study (SIM2).

Figure 2: Carbon tax (A$/t CO2)



4.2. Simulation Results

This study aims to clarify the impact of a carbon tax on prices and GDP over 16 years from 2020 to 2035. The carbon tax policy is going to be levied on all fossil fuels used in the industry sector in 2023 and increases annually to reach the final price proposed by each scenario in

[4] World Bank carbon pricing dashboard accessed in September 2022.

2030, staying at that level afterwards. To demonstrate this effect, the variations in the prices paid by each industry to secure fossil fuels after the imposition of a carbon tax, the changes in the price of intermediate consumption, the change in producers' prices and finally the impact of the policy on the final price paid by consumers is provided here. Finally, the impact of this policy on inflation and GDP is explained.

4.2.1 Total Carbon Tax

The carbon tax paid by each industry depends on the type of fossil fuel the industry uses as well as the carbon content of that specific fuel. Table 3 depicts the type of fossil fuels used in each industry sector in this study. Among the eight aggregated industry sectors, four of them are consumers of coal namely "AGR", "MIN", "MAN", "ELEC". None, except "MAN" and "COM", use crude oil as an intermediate commodity while all are categorized as consumers of natural gas. The rise in the price of coal after the imposition of a carbon tax (due to its higher carbon content) leads to substituting the coal with fossil fuels which have lower carbon content. This substitution is the main cause of reducing carbon emissions through the introduction of the carbon tax.

Table 3: Type of fossil fuels consumed in each production sector

Production sector	Fossil fuel type
AGR	Coal, Natural gas
MIN	Coal, Natural gas
MAN	Coal, Oil, Natural gas
ELEC	Coal, Natural gas
CON	Natural gas
TRAN	Natural gas
FIN	Natural gas
COM	Oil, Natural gas

Data is extracted from the Australian 2019 – 2020 Supply-Use tables. Coal considered in this study consists of black coal and brown coal. Data for oil contains only crude oil and its condensate and none of the products of oil are considered in this study. LNG is considered in the natural gas commodity.

Table 4 pictures the carbon tax paid by each industry in each policy scenario. The highest carbon tax cost is paid by the "ELEC" sector followed by the "MAN" sector. In the first scenario, the carbon tax cost paid by the "ELEC" sector starts with A$3703.027 million in 2023 and rises to A$5802.08 million in 2030, while in the second policy scenario the carbon tax cost paid by the "ELEC" sector reaches A$8122.91 million in 2030. The huge amount of carbon tax paid in "ELEC" industry relates to the high share of coal in total fossil fuel consumption in the “ELEC” sector. In “SIM1”, the imposition of a carbon tax results in a 3.1 percent rise in total production cost, while in “SIM2” the total production cost increases by 5.1 percent.

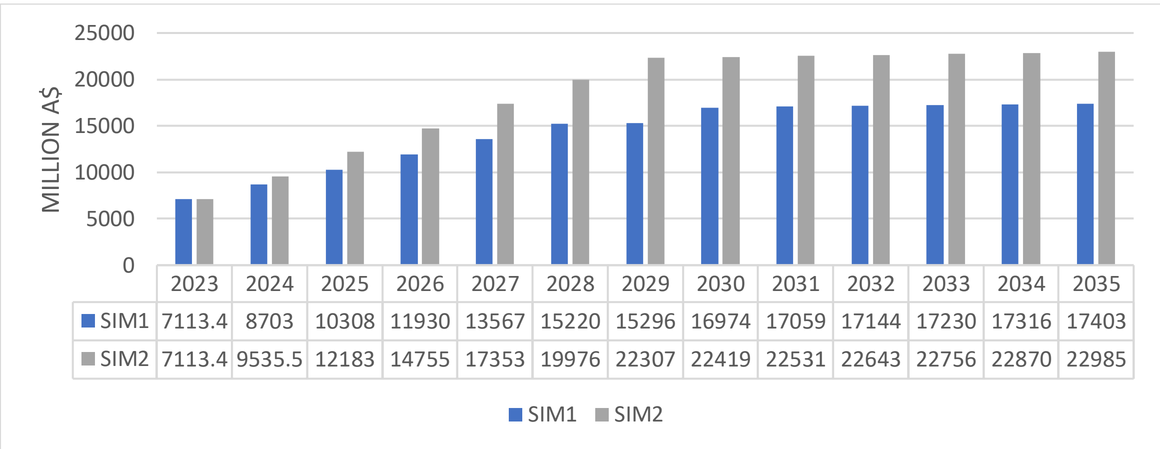
Table 4: Total carbon tax paid by each industry (A$ Million)

Prod. sector	2023		2026		2030		2035	
	SIM1	SIM2	SIM1	SIM2	SIM1	SIM2	SIM1	SIM2
AGR	3.359	3.359	5.634	6.968	8.016	10.588	8.219	10.855
MIN	724.89	724.89	1215.70	1503.61	1729.75	2284.57	1773.42	2342.26
MAN	2577.38	2577.38	4322.48	5346.22	6150.20	8122.91	6305.50	8328.027
ELEC	3703.027	3703.027	6210.66	7681.60	8336.59	11671.22	9059.92	11965.94
CON	2.4	2.4	4.02	4.97	5.72	7.56	5.87	7.7
TRAN	21.6	21.6	36.23	44.81	51.55	68.08	52.85	69.8
FIN	1.2	1.2	2.01	2.489	2.86	3.78	2.93	3.87
COM	79.25	79.25	132.91	164.4	189.12	249.78	193.89	256.09

Industries with the lowest fossil fuel consumption pay the lowest amount of carbon tax

The total cost of carbon tax in the “MAN” sector is A$ 2577.38 million in both simulation scenarios. In “SIM1”, the carbon tax paid by the “MAN” industry increases to A$4322.48 million in 2026 and continues its upwards trend to reach A$6305.50 million in 2035. In the second policy scenario (SIM2), the carbon tax paid by the “MAN” sector rises to A$5346.33 million in 2026 and soars to A$8328.027 million in 2035.

Figure 3: Total carbon tax paid by all industries



In both policy scenarios total carbon tax paid by industry sector equals A$7113.4 million in 2023. In “SIM1” the carbon tax cost increases to A$11930 million in 2026, then rises to A$16974 million in 2030 and finally reaches A$17403 million in 2035. In the second policy scenario (SIM2), the carbon tax paid by all the industries soars to A$14755 million in 2026 and continues its upwards trend to reach A$22419 million in 2030, finally reaching A$22985 million in 2035. An in-depth look into the data illustrated in Figure 3 shows that, in both policy scenarios, the rate of the rise in total carbon tax cost is decreasing over time, indicating the reduction in total carbon emissions, which translates to a reduction in total carbon tax paid by industries over time.

