Carbon Taxation, Revenue Recycling, and Policy Trade-offs in Thailand: A Dynamic CGE Analysis

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ABSTRACT

Climate change mitigation has become a critical global priority. In response, Thailand implemented a carbon tax of 200 baht per ton of CO_2 in 2025. Assessing the macroeconomic, distributional, and environmental impacts of such a policy is essential for designing effective and sustainable climate strategies. This study develops a Computable General Equilibrium (CGE) model calibrated to the Thai economy, incorporating carbon emissions and taxation to evaluate the nationwide effects of the carbon tax and explore alternative revenue-recycling strategies. The model is based on a Social Accounting Matrix constructed from the 2010 input–output table and energy-related emissions data. Two tax base designs are considered, namely a liquid fuel base and an all fossil fuel base, under two emission pathways: the Business-as-Usual (BAU) scenario and the Nationally Determined Contribution (NDC) scenario. The results show that a broader tax base leads to greater emissions reductions but at higher economic costs. Macroeconomically, the carbon tax produces modest GDP impacts and stimulates investment, while exerting downward pressure on household consumption. Among revenue-recycling options, no single strategy is universally optimal. Progressive transfers most effectively promote equity, while increased government spending emerges as the most efficient approach for minimizing economic losses.

Keywords: Carbon tax, CGE, revenue recycling, macroeconomic impacts, Thailand

MAIN CONTENT

1. Introduction

Climate change is a major global trend marked by profound alterations in the Earth's climate system. From an economic perspective, it has become an increasingly critical concern over the past decades due to the interconnection between economic growth and environmental degradation. Numerous studies have demonstrated a causal relationship whereby economic growth contributes to climate change, which in turn affects economic activity (Dobes et al., 2014). In the ASEAN region, the five largest economies, including Thailand, also exhibit a positive correlation between carbon emissions and economic growth (Tu et al., 2022). For low-income countries, empirical evidence indicates that climate change, particularly extreme weather events, has long-term adverse

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effects on economic growth (Shabir et al., 2022). Therefore, understanding the macroeconomic, distributional, and environmental impacts of climate-related policies is essential for designing effective and sustainable climate strategies.

In response to the continued rise in global temperatures and the growing concern for long-term climate mitigation, international organizations have established key agreements such as the United Nation Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol, and the Paris Agreement. According to the World Bank's Carbon Pricing Dashboard (2023), many developed countries have adopted carbon pricing instruments, such as carbon taxes and cap-and-trade systems, to internalize the cost of emissions and work toward achieving net-zero targets by 2050.

Thailand has not made a legally binding commitment to emission reductions but has pledged voluntary targets through its Nationally Appropriate Mitigation Actions (NAMAs) and Nationally Determined Contributions (NDCs). In Thailand's NDC 3.0, the latest version updated in November 2025, the mitigation target was set to reduce net greenhouse gas emissions to 152 million tCO2eq by 2035, equivalent to a 47% reduction from the 2019 net-emissions level of 287.2 million tCO2eq. The document also states that this target is aligned with a 1.5 °C pathway, with Thailand aiming to peak greenhouse gas emissions before 2030 and follow a trajectory toward net-zero emissions by 2050.

Thailand ranked ninth on the 2021 Global Climate Risk Index, indicating significant impacts from climate hazards in terms of fatalities and economic losses. Acknowledging this growing concern, the excise department implemented a carbon tax, as announced in the Royal Thai Government Gazette dated 28 March 2025. The tax is levied at a rate of 200 baht per ton of carbon dioxide equivalent. This policy aims to support Thailand's commitment to achieving carbon neutrality by 2050 and net-zero greenhouse gas emissions by 2065. It also serves as a preparatory measure for Thai exporters ahead of the enforcement of the Carbon Border Adjustment Mechanism (CBAM), thereby strengthening incentives for producers to consider carbon emissions in their production processes.

However, the existing research on the effects of carbon tax in Thailand remains limited. Most studies focus on how the country can prepare to meet its commitment to achieve net-zero emission by 2050, as pledge to the UN. These studies typically adopt the following two approaches: a bottom–up analysis of the energy system and top–down approaches using Computable General Equilibrium (CGE) models. While bottom–up approaches are valuable for estimating technical mitigation potential and associated costs within the energy system, they often overlook broader economic feedback and distributional impacts. By contrast, top–down approaches using CGE models provide a comprehensive framework to assess how carbon taxation affects macroeconomic variables, sectoral performance, and household welfare. Therefore, this study focuses on a top–down analysis using a recursive dynamic CGE model, which is particularly well-suited for capturing long-term structural adjustments and key economic drivers of decarbonization. Indirect studies on the carbon tax effects show that without economic and energy transformation, Thailand could face a 7.7%–8.5% GDP loss by 2050 (Rajbhandari et al., 2019; Lorm & Limmeechokchai, 2024; Muangjai et al., 2023; Rajbhandari et al., 2023). Only one study directly examines carbon

taxation, and the latter is found to reduce real GDP and household consumption while increasing unemployment and inflation (Puttanapong et al., 2015).

Therefore, this study aims to evaluate the impact of carbon tax on the Thai economy using the recursive dynamic CGE model. Accordingly, the research focuses on three key objectives. First, it seeks to develop a CGE model specifically tailored to the Thai context, incorporating the effects of carbon emissions and taxation. Second, it analyzes the economy-wide impacts of carbon tax, with particular emphasis on how variations in the tax base and emission pathways influence macroeconomic and environmental outcomes. Third, the study examines alternative revenue recycling strategies to provide a comprehensive understanding of their implications for economic efficiency and social equity. In doing so, the study assesses the effects of Thailand's current carbon tax implementation while addressing gaps in the literature concerning carbon tax recycling.

The following sections are organized as follows. Section 2 reviews the effects of carbon taxation and the use of CGE models in climate policy analysis. Section 3 represents the CGE model structure and methodology. Section 4 outlines the scenario design and results. Lastly, Section 5 provides the discussion and conclusions.

2. Literature Review

2.1) Thailand's initial approach to carbon tax policy

Thailand officially introduced a 200-baht carbon tax in 2025 under the Excise Department. However, this measure currently operates as an implicit tax folded into existing excise duties on oil and petroleum products. Although such pricing does not directly burden household consumption, it lacks transparency and emission-based targeting. Consequently, it limits its economic efficiency and policy effectiveness. By contrast, this study models an explicit carbon tax directly applied to fuel use based on carbon content. This process allows for a clear assessment of its macroeconomic, environmental, and distributional impacts. By adopting this forward-looking approach, the study addresses the current policy gaps and explores transparent and targeted carbon pricing strategies for Thailand's long-term climate commitments. Along with the growing international pressure for transparent carbon pricing driven by instruments such as the EU's CBAM, it adds relevance to the design of explicit carbon taxes for developing countries such as Thailand.

2.2) Empirical evidence on carbon tax impacts

The rationale for carbon taxation lies in its ability to create an economy-wide price signal that encourages emission reduction. Its impacts are typically categorized into the following four dimensions: environmental effectiveness, macroeconomic outcomes, trade competitiveness and innovation, and income distribution.

First, environmental effectiveness varies by region and sector often constrained by low rates and broad exemptions (Köppl & Schratzenstaller, 2022). While carbon pricing can improve environmental quality, it may also raise production costs and reduce output, investment, and consumption, potentially slowing economic growth (Tu et al., 2022).

Second, carbon taxation significantly affects macroeconomic indicators, especially in labor-intensive, high-emission sectors such as construction and manufacturing (Chua & She, 2023). Revenue recycling is often proposed to ease these impacts, depending on sectoral structures and price pass-through strength (Känzig & Konradt, 2023). While technical modeling offers insights into potential outcomes, behavioral responses and political acceptance (especially in low-trust environments) remain critical factors that can shape the real-world effectiveness of carbon tax policies (Frankowski et al., 2024).

Third, the impact of carbon taxes on trade competitiveness and innovation tends to be small or statistically insignificant (Venmans et al., 2020). Where significant, impacts are minimal. Firms may mitigate competitiveness losses by improving energy efficiency (Dorsey-Palmateer & Niu, 2020). At the international level, unilateral carbon taxes on imports may reduce trade welfare and cause carbon leakage, as emissions shift to countries with weaker carbon pricing (Larch & Wanner, 2014).

Lastly, given that carbon tax implementation has driven up the costs of energy and other goods, concern also exists on their negative effects on low-income households and income inequality. Carbon taxes tend to be regressive, disproportionately affecting low-income and rural households due to rising energy and goods prices, where redistribution mechanisms such as lump-sum transfers or tax credits can reduce inequality and support a double-dividend effect (Rausch et al., 2011; Guo et al., 2022; Antosiewicz et al., 2022; Zhao et al., 2022). Some studies even find progressive outcomes, with greater income losses for middle- and high-income urban workers than low-income rural groups (Zhang et al., 2023). Nevertheless, the effectiveness of revenue recycling in reducing inequality tends to be evident in high-income countries while remaining regressive in low-income settings (Nguyen & Song, 2021).

2.3) CGE applications in carbon tax and revenue recycling analysis

CGE models have become a key tool used by policymakers to assess the economic impacts of carbon taxation. Depending on the policy objective and national context, studies adopt static, dynamic, or multi-sectoral frameworks to simulate tax effects under various economic conditions (McKitrick, 1997; Böhringer et al., 2000; Meng, 2012; Tuladhar et al., 2015; Mengistu et al., 2019; Jia et al., 2023). These models typically incorporate labor and capital as primary inputs and use nested CES production functions to reflect sectoral complexity and substitution possibilities.

Essentially, revenue recycling is a critical design component in CGE simulations, influencing efficiency and equity outcomes. Studies explore a range of recycling strategies, including lump-sum household transfers, income tax reductions, and debt repayment, each with

distinct macroeconomic and distributional implications. These insights help inform carbon tax policy design that balances environmental goals with economic and social considerations.

In Thailand, existing studies rarely apply CGE models to assess explicit carbon taxation. To date, none have incorporated revenue-recycling mechanisms into the analysis. Therefore, this study fills that gap by evaluating macroeconomic and distributional implications of carbon tax policies under alternative revenue-recycling strategies.

3. CGE model structure

The CGE model structure is based on the PEP standard model 1-t, version 2.0, developed by members of the Partnership for Economic Policy (PEP) research network (Decaluwé et al., 2013). The version used in this study was revised in 2012. This PEP-1-t model is a recursive dynamic model that embeds capital accumulation and the economic mechanism into the CGE model, enabling adjustments to the prices and quantities of goods and input factors while allowing medium- and long-term simulations. As shown in Table 1, this model consists of 40 production activities, 49 commodities, 5 households, the government, and the rest of the world. The basic framework of the CGE model is shown in Figure 1, which illustrates the interaction mechanisms within the model.

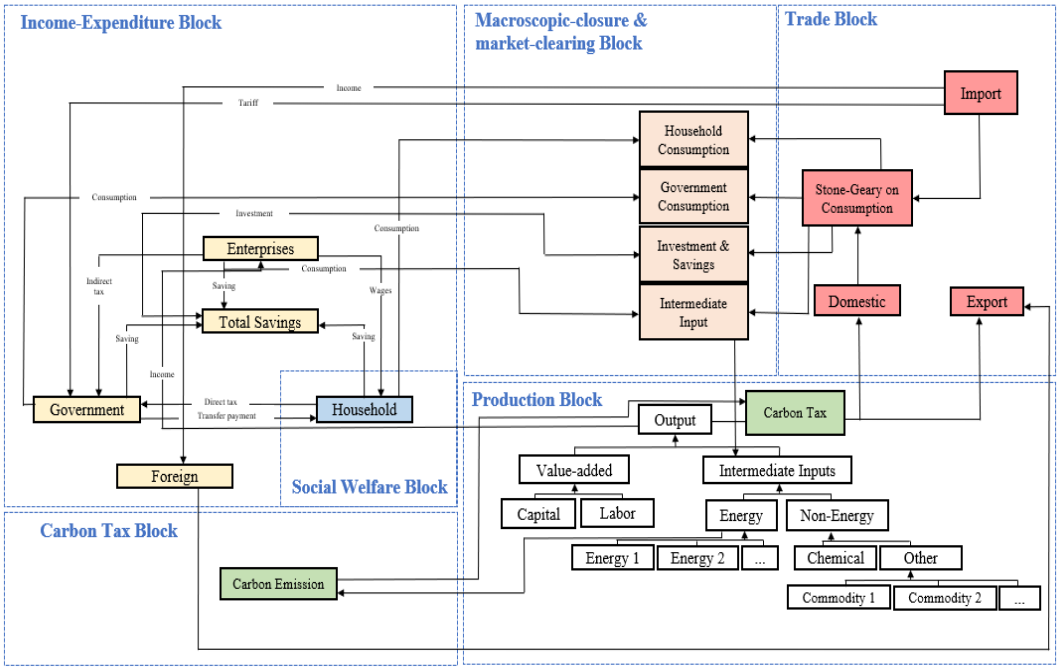

Figure 1. The basic framework of the CGE model.

Production in the model takes place under perfect competition, where producers in each sector maximize profits based on their production technologies and prevailing prices of goods, services, and factors. Fig. 1 illustrates the nested production structure used in the CGE model; it

consists of four hierarchical layers combining CES and Leontief functions. At the top level, total output is a composite of value-added and intermediate inputs integrated using a CES function.

The second layer separates value-added (a combination of capital and labor) from intermediate inputs, which include energy and non-energy products, using CES functions. The third layer further disaggregates intermediate inputs: energy inputs are modeled as a composite bundle of different energy sources, while non-energy inputs are divided into chemical and other components. At the final layer, Leontief technology governs the fixed proportions of energy and non-energy inputs required for each commodity.

Table 1. Sectors, commodities, and levels of household income.

Sec	Activity	Sec	Activity	Com	Commodities	Com	Commodities
1	Paddy	21	Paper	1	Paddy	26	Gasoline
2	Corn	22	Ethanol	2	Corn	27	Jet fuel
3	Cassava	23	Chemical	3	Cassava	28	LPG
4	Cane	24	Refinery	4	Cane	29	Diesel
5	Oil palm	25	Rubber	5	Oil palm	30	Fuel oil
6	Livestock	26	NonMetal	6	Livestock	31	Other refinery
7	Chcoal	27	Iron	7	Chcoal	32	Gasohol
8	Fishery	28	Metal	8	Fishery	33	Biodiesel
9	Residue agriculture	29	Motor	9	Other agriculture	34	Rubber
10	Coal	30	Machine	10	Coal and lignite	35	NonMetal
11	Oil Gas	31	Other industry	11	Crude oil	36	Iron
12	Mining	32	Electricity	12	Natural Gas	37	Metal
13	Food	33	Construction	13	Mineral	38	Motor
14	Palmoil	34	Trade	14	Food	39	Machine
15	Rice	35	Rail transport	15	Palm oil	40	Other industry
16	Starch	36	Road transport	16	Rice	41	Electricity
17	Maize	37	Water transport	17	Starch	42	Construction
18	Sugar	38	Air transport	18	Maize	43	Trade
19	Textile	39	Other transport	19	Sugar	44	Rail transport
20	Wood	40	Service	20	Molas	45	Road transport
Levels of household income				21	Textile	46	Water transport
1	Low-income household 1 (HH1)	4	High-income household 4 (HH4)	22	Wood	47	Air transport
2	Low-income household 2 (HH2)	5	High-income household 5 (HH5)	23	Paper	48	Other transport
3	Low-income household 3 (HH3)			24	Ethanol	49	Service
				25	Chemical product		

The value-added of each industry is calculated proportionally to its intermediate input, incorporating the relevant price index and specific intermediate consumption. Capital and labor are allocated through a CES structure, where factor demand responds to rental rates, wage rates, and the elasticity of transformation.

Intermediate input demand is also determined through CES functions, reflecting constant elasticity of substitution between energy and non-energy goods. Firms, operating under profit-maximization behavior, choose input bundles that optimize returns. For energy use, this process results in a zero-profit condition that defines the optimal composite energy demand. Similarly,

demand for non-energy inputs reflects imperfect substitutability, particularly between chemical and non-chemical products. For certain inputs, especially non-energy components excluding chemical, Leontief technology applies fixed input coefficients to capture rigid input proportions.

Households in the model act as consumers, maximizing utility under budget constraints and earning income through their ownership of production factors. Their consumption includes domestic and imported goods, with some households also receiving government transfers. The institutional framework consists of five household groups, firms, the government, and the rest of the world. Certain households are taxed on income and allocate part of it to savings. The government collects direct and indirect taxes; meanwhile, key policy variables, such as government revenue, interest rates, and subsidies, were treated as exogenous.

All markets are assumed to be clear, with prices adjusting to ensure equilibrium. This process includes goods market balance, savings equaling investment, labor and land market clearing, full allocation of post-tax income, a balanced government budget, and trade balance maintained via net foreign capital flows. The model also captures non-linear substitution between domestic and foreign goods. Import demand and export supply are governed by CES and CET functions, respectively, reflecting imperfect substitutability in international trade.

In general, a CGE model contains more variables than equations. Thus, specifying the exogenous and endogenous variables is necessary to ensure a unique solution and to satisfy Walras' Law. This process is achieved by defining closure rules, which determine the model's equilibrium structure based on the analytical objective. In this study, the following variables are specified as exogenous: the current account balance; minimum household consumption; government expenditure; capital investment; capital demand; wage rate; world prices of traded goods; inventory changes; household savings; household transfers to the government; business and household income taxes; tax rates on commodities, capital, and trade; industrial output; worker compensation; emission coefficients; and the carbon tax. The exchange rate is set as the numeraire to maintain the relative price system. Additionally, model parameters such as scale, share, and elasticity values are calibrated using standard numerical techniques common in CGE modeling.