4.2.2. Composite Fossil Fuel price

Imposing a carbon tax increases the price of fossil fuels used in the production process, but a similar price on carbon emissions does not have the same effect on the price of fossil fuels consumed in each industry. This difference relates to two factors, namely the percentage of coal in the whole fossil fuel input consumed in each industry, and the industry-specific price of each fossil fuel used in each industry. Coal share is an important factor because the carbon tax is levied based on the carbon content of fuels and coal has the highest carbon content. In 2019 –2020, coal generated 75 percent of energy needed to produce the output in the “ELEC” sector, but the allocated cost of securing coal for this industry was less than 40 percent of its total fossil fuels cost. Comparing the price paid by this industry with other industries in the model reveals that “ELEC” pays the lowest price to consume coal. In this situation, imposing a carbon tax, which is a constant rate on all fossil fuels based on their carbon content, will place the highest burden on this industry.

Table 5 shows the variations of the composite price of fossil fuels consumed in each industry based on each policy. In the first simulation (SIM1), the price of fossil fuels used in the “AGR” sector increases by 3.41 percent in 2023 after imposing a A$23 carbon tax. The rate of increase in the composite fossil fuel consumption rises to 7.120 percent in 2030 with a A$53 carbon tax, compared to BAU.

While variations in the “CON”, “TRAN”, and “COM” sectors are less than 5 percent, the price that should be paid by the “ELEC” sector soars by 151 percent, meaning the cost of providing fossil fuels in this sector in 2030 will be 1.5 times higher than the BAU scenario in the first simulation. In 2030, the price of securing fossil fuels for the “MIN” and “MAN” sectors would rise by 80.77 percent and 35.58 percent respectively. In the second simulation (SIM2), the price of supplying fossil fuels for the “ELEC” sector is 2.11 times higher than BAU, in the “MIN” sector is 1.13 times higher than BAU and in the “MAN” sector is 0.49 percent higher than BAU.

Table 5: Change in the composite price of fossil fuels in each industry compared to BAU (Percent)

Prod. sector	2023		2026		2030		2035	
	SIM1	SIM2	SIM1	SIM2	SIM1	SIM2	SIM1	SIM2
AGR	3.412	3.412	5.637	5.637	7.120	10.384	7.417	10.384
MIN	37.155	37.155	61.387	75.926	80.772	113.8	80.770	113.82
MAN	16.41	16.41	27.117	33.539	35.68	49.951	35.681	49.952
ELEC	69.517	69.517	114.85	142.05	151.12	211.15	151.12	210.15
CON	0.070	0.070	1.166	1.442	1.534	2.148	1.534	2.148
TRAN	2.989	2.989	4.938	6.108	6.498	9.097	6.498	9.097
FIN	19.69	19.69	32.54	40.25	42.81	59.94	42.821	59.948
COM	1.798	1.798	2.971	3.675	3.910	5.474	3.908	5.472

The composite price of fossil fuels used in the "ELEC" sector would be 2.1 times higher than in the BAU scenario, which places a lot of pressure on this industry, while the composite price of fossil fuels used in the "MIN" sector would 1.13 times higher.

4.2.3. Composite Price of Intermediate Consumption

An increase in the price of fossil fuels consumed in each industry leads to a rise in the cost of production, but the share of fossil fuels in the total intermediate consumption of each industry and the whole production cost should be taken into consideration. Without considering this share, the effect of a carbon tax on the economy could be overestimated. Table 6 depicts share of fossil fuels cost to total intermediate consumption and production cost in each industry.

Table 6: Share of total fossil fuel consumption to total production cost and intermediate consumption

Total consumption of fossil fuels (A$ Million)					
Production sector	Fossil fuel cons.	Total production cost	Share to prod. Cost (%)	Total intermediate cons.	Share to intermediate cons (%)
AGR	97	104547	0.09	64809	0.14
MIN	1922	335475	0.57	132189	1.45
MAN	15470	410219	3.77	298278	5.18
ELEC	5248	125397	4.18	78028	6.72
CON	335	470358	0.07	328584	0.10
TRAN	712	201112	0.35	113347	0.62
FIN	6	253761	0	102703	0
COM	4341	1830391	0.23	757253	0.57

Data is extracted from the Australian 2019 – 2020 Supply-Use tables. Coal considered in this study consists of black coal and brown coal. Data for oil contains only crude oil and its condensate and none of the products of oil are considered in this study. LNG is considered in the natural gas commodity.

As Table 7 shows, the composite price of intermediate consumption in all industries increases but at a varying rate. The highest rise is in the electricity sector, followed by manufacturing and mining. The variation in the composite price of intermediate consumption in "AGR", "CON", "TRAN", "FIN", "COM" and in both simulation scenarios is less than 0.05 percent, which is a negligible rate, but in the first simulation the composite price of intermediate consumption in the “ELEC” sector increases by 10.761 percent in 2030 compared to BAU, while in the second scenario the increased rate equals 15.06 percent. In 2030, the price of intermediate consumption in the “MAN” sector increases by 1.857 percent in SIM1 and 2.6 percent in SIM2, compared to the BAU scenario.

Table 7: Change in the composite price of intermediate consumption compared to BAU (Percent)

Prod. sector	2023		2026		2030		2035	
	SIM1	SIM2	SIM1	SIM2	SIM1	SIM2	SIM1	SIM2
AGR	0.005	0.005	0.008	0.008	0.011	0.016	0.011	0.016
MIN	0.592	0.592	0.985	1.219	1.297	1.816	1.297	1.819
MAN	0.854	0.854	1.411	1.746	1.857	2.600	1.858	2.612
ELEC	4.950	4.950	8.178	10.116	10.761	15.066	10.760	15.065
CON	0.001	0.001	0.002	0.002	0.002	0.003	0.003	0.004
TRAN	0.019	0.019	0.032	0.039	0.042	0.059	0.041	0.058
FIN	0.001	0.001	0.001	0.002	0.002	0.0032	0.002	0.0032
COM	0.010	0.010	0.017	0.022	0.023	0.032	0.022	0.030

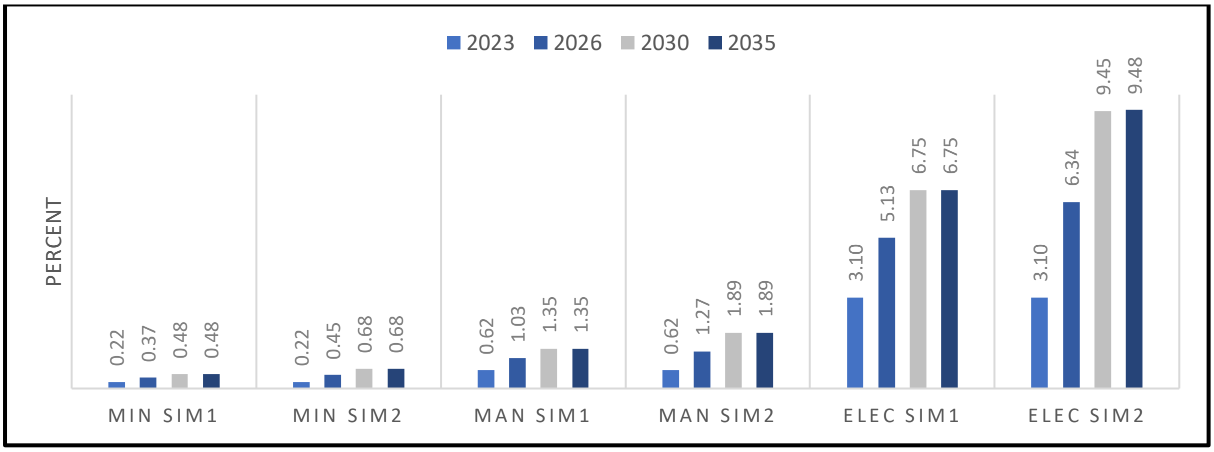
The variation in the composite price of intermediate consumption is due to the rise in the price of coal, oil and natural gas.

4.2.4. Producers’ Price

A rise in the price of composite intermediate commodities used in each industry sector leads to an increase in each industry’s final output price but policies, such as government subsidies for each industry, and the industry-specific rates of taxes on production impact the final price of commodities supplied by domestic producers. Table 7 shows that, except for “MIN”, “MAN”, and “ELEC”, the increase in the price of intermediate commodities used during the production process is negligible and it is reasonable to deduce that the greatest effect from the introduction of a carbon tax would be seen in the final producer price of the three mentioned industries. The rise in the producers’ price reflects the increase in the final production cost due to the introduction of the carbon tax. Figure 4 illustrates the variation in the price of each industry’s output under both policy scenarios.

It is evident that the highest increase is in the electricity sector, where the final price increases by 7 percent in “SIM1” and by 9.5 percent in “SIM2” compared to the BAU scenario. The lowest increase in the producers’ prices is detected in the “MIN” industry, while the final producer price in the “MAN” sector rises by 1.43 percent in the first simulation and 1.59 percent in the second simulation in 2030 compared to BAU. The result indicates that imposing a carbon tax on fossil fuels does not lead to a significant rise in the producer price for the five industries but the price of producing the output in “MIN”, “MAN”, and “ELEC”, which are the main coal consumers, means a rise in the price of their final output.

Figure 4: Change in the price of each industry’s output in each policy scenario (Percent)



4.2.5. Commodity Price

Despite the variations in the producers’ prices due to the introduction of the carbon tax, the final price of all commodities in the local market rises incrementally. This study shows that the producers’ price for five industries of the eight chosen industries for this study does not change significantly after the imposition of the carbon tax on three fossil fuels but the consumer price of all the commodities in the market rises, which relates to the rise in the price of electricity and transport after the introduction of the carbon tax.

Figure 5 illustrates the changes in the price of commodities in the local market in the first policy scenario. The price of the “AGR” commodity rises 0.5 percent after imposing a carbon tax in 2023 and soars to reach 0.82 percent in 2026 and 1.08 percent in 2020. The price of the “MIN” commodity, excluding coal, oil and natural gas, rises 0.48 percent in the first year and then enhances to 1.05 percent in 2030.

The increase in the final price of the “MAN” commodity is 0.25 percent in the initial year and reaches 0.55 percent in 2030, while the price of the “ELEC” commodity in the local market rises 0.51 percent at the start of the policy implementation and soars to 1.11 percent in 2030.This model shows that due to the imposition of the carbon tax, the price of final commodities in the market rises, even the commodities that do not consume fossil fuels as an intermediate commodity.

Figure 5: Change in the price of commodities in “SIM1” compared to “BAU” (Percent)

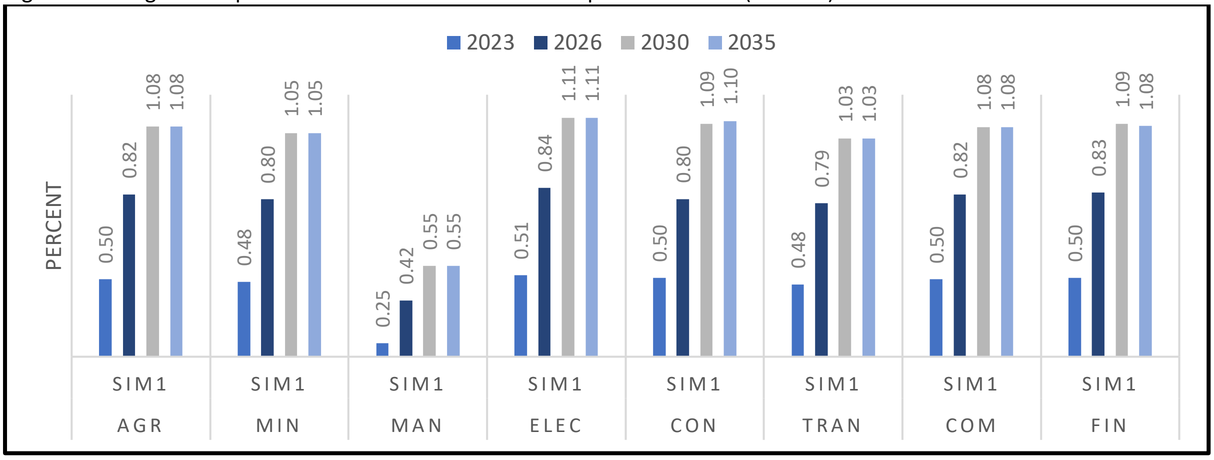
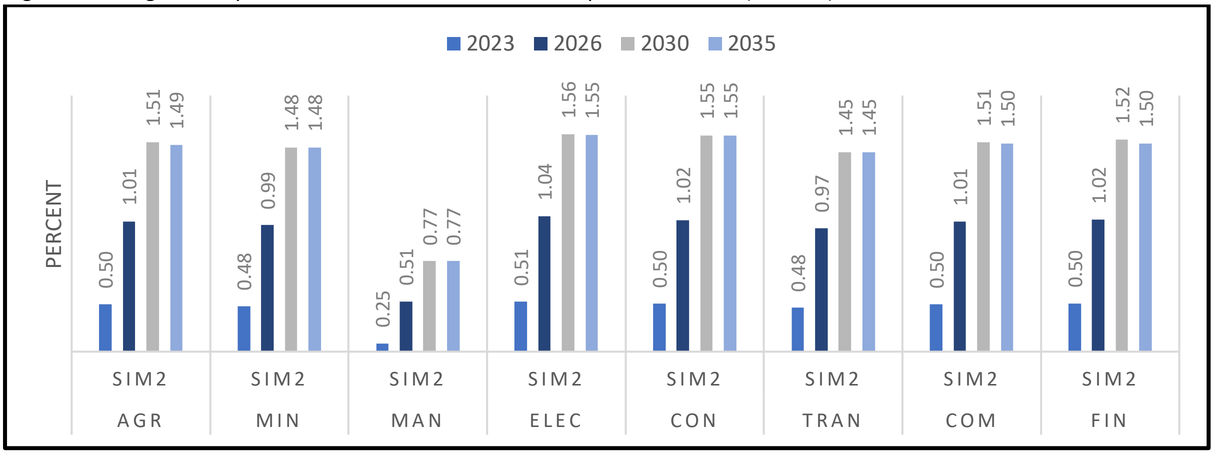