3.1) Income distribution

Household income, broadly defined as total income, is derived from returns on capital, labor, and transfers. Specifically, it includes income from capital rental, wages, and transfers received from other agents. Capital and labor income are distributed according to each household's respective share in factor ownership. These income components reflect the household's role as a supplier of primary production factors in the economy. Household behavior in the model assumes that disposable income is allocated for consumption based on a linear expenditure system. This framework captures basic consumption needs and responses to income changes. Any remaining income after fulfilling consumption needs is saved.

The model allows household income and consumption to respond endogenously to policy shocks such as carbon tax, through changes in wage, capital returns, prices of consumption goods, and government transfer, consequently capturing potential distributional impacts across household groups.

3.2) Carbon emission

In this model, carbon emissions subject to the carbon tax are derived solely from fossil fuel combustion associated with intermediate and final demands. Emissions from intermediate demand are calculated on the basis of the quantity of energy-related inputs used in production, multiplied by their respective carbon emission coefficients and adjusted by factor prices. For final demand, emissions are computed from household consumption, government spending, and investment, similarly weighted by their carbon intensities. These emission estimates reflect the direct link between fossil fuel use and carbon output, forming the basis for applying the carbon tax in the model. Total carbon emissions from all taxed activities are aggregated to assess the overall impact of carbon pricing across the economy.

3.3) Carbon taxes

The carbon tax is embedded within the indirect tax on products, which appears in the income-saving blocks. This tax is collected by the government and treated as part of government revenue. Technically, the carbon tax is modeled through the product of the carbon tax rate and the embedded emission coefficient, representing carbon emissions per unit of commodity. It functions not only as an emission factor but also as a converter that monetizes emissions, linking physical carbon output to economic values in the model. Essentially, this tax base focuses solely on Scope 1 emissions, which are direct emissions from production activities. Upstream fuel inputs are excluded to avoid the issue of double taxation.

3.4) Dynamics

The model is structured as a multi-period framework, with each period solved sequentially in the same manner as a static single-year CGE model. Covering the timeframe from 2010 to 2050, the dynamic growth of the Thai economy is primarily driven by capital accumulation. Investment plays a crucial role not only in shaping overall growth trends but also in determining the capital intensity across sectors. Future capital demand arises from the need to replace depreciated capital and accommodate new investment, with the latter divided into public and private components. Public investment represents the value of new capital acquired by the government, while private investment reflects new capital formation within the business sector. Balancing capital accumulation between the public and private sectors requires careful coordination, with the policy interest rate serving as a key determinant. This rate influences the cost of capital and subsequently affects the price and volume of new capital investments.

The model's equations are based on the work of Phomsoda et al. (2021). All calculations based on the GAM program serve as the primary analytical tool.

3.5) Database

The main data source for this CGE model is the Social Accounting Matrix (Benhamed et al.) developed on the basis of the 2010 Input–Output table and supplemented with additional statistics, such as real gross domestic product (GDP) and real private consumption expenditure (PCE); these data are publicly provided by the National Economic and Social Development Council (NESDC). The SAM captures the core structure of the Thai economy and serves as the foundation for the macroeconomic variables used in the model, following the approach of Phomsoda et al. (2021). In addition, emission coefficient data are obtained from the Energy Policy and Planning Office (EPPO) under the Ministry of Energy.

4. Scenarios and results

4.1) Setting scenarios

(1) Carbon tax rate and base

According to the Thai government, the Excise Department began collecting a 200-baht carbon tax on petroleum products such as gasoline, jet fuel, liquefied petroleum gas (LPG), diesel, and gasohol. It defines the liquid fuel base, aligned with the current tax structure. In addition, the following two alternative bases are considered: a broader base, which further includes coal, natural gas, and biodiesel to reflect potential future expansions of the carbon tax scope; and a narrow base, which focuses solely on gasoline to explore the implications of a minimal, targeted tax base.

(2) Roles of carbon tax revenue recycling

According to the World Bank's Carbon Tax Guide (Conway et al., 2017), carbon tax revenues can be used in two primary ways: revenue neutrality, where funds are returned to the economy through tax cuts or direct transfers (e.g., to low-income households), and increased public spending. This study evaluates three revenue-recycling options with a focus on equity and efficiency. The first option, direct transfers to households, is analyzed primarily through an equity lens, comparing regressive and progressive schemes based on the work of Zhao et al. (2022) to determine which best supports low-income households. This benchmark is then compared with the other two strategies to assess efficiency, using the framework of Combet et al. (2025) to explore their economic impacts and highlight trade-offs between distributional fairness and overall economic performance.

Therefore, to address the core research questions, which examine how different carbon tax bases and emission pathways affect economic and environmental outcomes and how revenue recycling influences distribution and macroeconomic performance, the simulation scenarios are summarized in Table 2. Section 4.2 provides details on emission pathways.

Table 2. Main assumptions of each scenario

Simulations	Detail	Emission Path
Section 1: Impact of carbon tax implementation		
Simulation 1	Imposing a carbon tax at 200 baht/tCO2e – All fossil fuels	BAU path and NDC path
Simulation 2	Imposing a carbon tax at 200 baht/tCO2e – Only liquid fuels	
Section 2: Carbon tax revenue recycling strategies		
Section 2.1: All fuel-based		
Section 2.1.1: Equity Considerations		
Simulation 3	Regressive transfer to low-income households	BAU path and NDC path
Simulation 4	Progressive transfer to low-income households	
Section 2.1.2: Efficiency Considerations		
Simulation 4	Progressive transfer to low-income households	BAU path and NDC path
Simulation 5	A reduction in household income taxes	
Simulation 6	Increasing government spending	
Section 2.2: Liquid fuel base		
Section 2.2.1: Equity Considerations		
Simulation 7	Regressive transfer to low-income households	BAU path and NDC path
Simulation 8	Progressive transfer to low-income households	
Section 2.2.2: Efficiency Considerations		
Simulation 8	Progressive transfer to low-income households	BAU path and NDC path
Simulation 9	A reduction in household income taxes	
Simulation 10	Increasing government spending	

4.2) Model validations and projections

This CGE model simulates medium- and long-term economic dynamics by adjusting parameters to align with real-world macroeconomic and emission data. Calibration ensures that the model reflects observed conditions, while future projections help assess long-term impacts. Parameters, which influence model behavior, interact with closure rules and exogenous variables to shape economic outcomes. Operating under a recursive dynamic framework, the model

sequentially solves each period with updated parameters. However, accurately capturing real-world complexity remains challenging, especially during disruptions such as the pandemic, when exogenous shocks and interdependent variables can lead to deviations from actual economic behavior.

Beyond validating the past trends, the model also offers crucial insights into future projections. Its design has incorporated interrelated factors from historical data, present conditions, and future national forecasts to generate reliable and meaningful results.

(1) Macroeconomic variables

Model validation was conducted using the root mean square error (RMSE) to compare model estimates with official data. National accounts from the NESDC (2023) served as benchmarks for key macroeconomic indicators from 2010 to 2023. As shown in Table 3 and Figure 2, the model demonstrates strong predictive accuracy, with small percentage errors for real GDP (0.78%), GFCF (−0.33%), GCE (−0.39%), and exports (−0.44%). However, private consumption (PCE) and real imports exhibit larger discrepancies with RMSE values of −3.95% and 3.44%, respectively. These deviations suggest challenges in capturing rapid changes during disruptive periods such as the pandemic, potentially leading to underestimated household consumption and overestimated imports.

Table 3. Comparison of the model's estimates of macroeconomic variables and official data (2010-2023).

	RMSE
Real Gross Domestic Product (GDP)	0.78%
Private Consumption Expenditure (PCE)	-3.95%
Real Gross Fixed Capital Formation (GFCF)	-0.33%
Government Consumption Expenditure (GCE)	-0.39%
Real Export	-0.44%
Real Import	3.44%

In terms of macroeconomic projections, NESDC data show that Thailand's GDP grew by an average of 2.88%–3% over the past decade, although post-pandemic recovery has lagged due to shifts in tourism, exports, and productivity. Revised projections from the IMF and World Bank estimate growth at 2.7% in 2024, 2.9% in 2025, and a decline to 2.6% in 2026 as stimulus fades, stabilizing at 2.7% through 2030. In the medium term, this study projects GDP growth between 2.5% and 3%, factoring in fiscal constraints from decarbonization efforts. The World Bank also notes that carbon pricing may lower GDP by 0.5%–1.0% annually. Overall, post-2023 GDP is expected to grow at an average of 2.88%, with other macroeconomic indicators following a similar 2.5%–3% growth range through 2050.