Figure 6 depicts the variation in the price of commodities in the local market in the second policy scenario. As both policies start with the same rate, the variation in the price of commodities in the local market is identical in both the “SIM1” and “SIM2” policy scenarios in the year 2023. However, the rate of increase is greater in the second policy scenario because of the higher rate of carbon tax.

Figure 6: Change in the price of commodities in “SIM2” compared to “BAU” (Percent)



It is evident that imposition of a carbon tax in both policy scenarios leads to a rise in the commodity price index and inflation, but the inflation rate declines with an increasing rate after 2030. In “SIM1” the estimated inflation is 0.5 percent in 2023, which rises to 0.95 percent and 1.06 percent in 2026 and 2030 respectively. The inflation in the commodity prices declines to 1.03 percent in 2035. In the “SIM2” scenario, the estimated inflation starts with the exact same rate as “SIM1” but increases with a higher rate to reach 1.21 percent in 2026 and 1.55 percent in 2030 and then falls to 1.52 percent in 2035. The results are depicted in Table 8.

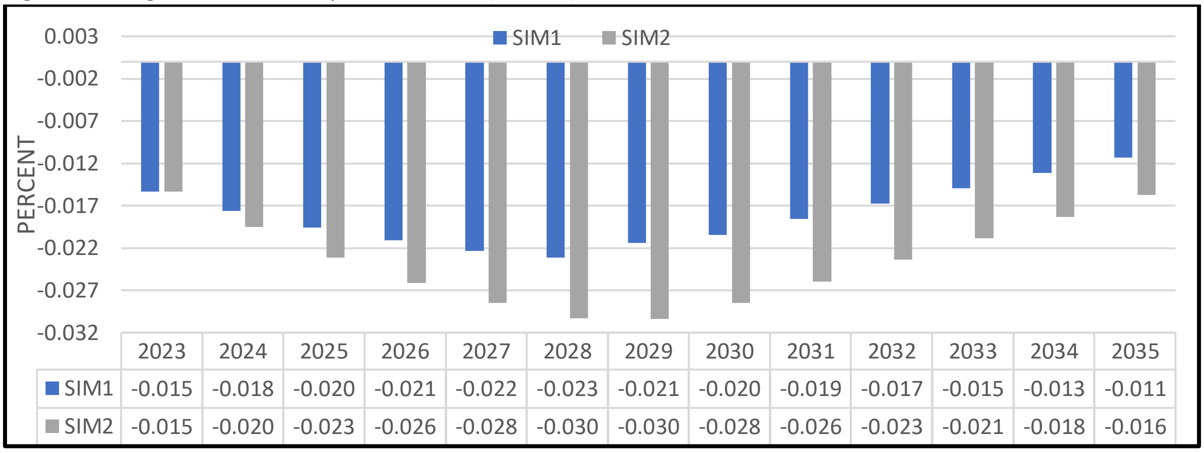
Table 8: Inflation rate (Percent)

	2023	2026	2030	2035
Inflation/SIM1	0.5	0.95	1.06	1.03
Inflation/SIM2	0.5	1.21	1.55	1.52

4.2.6. GDP

The impact of carbon tax policy imposition on the GDP is pictured in Figure 7. In both policy scenarios, implementing a carbon tax policy leads to a fall in Australia's real GDP, with a decreasing rate up to 2028 (six years after introducing the policy) and then the negative impact of policy imposition on Australia's real GDP declines. Figure 7 shows that in the first policy scenario (SIM1), real GDP falls by 0.015 percent compared to "BAU" in the first year, while in 2028 the real value of GDP would be 0.023 percent lower than the "BAU" scenario. Ten years after the imposition of a carbon tax in 2033, the real value of GDP would be 0.015 percent lower than the "BAU" scenario and the negative impact of policy imposition abates. Compared to "SIM1", in the second policy scenario, with a higher rate the real value of GDP plunges. Under this policy scenario, the real value of GDP in 2028 would be 0.030 percent lower than "BAU" and the negative impact continues to lessen. In 2035, the value of real GDP would be 0.016 percent lower than the "BAU" scenario.