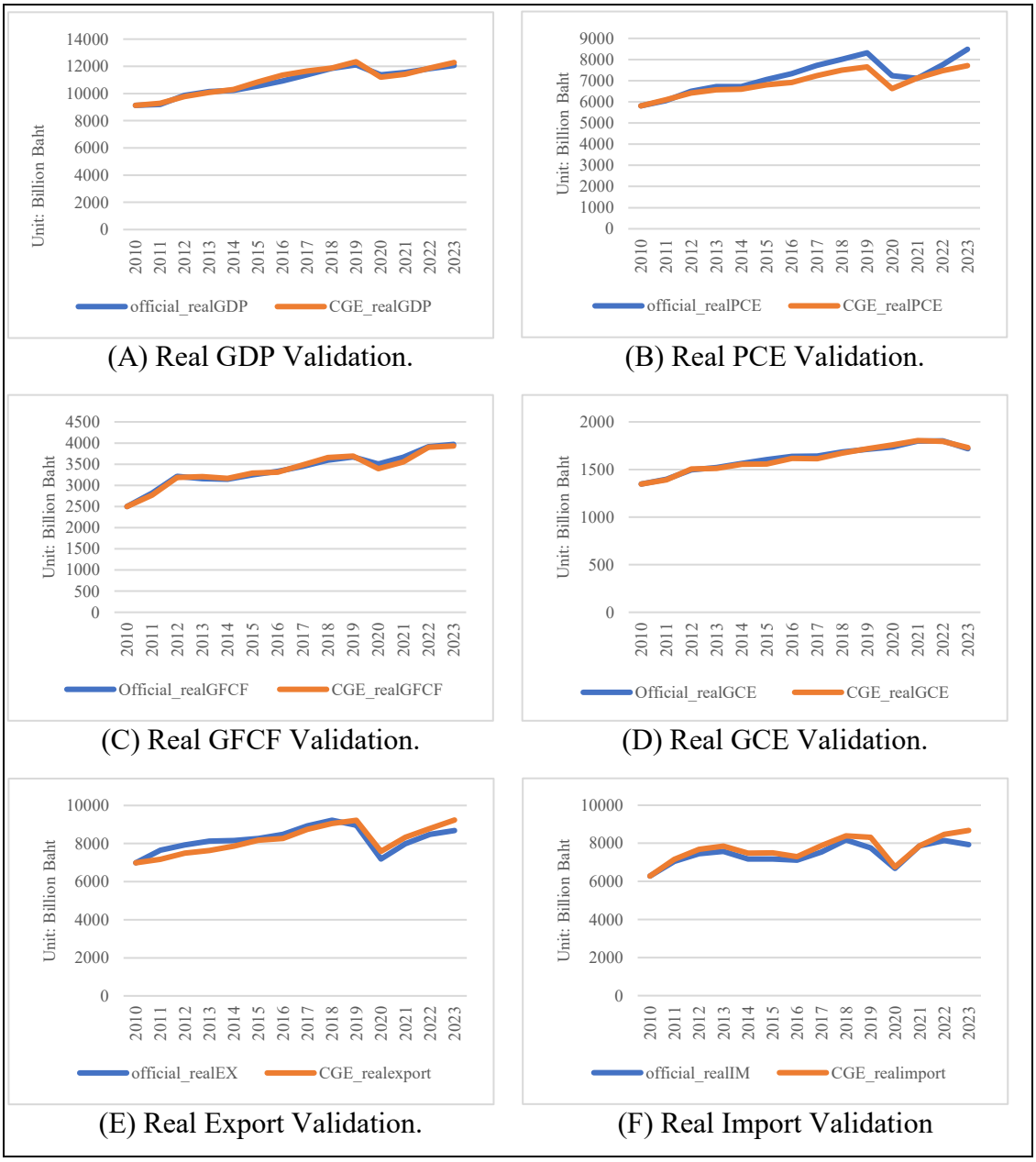

Figure 2. Validation for macroeconomic variables.

(2) Emission variables

Emission data validation also relies on RMSE, using data from the Energy Policy Planning Office (Ministry of Energy) covering carbon emissions by energy type and sector from 2010 to 2022. Table 4 details sector classifications. As shown in Table 5 and Figure 3, the model accurately captures emission trends, with a low RMSE of 0.11% for total emission from energy used. Subsector performance is similarly strong, with low RMSE values for power generation (0.96%), transport (2.25%), industry (−1.44%), and other sectors (1.98%).

Table 4

Comparison of Model Emission Estimates and Official Data (2010-2022)

Power Generation (SMCO_POW)		Industry (SMCO_IND)		Others (SMCO_OTH)			
Sec	Activity	Sec	Activity	Sec	Activity	Sec	Activity
10	Coal	21	Paper	1	Paddy	13	Food
11	Oil Gas	22	Ethanol	2	Corn	14	Palmoil
32	Electricity	23	Chemical	3	Cassava	15	Rice
		24	Refinery	4	Cane	16	Starch
Transportation (SMCO_TRA)		25	Rubber	5	Oil palm	17	Maize
Sec	Activity	26	NonMetal	6	Livestock	18	Sugar
35	Rail transport	27	Iron	7	Chcoal	19	Textile
36	Road transport	28	Metal	8	Fishery	20	Wood
37	Water transport	29	Motor	9	Residue agriculture	40	Service
38	Air transport	30	Machine	12	Mining		
39	Other transport	31	Other industry				
		33	Construction				
		34	Trade				

Table 5

Comparison of Model Emission Estimates and Official Data (2010-2022)

CO2 Emission from Activity j (SMCO)	RMSE
Power Generation	0.96%
Transportation	2.25%
Industry	-1.44%
Others	1.98%
Total SMCO	0.11%

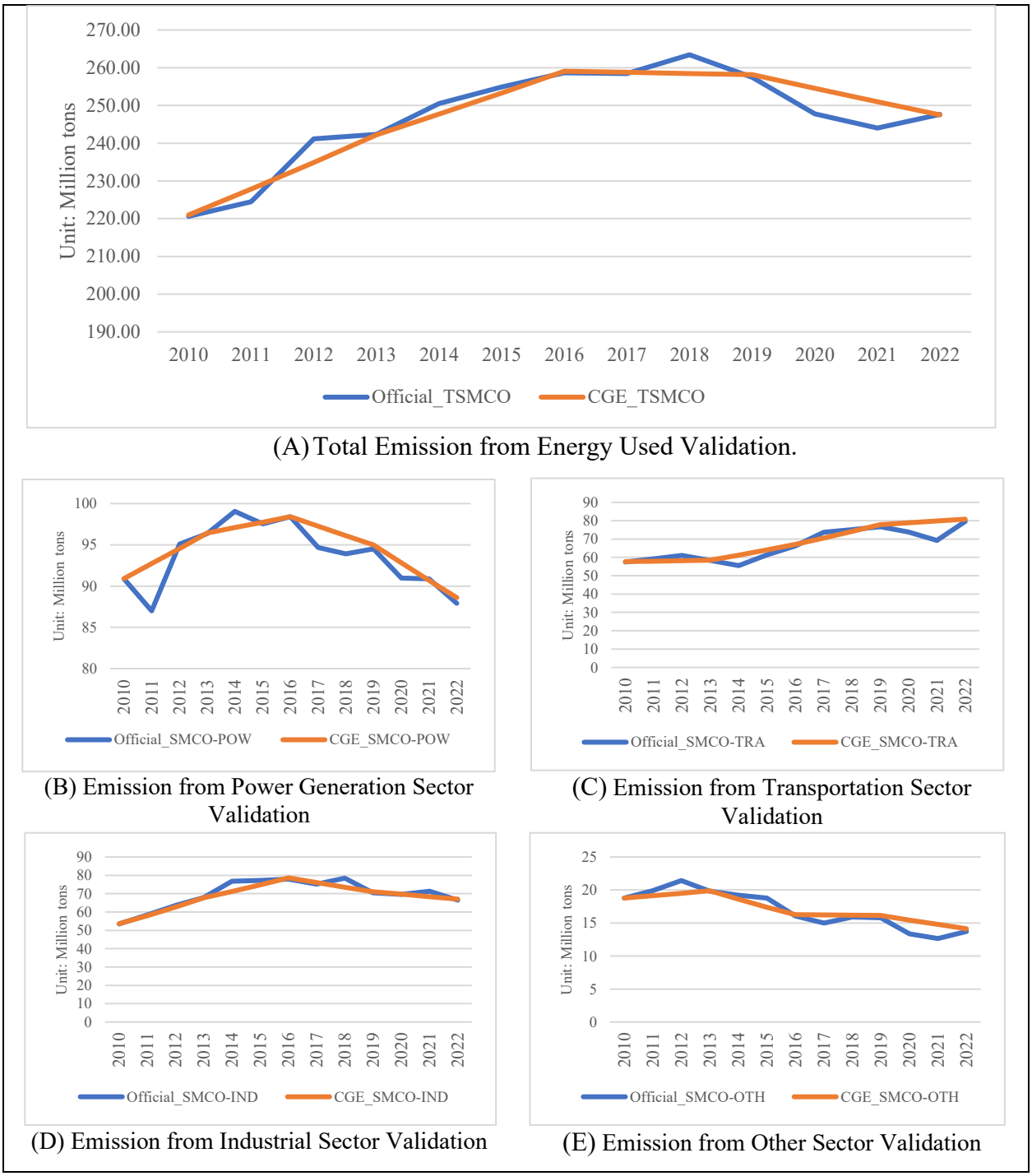

Figure 3. Validation for emission variables.