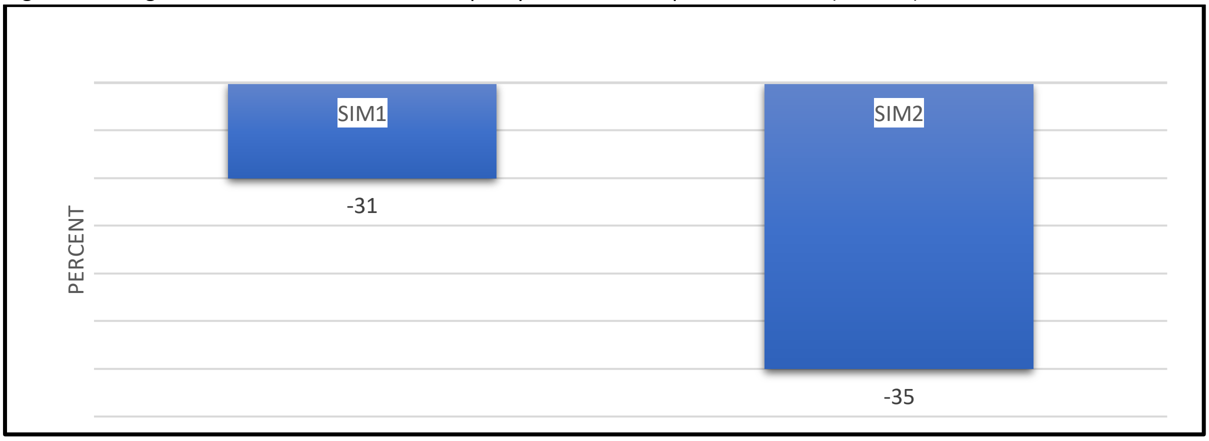
Figure 7: Change in real GDP compared to "BAU" (Percent)



4.2.7. Total emissions

This model confirms that the imposition of a carbon tax leads to a significant reduction in coal consumption and transition to fossil fuels with lower carbon content. In the first policy scenario, the imposition of a carbon tax results in a 31 percent reduction in total CO_2 emitted in Australia compared to BAU, while in the second policy scenario, total carbon emitted in the country in 2035 is 36 percent lower than BAU. The decline in total carbon emissions is because of the decline in total coal consumption in the country as this model confirms imposing a carbon tax results in substituting coal with fossil fuels with lower carbon contents. Figure 8 shows the reduction in the total carbon emissions per industry sector in Australia due to the imposition of a carbon tax in each policy scenario in 2035.

Figure 8: Change in total CO2 emissions in each policy scenarios compared to “BAU” (Percent)



5. Revenue Recycling Options

Following a revenue neutral approach and redirecting all the accumulated tax revenue back into the economy is vital in offsetting the negative impact of the policy on the economy. By adopting the revenue neutral approach, the accumulated carbon tax revenue would be redirected back into the economy without affecting total government revenue. Supporting the consumption power of households through reducing income taxes and investing in R&D projects are among the most widely used policies in the carbon tax adopter countries (Bayindir-Upmann and Raith, 2003; Amdur et al., 2014; Yamazaki, 2017; Pereda et al., 2019).

Without adopting the revenue recycling approach, implementation of the policy increases government revenue, increases production costs and inflation, and causes a fall in real consumption and total investment in industry sectors, which finally leads to a decline in GDP. To offset this negative effect on the economy, the accumulated tax revenue needs to be redirected back into the economy to compensate for the loss of purchasing power in the household sector and fall in investment.

This study evaluates the effect of three different revenue recycling approaches on Australia’s economy to clarify which policy option leads to the biggest rise in real GDP. The results are presented in the following sections.

5.1 Reducing Individual Income Tax Plus Investing in R&D

Reducing individual income tax to compensate for the reduction in purchasing power of households is followed by all the carbon tax adopter countries, yet an increasing share of the carbon tax revenue is investing in R&D projects to accelerate the transition to a low carbon economy. To compensate for the loss of purchasing power and consumption in this model, in the initial year of policy imposition, all the carbon tax revenue should be redirected back into the economy through reduction in income tax. In the second year, three quarters of the carbon tax revenue should be used to support consumption while the remaining one quarter should be invested in R&D projects, aiming to enhance energy efficiency in the industry sector and accelerating the transition to a low carbon economy.

As the rate of rise in the accumulated tax revenue is higher than the rate of fall in real consumption, in the following years the share of the accumulated tax revenue needed to compensate for the loss of households' purchasing power decreases while a larger amount would be invested in R&D, and greater investment leads to creation of jobs and wealth. In all the revenue recycling scenarios, the accumulated tax revenue equals the amount directing back to the economy through either reducing income taxes or transferring to income families plus the amount allocated to investing in R&D. This study follows the revenue neutral approach, in which the carbon tax does not lead to change in government revenue.

The revenue recycling approaches designed for Australia's economy for each policy scenario are as follows:

1- In "SIM1", the rate of fall in income taxes in the first two years is 3 percent rising 0.5 percent biennially up to 2030 and staying at that same level afterwards. In 2030 the rate of income tax is 4.5 percent lower than BAU. In 2023, the initial year of the policy, all the accumulated tax revenue is used to support consumption but in the second year this share declines to 75 percent and reaches 66 percent of the accumulated tax revenue in 2030, leaving more money for investment projects. By adopting this policy, real consumption rises by 0.237 percent in the initial year of application of the carbon tax. The rate of rise in the real consumption of households decreases substantially compared to BAU, but still is 0.057 percent higher than BAU in 2030. Moreover, due to the declining share of accumulated carbon tax revenue dedicated to support consumption, the investment budget rises incrementally over 13 years of the post treatment period, thus obtaining a positive effect on GDP. Comparing the value of real GDP with the BAU scenario shows the rise in real GDP is 0.095 in 2023, reaching 0.197 percent in 2030.

2- In “SIM2”, the income tax dips by 3 percent in 2023 and stays at the same level the year after. To compensate for the reduction of purchasing power, the rate of income tax should be dropped by 1 percent biennially. Finally, in 2030, the income tax rate is 6 percent lower than BAU. Again, in the first year, all the carbon tax revenue should be used to support consumption, while the share of tax revenue used for supporting consumption declines substantially to reach 66 percent in 2030, leaving more money to be invested in the industry sector. Following this revenue recycling approach leads to a 0.237 percent increase in real consumption in the first year. Although the rate of rise in real consumption declines over time, for the period of this study it is positive and higher than BAU. By investing the remaining carbon tax revenue in R&D, Australia’s economy would experience a 0.193 percent increase in real GDP that increases to reach a 0.286 percent rise in real GDP in 2030.

5.2 Transferring to households plus investing in R&D

Uniform transfer of the accumulated tax revenue to households is another policy option followed by some carbon tax adopter countries. To compensate for the loss of purchasing power identified in this study, 80 percent of tax revenue should be transferred to households, leaving 20 percent of the annual tax revenue to be invested in R&D projects. Applying this revenue recycling approach leads to the following results:

1- In “SIM1”, the rate of rise in real consumption is 0.025 percent in 2023 compared to BAU and reaches 0.057 percent in 2030. As a result of redirecting 80 percent of carbon tax into the economy through uniform transfer to households and investing 20 percent of carbon tax revenue, the negative effect of the carbon tax on GDP is eliminated and a small positive effect could be captured. The rate of rise in real GDP of Australia is 0.009 percent in 2023, increasing to 0.016 percent and reaching 0.029 percent in 2030.