This study defines the following two emission pathways: a Business-as-Usual (BAU) scenario and one aligned with Thailand's 2nd updated NDC. The BAU scenario assumes no major climate policies and projects emissions at 555 million tons CO_2e by 2030. The NDC outlines a 40% conditional reduction target, aiming for 333 million tons CO_2e by 2030. This

target aligns with Thailand's 2065 net-zero goal under the LT-LED strategy and is adopted in this study.

The model applies projected annual growth rates for each pathway: total emissions increase by 1.78% per year under BAU, while the NDC scenario sees a 0.33% annual decline due to a shift toward renewables. Energy-related emissions also follow these paths, with a 1.46% increase under BAU and a 3.01% annual decline under NDC.

4.2) Carbon tax effects

According to Table 6, under the BAU pathway, implementing a carbon tax of 200 Baht per ton over the period 2025 to 2050 generates heterogeneous effects across tax base scenarios, including all fuels (SIM1) and liquid fuels (SIM2). A broader tax base leads to more pronounced economic impacts. Real GDP declines modestly by 0.10% in SIM1 and 0.05% in SIM2, while household consumption and welfare decrease across all income groups, with relatively larger percentage reductions observed among higher-income households. However, despite experiencing smaller proportional declines, low-income households are likely to be more vulnerable to the adverse effects of the carbon tax due to their more limited capacity to absorb income shocks, suggesting potentially regressive welfare implications. Meanwhile, investment, measured by real gross fixed capital formation, increases substantially, indicating a reallocation of expenditure toward capital accumulation. Emissions are reduced more significantly under the broader tax base, with SIM1 achieving a 4.39% decline, primarily driven by reductions in the power generation sector.

On the other hand, under the NDC pathway, the results reported in Table 7 are generally more moderate. Real GDP increases marginally across all scenarios, while household consumption and welfare exhibit smaller declines. Emission reductions are also less pronounced, with emissions declining by 3.55% in SIM1 and 2.08% in SIM2, with the power generation sector again contributing the largest share of the reduction.

In summary, both pathways indicate that a broader carbon tax base leads to stronger environmental outcomes but entails greater economic trade-offs. The BAU pathway exhibits more pronounced economic and environmental effects, whereas the NDC scenario reflects the role of behavioral adjustments and existing policy efforts in mitigating these impacts. Regardless of the pathway, strengthening Thailand's climate policy framework remains essential for achieving its emission reduction targets.

Table 6. Macroeconomic and Emissions Impacts of Carbon Tax Relative under the BAU path.

		Simulation 1 *200-baht/tCO2* All fuel base	*Simulation 2* *200-baht/tCO2* Liquid fuel base
Variable	Variable name	Variation rate (%)	
Macroeconomic variables			
Gross domestic product	GDP	-0.10	-0.05
Carbon tax revenue to GDP	REV	0.38	0.21
Household expenditure	PCE	-1.52	-0.89
HH1 welfare	HH1	-3.04	-1.77
HH2 welfare	HH2	-3.33	-1.94
HH3 welfare	HH3	-3.65	-2.12
HH4 welfare	HH4	-3.94	-2.30
HH5 welfare	HH5	-3.96	-2.31
Gross fixed capital formation	GFCF	4.60	2.75
Government expenditure	GCE	0.39	0.24
Export	EX	0.36	0.23
Import	IM	0.29	0.18
Emission Variables			
Total emission	TEMISS	-4.53	-2.65
Emission from energy used	TSMCO	-5.36	-3.14
Power Generation	$SMCO_{POW}$	-6.94	-4.09
Transportation	$SMCO_{TRA}$	-5.21	-3.05
Industry	$SMCO_{IND}$	-3.26	-1.89
Others	$SMCO_{OTH}$	-6.66	-3.94

Table 7. Macroeconomic and Emissions Impacts of Carbon Tax Relative under the NDC path.

		Simulation 1: *200-baht/tCO2* All fuel base	*Simulation 2:* *200-baht/tCO2* Liquid fuel base
Variable	Variable name	Variation rate (%)	
Macroeconomic variables			
Gross domestic product	GDP	-0.04	-0.02
Carbon tax revenue to GDP	REV	0.17	0.10
Household expenditure	PCE	-0.98	-0.57
HH1 welfare	HH1	-1.94	-1.12
HH2 welfare	HH2	-2.06	-1.19
HH3 welfare	HH3	-2.13	-1.23
HH4 welfare	HH4	-2.24	-1.30
HH5 welfare	HH5	-2.30	-1.34
Gross fixed capital formation	GFCF	3.38	2.02
Government expenditure	GCE	0.15	0.09
Export	EX	0.09	0.07
Import	IM	0.12	0.08
Emission Variables			
Total emission	TEMISS	-3.55	-2.08
Emission from energy used	TSMCO	-5.63	-3.31
Power Generation	$SMCO_{POW}$	-7.08	-4.18
Transportation	$SMCO_{TRA}$	-5.80	-3.41
Industry	$SMCO_{IND}$	-3.36	-1.96
Others	$SMCO_{OTH}$	-6.57	-3.89

4.3) Revenue-recycling results

As shown in Section 4.2, both emission pathways result in declines in GDP, household consumption, and welfare, suggesting the presence of economic costs. However, carbon tax revenues provide an opportunity to improve public welfare and enhance system efficiency. The magnitude of these revenues is non-negligible, with tax revenue from all fuels accounting for 0.38 percent of GDP under the BAU pathway and 0.21 percent under the NDC pathway, while revenue from liquid fuels accounts for 0.17 percent and 0.10 percent of GDP, respectively, as reported in Tables 6 and 7. Section 4.3 therefore examines revenue recycling strategies with a focus on equity and efficiency, drawing on revenues from both all fuel and liquid fuel tax bases, which are consistent with Thailand's current tax structure and its potential future expansion.

(1) Equity considerations

To address the distributional effects of carbon taxation, this study evaluates two direct transfer schemes: regressive transfers, defined as transfers allocated in proportion to household consumption, and progressive transfers targeted at low-income households. The objective is to mitigate welfare losses and protect vulnerable groups that are disproportionately affected by rising costs.

Under the all fuel tax base, results reported in Table 8 for the BAU pathway and Table 9 for the NDC pathway indicate that the BAU scenario exhibits stronger impacts on both macroeconomic outcomes and household welfare, while the NDC pathway achieves relatively greater emission reductions. Both transfer schemes lead to slight declines in GDP and investment but contribute to improvements in household consumption. Notably, progressive transfers (SIM 4) effectively offset the regressive welfare effects of the carbon tax for the lowest-income group (HH1), shifting welfare from a loss of approximately -3.04% to a gain of around 1.64% under BAU pathway and 0.38% under NDC pathway. In contrast, regressive transfers (SIM3) tend to favor low-income groups (HH2 and HH3), as they experience relatively smaller welfare losses compared to the progressive transfer scheme, although welfare remains negative overall. However, this approach provides more limited support to the lowest-income group (HH1). Both schemes also generate modest additional emission reductions, suggesting the presence of co-benefits beyond equity considerations.

Under the liquid fuel tax base, results reported in Table 10 for the BAU pathway and Table 11 for the NDC pathway exhibit patterns similar to those observed under the all fuel tax base, but with more moderate impacts on macroeconomic outcomes, household welfare, and emissions. As before, the BAU pathway shows stronger overall effects than the NDC pathway. From an equity perspective, progressive transfers (SIM 4) remain more effective in offsetting regressive welfare effects, particularly for the lowest-income group (HH1), where welfare shifts from a loss of approximately 1.77% to a modest gain of around 0.91% under BAU pathway and 0.02% under NDC pathway, although the magnitude of improvement is smaller than under the all fuel tax base.

In contrast, regressive transfers (SIM 3) provide less equitable outcomes, although they yield slightly better welfare results for middle-income groups (HH2 and HH3).

Overall, progressive transfers prove more effective in promoting equity without undermining environmental outcomes. Given their stronger support for the poorest households and consistency with equity objectives, the progressive approach is selected as the baseline for subsequent efficiency-focused analysis. Building on this benchmark, the next section evaluates alternative revenue recycling mechanisms, including income tax reductions and increased government spending, to examine their implications for economic efficiency and overall welfare.

(2) Efficiency considerations

This section compares three revenue recycling options, namely direct transfers, income tax cuts, and increased government spending, to assess which approach best supports economic performance while achieving emission reductions.

Under the all fuel tax base, results reported in Table 8 for the BAU pathway and Table 9 for the NDC pathway indicate that all policy scenarios achieve emission reductions, although their economic impacts differ. Direct transfers (SIM4) primarily benefit low income households, while income tax cuts (SIM5) tend to favor higher income groups; both schemes result in GDP declines of approximately 0.18% under the BAU pathway and 0.10% under the NDC pathway. From an economic efficiency perspective, increased government spending (SIM6) yields the smallest decline in GDP, at around 0.12% under BAU and 0.07% under NDC, while maintaining relatively stable household consumption and slightly improving overall welfare. Although investment decreases modestly, the substantial increase in public spending supports stronger macroeconomic performance under this approach.

Under the liquid fuel tax base, results reported in Table 10 for the BAU pathway and Table 11 for the NDC pathway exhibit patterns similar to those observed under the all fuel tax base, but with more moderate impacts on macroeconomic outcomes, household welfare, and emissions. Direct transfers (SIM8) primarily benefit low-income households, while income tax cuts (SIM9) tend to favor high income groups; both schemes result in GDP declines of approximately 0.13% under BAU and around 0.05% under NDC. From an economic efficiency perspective, increased government spending (SIM10) again yields the smallest decline in GDP, at around 0.07% under BAU and 0.03% under NDC, while maintaining relatively stable household consumption and slightly improving overall welfare.

Across both pathways, increased government spending emerges as the most efficient revenue recycling strategy. It minimizes GDP losses, avoids placing a direct burden on households, and supports broader economic stability. In comparison, direct transfers and income tax cuts provide more targeted distributional benefits but are less efficient overall. This suggests that public spending recycling offers a more effective balance between economic efficiency and welfare outcomes.

Table 8. Revenue Recycling Strategies under the BAU Pathway: All Fuel Tax Base

Variable		*Simulation 1: no RR*	*Simulation 3: RR in* regressive transfer	*Simulation 4: RR in* progressive transfer	*Simulation 5: RR in* income tax reduction	*Simulation 6: RR in* increased government spending
		Var (%)				
Macroeconomic variables						
Gross domestic product	GDP	-0.10	-0.17	-0.18	-0.18	-0.12
Household expenditure	PCE	-1.52	-1.32	-1.30	-1.38	-1.52
HH1 welfare	HH1	-3.04	-0.66	1.63	-3.16	-3.04
HH2 welfare	HH2	-3.33	-1.74	-1.76	-3.44	-3.31
HH3 welfare	HH3	-3.65	-2.27	-3.00	-3.76	-3.62
HH4 welfare	HH4	-3.94	-4.05	-4.06	-4.05	-3.91
HH5 welfare	HH5	-3.96	-4.05	-4.06	-3.00	-3.91
Gross fixed capital formation	GFCF	4.60	4.15	4.10	4.16	4.12
Government expenditure	GCE	0.39	0.32	0.31	0.33	1.73
Export	EX	0.36	0.25	0.24	0.26	0.23
Import	IM	0.29	0.23	0.22	0.20	0.21
Emission Variables						
Total emission	TEMISS	-4.53	-4.55	-4.55	-4.57	-4.55
Emission from energy used	TSMCO	-5.36	-5.43	-5.43	-5.43	-5.41
Power Generation	$SMCO_{POW}$	-6.94	-6.96	-6.96	-6.99	-6.89
Transportation	$SMCO_{TRA}$	-5.21	-5.28	-5.29	-5.25	-5.30
Industry	$SMCO_{IND}$	-3.26	-3.40	-3.41	-3.39	-3.41
Others	$SMCO_{OTH}$	-6.66	-6.61	-6.60	-6.68	-6.53

Table 9. Revenue Recycling Strategies under the NDC Pathway: All Fuel Tax Base.

Variable		*Simulation 1: no RR*	*Simulation 3: RR in* regressive transfer	*Simulation 4: RR in* progressive transfer	*Simulation 5: RR in* income tax reduction	*Simulation 6: RR in* increased government spending
		Var (%)				
Macroeconomic variables						
Gross domestic product	GDP	-0.04	-0.09	-0.10	-0.10	-0.07
Household expenditure	PCE	-0.98	-0.90	-0.89	-0.93	-0.99
HH1 welfare	HH1	-1.94	-0.80	0.38	-2.02	-1.96
HH2 welfare	HH2	-2.06	-1.29	-1.30	-2.13	-2.07
HH3 welfare	HH3	-2.13	-1.46	-1.83	-2.20	-2.13
HH4 welfare	HH4	-2.24	-2.30	-2.31	-2.31	-2.24
HH5 welfare	HH5	-2.30	-2.36	-2.37	-1.85	-2.30
Gross fixed capital formation	GFCF	3.38	3.14	3.11	3.14	3.13
Government expenditure	GCE	0.15	0.11	0.10	0.11	0.79
Export	EX	0.09	0.02	0.02	0.03	0.01
Import	IM	0.12	0.09	0.08	0.07	0.08
Emission Variables						
Total emission	TEMISS	-3.55	-3.58	-3.58	-3.59	-3.59
Emission from energy used	TSMCO	-5.63	-5.67	-5.67	-5.67	-5.67
Power Generation	$SMCO_{POW}$	-7.08	-7.10	-7.10	-7.11	-7.07
Transportation	$SMCO_{TRA}$	-5.80	-5.84	-5.85	-5.83	-5.85
Industry	$SMCO_{IND}$	-3.36	-3.45	-3.46	-3.45	-3.46
Others	$SMCO_{OTH}$	-6.57	-6.55	-6.54	-6.58	-6.52

Table 10. Revenue Recycling Strategies under the BAU Pathway: Liquid Fuel Tax Base.

Variable		*Simulation 2: no RR*	*Simulation 7: RR in* regressive transfer	*Simulation 8: RR in* progressive transfer	*Simulation 9: RR in* income tax reduction	*Simulation 10: RR in* increased government spending
		Var (%)				
Macroeconomic variables						
Gross domestic product	GDP	-0.05	-0.09	-0.13	-0.13	-0.07
Household expenditure	PCE	-0.89	-0.77	-0.67	-0.75	-0.89
HH1 welfare	HH1	-1.77	-0.41	2.90	-1.88	-1.76
HH2 welfare	HH2	-1.94	-1.03	-0.36	-2.05	-1.92
HH3 welfare	HH3	-2.12	-1.34	-1.48	-2.24	-2.10
HH4 welfare	HH4	-2.30	-2.36	-2.41	-2.41	-2.27
HH5 welfare	HH5	-2.31	-2.36	-2.41	-1.35	-2.26
Gross fixed capital formation	GFCF	2.75	2.49	2.25	2.31	2.28
Government expenditure	GCE	0.24	0.20	0.16	0.18	1.58
Export	EX	0.23	0.17	0.11	0.12	0.10
Import	IM	0.18	0.14	0.11	0.09	0.10
Emission Variables						
Total emission	TEMISS	-2.65	-2.67	-2.68	-2.70	-2.68
Emission from energy used	TSMCO	-3.14	-3.18	-3.22	-3.22	-3.20
Power Generation	$SMCO_{POW}$	-4.09	-4.10	-4.11	-4.14	-4.05
Transportation	$SMCO_{TRA}$	-3.05	-3.09	-3.13	-3.09	-3.14
Industry	$SMCO_{IND}$	-1.89	-1.97	-2.05	-2.03	-2.05
Others	$SMCO_{OTH}$	-3.94	-3.92	-3.88	-3.96	-3.81

Table 11. Revenue Recycling Strategies under the NDC Pathway: Liquid Fuel Tax Base.

Variable		*Simulation 2: no RR*	*Simulation 7: RR in* regressive transfer	*Simulation 8: RR in* progressive transfer	*Simulation 9: RR in* income tax reduction	*Simulation 10: RR in* increased government spending
		Var (%)				
Macroeconomic variables						
Gross domestic product	GDP	-0.02	-0.05	-0.05	-0.05	-0.03
Household expenditure	PCE	-0.57	-0.52	-0.51	-0.54	-0.57
HH1 welfare	HH1	-1.12	-0.47	0.02	-1.17	-1.13
HH2 welfare	HH2	-1.19	-0.75	-0.76	-1.23	-1.20
HH3 welfare	HH3	-1.23	-0.85	-1.06	-1.27	-1.23
HH4 welfare	HH4	-1.30	-1.33	-1.34	-1.34	-1.30
HH5 welfare	HH5	-1.34	-1.37	-1.38	-1.08	-1.33
Gross fixed capital formation	GFCF	2.02	1.89	1.87	1.89	1.88
Government expenditure	GCE	0.09	0.07	0.07	0.07	0.46
Export	EX	0.07	0.03	0.03	0.03	0.02
Import	IM	0.08	0.06	0.06	0.05	0.06
Emission Variables						
Total emission	TEMISS	-2.08	-2.10	-2.10	-2.11	-2.10
Emission from energy used	TSMCO	-3.31	-3.34	-3.34	-3.34	-3.34
Power Generation	$SMCO_{POW}$	-4.18	-4.19	-4.19	-4.20	-4.18
Transportation	$SMCO_{TRA}$	-3.41	-3.43	-3.44	-3.43	-3.44
Industry	$SMCO_{IND}$	-1.96	-2.01	-2.01	-2.01	-2.01
Others	$SMCO_{OTH}$	-3.89	-3.88	-3.88	-3.90	-3.86