2- In “SIM2”, the rate of rise in real consumption starts with 0.025 percent in 2023 and reaches 0.075 percent compared to BAU in 2030. Due to the higher carbon tax rate, a larger amount of money would be redirected into investment projects, leading to a sharper increase in GDP. The real value of GDP in 2023 is 0.009 percent higher than BAU, indicating the revenue recycling approach offsets the negative impact of the carbon tax on GDP. The rate of rise in real value of GDP increases to 0.023 percent in 2026 and reaches 0.041 percent in 2030 compared to BAU.

5.3. Reducing Firms' Income Tax Plus Investing in R&D

Reducing firms' income tax in addition to investing in R&D is another revenue recycling option. To compare the impact of this policy with the effect of reducing individual income taxes on the economy, we follow the same process.

In the first year, 80 percent of the carbon tax would be redirected into the economy through reducing firms' income taxes while 20 percent of the tax revenue would be invested in R&D. After covering costs, firms would transfer a share of their increased profit gained from the reduction in income taxes to households (profit, dividend, etc.) and save the remainder. As household consumption is not supported directly in this approach, there will be a decline in real consumption, while increasing the firm's savings and allocating 20 percent of total carbon tax revenue to investing in R&D, increases total investment and offsets the negative effect of the carbon tax on GDP. Note that as a part of firms' revenue is allocated to transferring to households, this revenue recycling approach can have a small positive effect on the disposable income of families. The effect of the proposed revenue recycling approach is explained below:

1- In "SIM1", not supporting the consumption power of households after implementing a carbon tax reduces the real consumption of households, which has a negative impact on GDP. While reducing firms' income tax and redirecting half of the tax revenue into investment offsets the negative effect of the carbon tax on GDP. As a result of applying this revenue recycling approach, real GDP rises by 0.005 percent in 2023, reaching 0.022 percent higher than BAU in 2030.
2- In "SIM2", real consumption declines at a higher rate but a larger amount of investment leads to a higher rise in real GDP over time. Following this revenue recycling approach increases real GDP by 0.005 percent in 2023, which rises to 0.015 percent in 2026 and finally reaches 0.031 percent higher than BAU in 2030.

Table 9 depicts the effect of three different revenue recycling approaches on Australia's real GDP over time. It is evident that the best policy approach is supporting consumption directly through reducing income tax while investing the remainder of the carbon tax revenue in the R&D projects annually. The allocated share of investing would be rising incrementally over time.

Table 9: Effect of different revenue recycling approaches on real GDP compared to BAU (Percent)

	Reducing individuals' income tax plus investment		Transfer to households plus investment		Reducing firm income tax plus investment	
	SIM1	SIM2	SIM1	SIM2	SIM1	SIM2
2023	0.095	0.095	0.009	0.009	0.005	0.005
2026	0.156	0.193	0.016	0.023	0.011	0.015
2030	0.197	0.252	0.023	0.035	0.017	0.026
2035	0.217	0.286	0.029	0.041	0.022	0.031

6. Sensitivity Analysis

To check for the robustness of the results we conduct a sensitivity analysis with respect to the elasticity of substitution between coal and oil-gas in the upper-level energy subdivision and the elasticity of substitution between oil and natural gas in the lower-level energy subdivision. We increased both elasticities by 10 percent and 20 percent respectively and ran the BAU, SIM1, SIM2 scenarios to check if the results change significantly. Checking for the variation of real GDP, inflation and industry-specific composite energy prices confirms that increasing the elasticity of substitution in energy subdivision compared to the model estimated in this paper does not change significantly, confirming that the model is robust.

7. Conclusion and Policy Implications

This study develops two policy scenarios to evaluate the impact of a carbon tax policy on the economy. In both scenarios a carbon tax would be levied in 2023 and continue up to 2035. In the first scenario Australia's carbon tax rises by A$4.5 annually to reach A$53 (US$37), equivalent to average carbon tax price in OECD countries. In the second policy scenario it rises by A$7 annually to reach A$70 (US$50), equivalent to the US Government's proposed carbon tax rate.

This study indicates the imposition of a carbon tax in Australia would lead to an increase in the composite price of fossil fuels in coal consuming industries, specifically electricity, gas, water, and waste, resulting in a rise in the total production cost, as well as leading to a rise in the inflation rate. As the electricity, gas, water, and waste sector is the biggest consumer of coal and pays the lowest price among industries to secure this fossil fuel in the production process, the highest rise in the final price of coal is seen in this industry. Increasing the final price of coal in this sector leads to a decline in the reliance on coal over time. However, the total cost of production in non-coal consuming industries does not change significantly although the price of all commodities in the market soars, which leads to a rise in the inflation rate.

A controversial topic in carbon tax policy is the impact of the policy on GDP and the negative effect of the policy on the economy is the reason for resisting the policy in many countries. This study confirms that the carbon tax accompanied by a revenue recycling policy increases Australia's GDP. In both policy scenarios designed in this study, the imposition of the carbon tax, not associated with a revenue recycling method, causes a decline in the real value of GDP, albeit at a negligible rate and this negative impact fades over time. To offset the negative impact of the carbon tax policy on GDP, the adaptation of a proper revenue recycling approach is recommended.

This study examines the impact of three revenue recycling policies on Australia's real GDP. Redirecting the accumulated tax revenue back into the economy through a reduction in individual income taxes, transferring it to households, and reducing firms' income tax while also allocating a share to R&D offsets the negative effect of the policy on the economy. Comparing these three revenue recycling approaches shows the largest positive effect on real consumption and real GDP occurs if income taxes decline to compensate for the reduction in purchasing power of households, while the remaining carbon tax revenue is recycled back into R&D.

This result is in line with the findings of Allan et al. (2014), Lin and Jia (2018), Freire-Gonzalez and Ho (2019) who found reducing income taxes can offset the negative effect of a carbon tax policy on the economy, although there are no studies that compare the three revenue recycling approaches that are offered in this study. Furthermore, all the previous studies used differentiated tax rates or partial coverage of a tax policy, while in this study we focus on the application of a uniform tax rate that covers the whole industry sector. Using a uniform tax rate which starts from a A$23/t CO2 and increases gradually, this study shows that the proportion of carbon tax revenue allocated to support consumption through reducing income taxes declines over time while a larger share would be left to be invested into R&D projects in Australia. The uniform tax rate and full coverage of the policy provides an incentive to industries for transitioning to low carbon technologies.

This study suggests that it would be better for Australia to apply the higher tax rate (SIM2) and, after allocating a share of the tax revenue to compensate for the reduction in income taxes, increases the ratio of tax revenue invested in R&D projects gradually. Applying this policy leads to reducing total emissions by 35 percent and increase the GDP by 0.286 percent in 2035. This policy leads to a 0.193 percent rise in Australia's GDP in 2026, reaching a 0.286 percent increase compared to BAU in 2030. By applying this policy, the amount of carbon emissions in 2035, 13 years after the policy is introduced, declines by 35 percent compared to BAU. This result is consistent with findings of Beck et al. (2015), Marron and Morris (2016), Thapar (2020), Roach (2021), and Budolfson et al. (2021) that a carbon tax should be accompanied by a revenue recycling policy to generate economic benefits.

Working on Australia's economy, a resource-dependent economy that heavily relies on coal in its production sector, this study suggests that following a revenue-neutral carbon tax policy, supporting the consumption power of workers through reduction of income taxes and investing in R&D can generate both environmental and economic benefits for Australia and paves the way to transition to a low carbon economy. This study suggests Australia to impose a uniform tax rate that covers the whole industry sector. It recommends starting the policy with A$23/tCO2 and raising it gradually to reach A$70/tCO2 during seven years. Following a revenue-neutral policy, all the accumulated tax revenue should be used to support consumption in the first year through reduction in income taxes. A gradual rise in the carbon tax rate over time would leave more money to be invested in R&D projects after compensating the loss of purchasing power of families.This study provides a baseline for further research regarding the effect of the carbon tax on different aspects of the Australian economy. For more detailed results, further disaggregation of industries, commodities, as well as households based on their income, is vital. Disaggregation of households based on their income is vital to clarify the impact of the policy on different economic classes in the country. These can be conducted in future studies.

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Appendix A. Equation System

The system of equations is based on Partnership for Economic Policy (PEP), one country, dynamic recursive version standard CGE model, modified based on the requirements of this study.

$$VAE_{j,t} = v_j \ XST_{j,t}$$

$$CI_{j,t} = io_j \ XST_{j,t}$$

$$VAE_{j,t} = B_{VAE_j} \{ \beta_{VAE_j} \ VA_{j,t}^{\rho_{VAE_j}} + \left(1 - \beta_{VAE_j}\right) ENEC_{j,t}^{\rho_{VAE_j}} \}^{-1/\rho_{VAE_j}}$$

$$VA_{j,t} = (\{ \beta_{VAE_j} / (1 - \beta_{VAE_j}) \} \{ PTECEC_{j,t} / PVA_{j,t} \})^{\sigma_{VAE_j}}) \ ENEC_{j,t}$$

$$VA_{j,t} = B_{VA_j} \{ \beta_{VA_j} LD_{j,t}^{\rho_{VA_j}} + \left(1 - \beta_{VA_j}\right) KD_{j,t}^{\rho_{VA_j}} \}^{-1/\rho_{VA_j}}$$

$$LD_{j,t} = (\{ \beta_{VA_j} / (1 - \beta_{VA_j}) \} \{ R_{j,t} / W_{j,t} \})^{\sigma_{VA_j}} \ KD_{j,t}$$

$$ENEC_{j,t} = B_{ENE_j} \{ \beta_{ENE_j} COAL_{j,t}^{\rho_{ENE_j}} + \left(1 - \beta_{ENE_j}\right) OG_{j,t}^{\rho_{ENE_j}} \}^{-1/\rho_{ENE_j}}$$

$$COAL_{j,t} = (\{ \beta_{ENE_j} / (1 - \beta_{ENE_j}) \} \{ PTOG_{j,t} / PTCOAL_{j,t} \})^{\sigma_{ENE_j}}) \ OG_{j,t}$$

$$OG_{j,t} = B_{OG_j} \{ \beta_{OG_j} OIL_{j,t}^{\rho_{OG_j}} + \left(1 - \beta_{OG_j}\right) NG_{j,t}^{\rho_{OG_j}} \}^{-1/\rho_{OG_j}}$$

$$OIL_{j,t} = (\{ \beta_{OG_j} / (1 - \beta_{OG_j}) \} \{ PTNG_{j,t} / PTOIL_{j,t} \})^{\sigma_{ENE_j}}) \ NG_{j,t}$$

$$DI_{i,j,t} = a_{ij} \ CI_{j,t}$$

$$YH_t = YHL_t + YHK_t + YHTR_t$$

$$YDH_t = YH_t - TDH_{\ t}$$

$$CTH_t = YDH_t - SH_t - TRH_t$$

$$SH_t = Share_h YDT_{\ t}$$

$$YF_t = YFK_t + YFTR_t$$

$$YDF_t = YF_t - TDF_t$$

$$SF_t = YDF_t - TRF_t$$

$$YG_t = YGK_t + TICT_t + TIPT_t + YGTR_t + TDH_t + TDF_t + TDROW_t$$

$$TIC_{i,t} = ttic_{i,t} \{ \left(PL_{i,t} + PC_{i,t} \ tmrg_i \ DD_{i,t} \right) \}$$

$$TIX_{i,t} = ttix_{i,t} \{ \left(PWM_{i,t} \ er_t + PC_{i,t} \ tmrg_i \ IM_{i,t} \right) \}$$

$$TICT_t = \sum_i (TIC_{i,t} + TIX_{i,t})$$

$$TIPT_t = \sum_j TIP_{j,t} + TCTAX_{j,t}$$

$$TIP_{j,t} = ttip_{j,t}\, PP_{j,t}\, XST_{j,t}$$

$$CTAX_{COAL,j,t} = R_{COAL,j,t}\, EM_{COAL,j,t}$$

$$CTAX_{OG,j,t} = R_{OIL,j,t}\, EM_{OIL,j,t} + R_{NG,j,t}\, EM_{NG,j,t}$$

$$TCTAX_{j,t} = CTAX_{COAL,j,t} + CTAX_{OG,j,t}$$

$$EM_{COAL,j,t} = \gamma^{COAL} COAL_{j,t}$$

$$EM_{OG,j,t} = \gamma^{OIL} OIL_{j,t} + \gamma^{NG} NG_{j,t}$$

$$TEM_{j,t} = EM_{COAL,j,t} + EM_{OG,j,t}$$

$$TDH_t = ttdh_t\, YH_t$$

$$TDF_t = ttdf_t\, YFK_t$$

$$SG_t = YG_t - YGTR_t - G_t$$

$$YROW_t = er_t \sum_i PWM_{i,t} IM_{i,t} + W_t\, LD_{ROW,j,t} + TRROW$$

$$SROW_t = -current\ account\ balance_t$$

$$XST_{j,t} = B_{XT_j} [\sum_i \beta_{XT_{j,i}} XS_{j,i,t}{}^{\rho_{XT_j}}]^{1/\rho_{XT_j}}$$