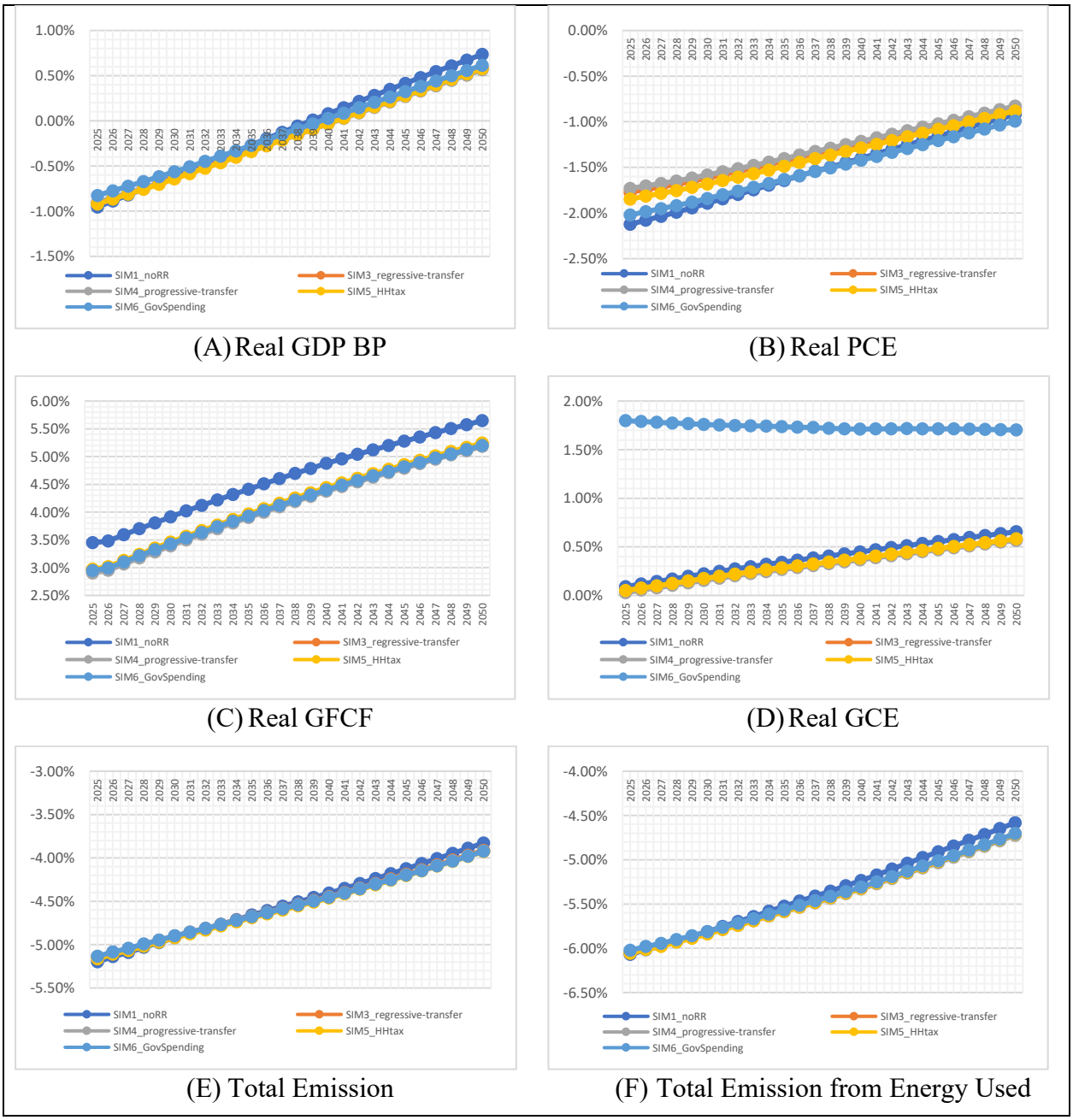

Figure 4. Impacts of revenue recycling under the BAU Pathway: All Fuel Tax Base.

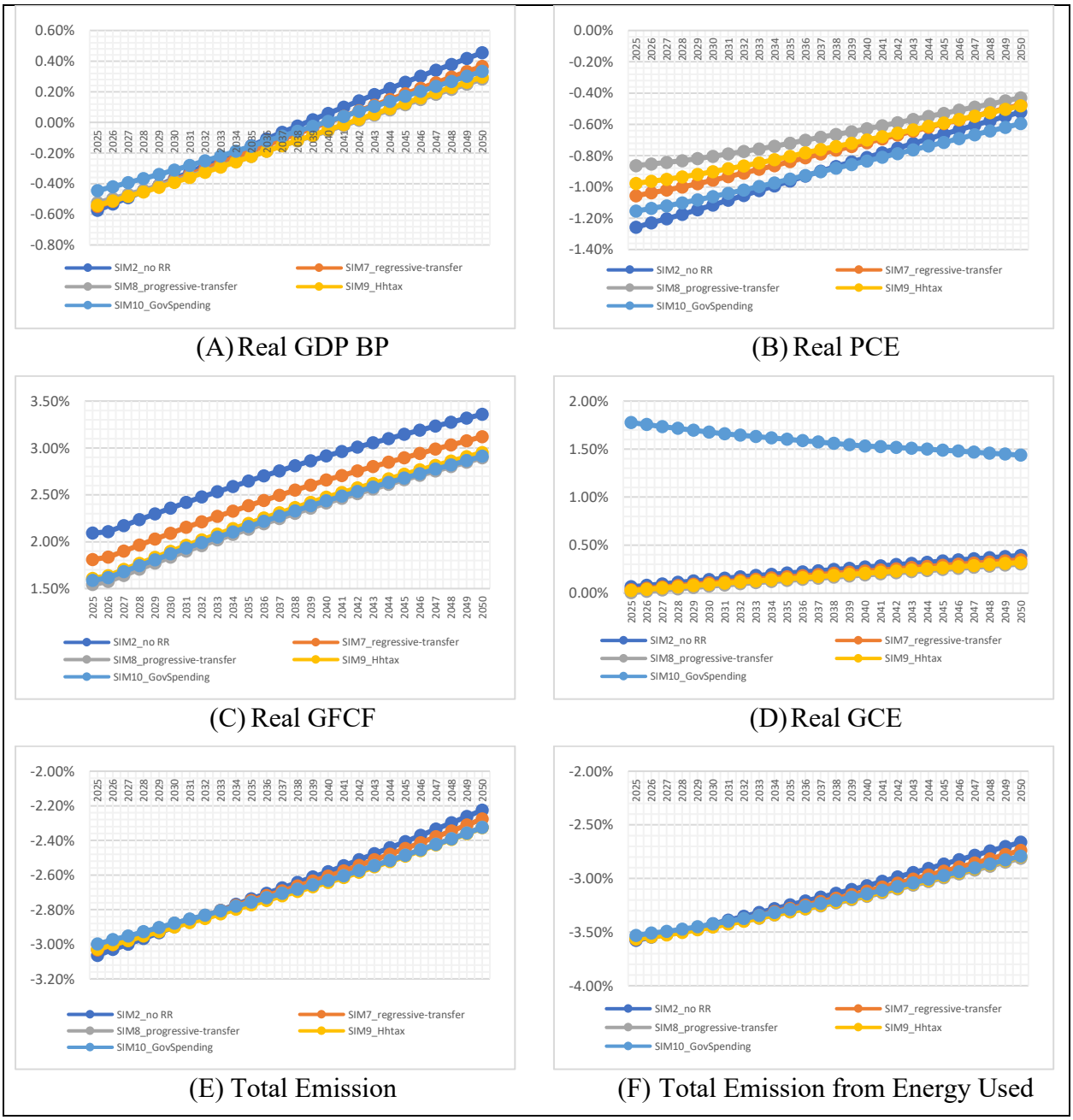

Figure 5. Impacts of revenue recycling under the BAU Pathway: Liquid Fuel Tax Base.