$$XS_{j,i,t} = \left\{ XST_{j,t} \middle/ (B_{XT_j}) \right\} \left\{ P_{j,i,t} \middle/ \beta_{XT_{j,i}} PT_{j,i} \right\}^{\sigma_{XT_j}}$$

$$XS_{j,i,t} = B_{X_{j,i}} \{ \beta_{X_{j,i}} EX_{j,i,t}^{\rho_{X_{j,i}}} + (1 - \beta_{X_{j,i}}) DS_{j,i,t}^{\rho_{X_{j,i}}} \}^{-1/\rho_{X_{j,i}}}$$

$$EX_{j,i,t} = (\{ \beta_{X_{j,i}} / (1 - \beta_{X_{j,i}}) \} \{ PET_{j,i,t} / PLT_{j,i,t} \})^{\sigma_{X_{j,i}}} DS_{j,i,t}$$

$$Q_{i,t} = B_{M_i} \{ \beta_{M_i} IM_{i,t}^{\rho_{M_i}} + (1 - \beta_{M_i}) DD_{i,t}^{\rho_{M_i}} \}^{-1/\rho_{M_i}}$$

$$IM_{i,t} = (\{ \beta_{M_i} / (1 - \beta_{M_i}) \} \{ PD_{i,t} / PM_{i,t} \})^{\sigma_{M_i}} DD_{i,t}$$

$$EXD_{i,t} = \sum_j EX_{j,i,t} (\frac{er_t PWX_{i,t}}{PE_{fob,i,t}})^{\sigma_{XT_i}}$$

$$PP_{j,t} XST_{j,t} = PVAE_{j,t} VAE_{j,t} + PCI_{j,t} CI_{j,t}$$

$$PT_{j,t} = (1 + ttip_{j,t}) PP_{j,t}$$

$$PTENEC_{j,t} ENEC_{j,t} = PTCOAL_{j,t} COAL_{j,t} + PTOG_{j,t} OG_{j,t}$$

$$PTCOAL_{j,t} = (1 + ttcarbon_{COAL,j,t}) PCOAL_{j,t}$$

$$PTOG_{j,t} = (1 + ttcarbon_{OG,j,t})POG_{j,t}$$

$$PVAE_{j,t}VAE_{j,t} = PVA_{j,t}VA_{j,t} + PTENEC_{j,t}ENEC_{j,t}$$

$$PVA_{j,t}VA_{j,t} = LD_{j,t}W_{j,t} + KD_{j,t}R_{j,t}$$

$$PD_{i,t} = (1 + ttic_{i,t})\{PL_{i,t} + PC_{i,t}tmrg_i)$$

$$PM_{i,t} = (1 + ttic_{i,t})\{er_t PWM_{i,t} + PC_{i,t}tmrg_i)$$

$$P_{j,i,t}X_{j,i,t} = PET_{j,i,t}EX_{j,i,t} + PLT_{j,i,t}DS_{j,i,t}$$

$$PE_{fob,i,t} = (1 + ttix_{i,t})\, PE_{i,t} + PC_{i,t}tmrg_i$$

$$PC_{i,t}\, Q_{i,t} = PM_{i,t}\, IM_{i,t} + PD_{i,t}DD_{i,t}$$

$$Q_{i1,t} = CH_{i1,t} + CG_{i1,t} + INV_{i1,t} + DIT_{i1,t}$$

$$LS_t = \sum_j LD_{j,t}$$

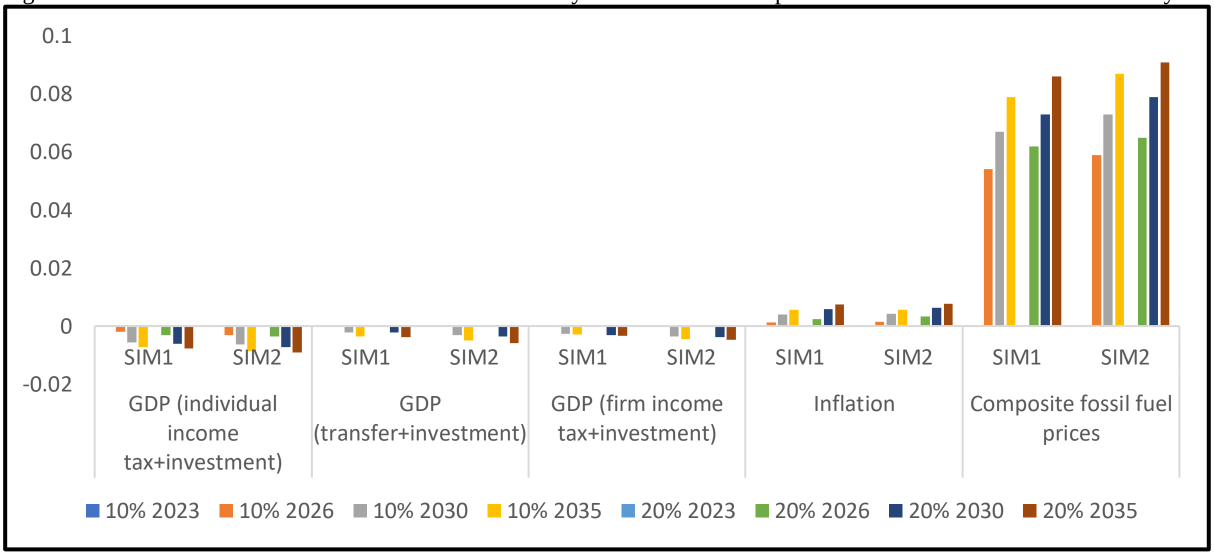
$$KS_t = \sum_j KD_{j,t}$$

$$IT_t = SH_t + SF_t + SG_t + SROW_t$$

Appendix B. Sensitivity Analysis Figure

Figure 9 shows the variation in the GDP, inflation and composite fossil fuel prices in case of increasing the elasticity of substitution by either 10 percent or 20 percent compared to the model estimated in this study. It shows that variation in the GDP and inflation is less than 0.01 percent while the variation in composite fossil fuel prices is less than 0.1 percent during the 13-year period of policy implementation.

Figure 9: Variation in case of 10% and 20% rise in elasticity of substitution compared to the model estimated in this study



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