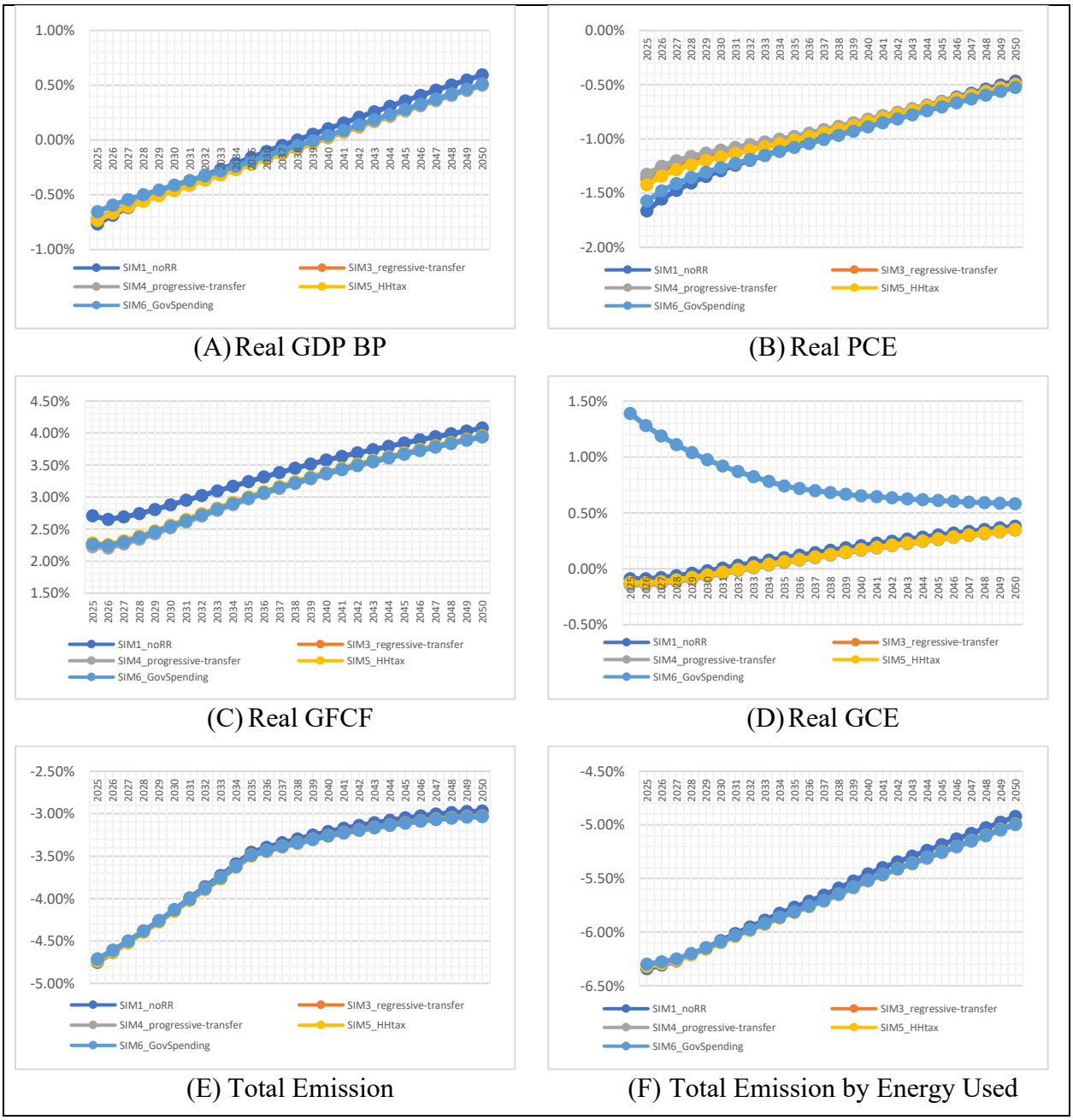

Figure 6. Impacts of revenue recycling under the NDC Pathway: All Fuel Tax Base.

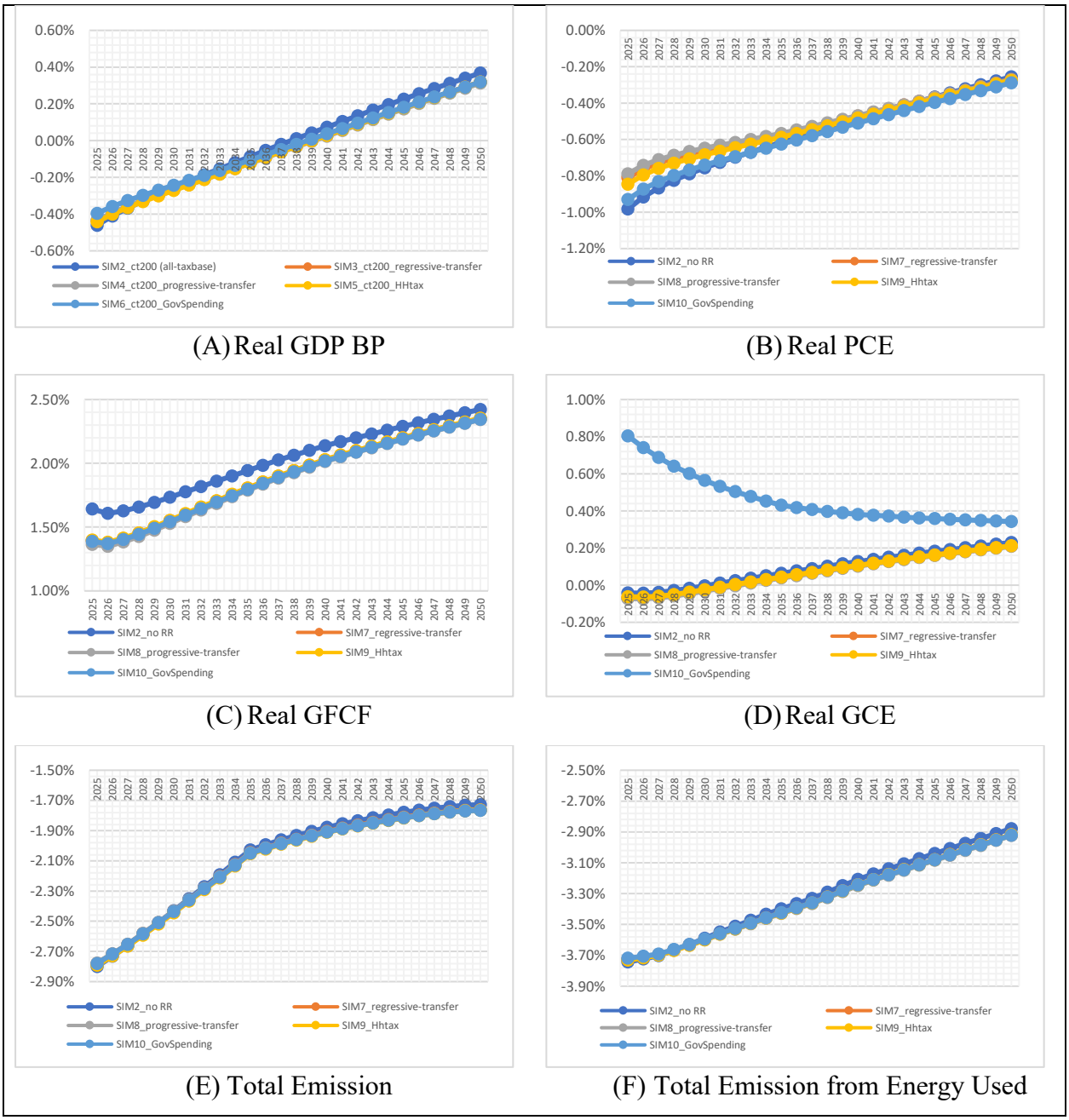

Figure 7. Impacts of revenue recycling under the NDC Pathway: Liquid Fuel Tax Base.

5. Discussion and conclusions

5.1) Discussions

The impact of carbon tax on economic circulation begins with its imposition on products based on the carbon emissions embedded in intermediate inputs used in production. This scenario leads to high production costs and subsequent price increases that affect output levels over time. These rising costs ripple through the economy, influencing export volumes, domestic production, and imports, ultimately shaping the overall supply of composite goods. Simultaneously, the carbon tax generates substantial government revenue, strengthening fiscal resources available for redistribution or investment. As revenue increases, government and national savings improve, supporting increasing investment through gross fixed capital formation. The latter contributes to capital stock expansion and high output in the long term. This outcome contrasts with some previous studies that suggest contractionary effects from carbon taxation. However, the resulting increase in output prices may reduce private consumption, signaling a potential long-term adverse impact on household expenditure.

According to Appendix 1, building on the economic effects of carbon taxation, this section compares key findings with studies from other developing countries, focusing on tax design, revenue, GDP impacts, and household consumption. Carbon tax designs in other developing countries commonly use a rate per ton of CO_2, with wide variation—from \$1–\$10 in Vietnam and Indonesia to \$700 in Mexico by 2050 (Nurdianto & Resosudarmo, 2016; Landa Rivera et al., 2016; Nguyen, 2023). Most taxes target emissions from fossil fuel use. The share of tax revenue relative to GDP also varies, ranging from 0.42 percent in Singapore to 6 percent in Mexico, depending on the tax structure and economic conditions. GDP impacts are typically negative, especially in carbon-intensive economies. Thailand's results align with this trend, showing a regressive effect on growth. Household consumption also tends to decline. This study finds a regressive effect in Thailand, similar to Vietnam, Singapore, and the Philippines. By contrast, countries such as India and Myanmar report progressive outcomes likely due to different energy use patterns (Alonso & Kilpatrick, 2022).

Complementing these findings, a joint report by the IMF and World Bank (2020), Implications of the Global Economic Crisis for Carbon Pricing, highlights broader insights from international carbon tax experiences. The report emphasizes that the effectiveness of carbon taxation depends heavily on tax design, the structure of the economy, and the degree of reliance on fossil fuels. Higher carbon tax rates are generally associated with substantial emission reductions and increased government revenue, albeit, with strong economic trade-offs. In line with this finding, the re-estimated \$75 per ton tax examined in this study is projected to reduce emissions by 22.59 percent while generating revenue equivalent to 2.69 percent of GDP. These findings support the notion that well-designed carbon taxes can yield environmental and fiscal benefits.

Given these substantial revenues, a key policy consideration pertains to how they can be effectively allocated, particularly through revenue recycling. For the latter, its primary purpose is to guide policymakers in using carbon tax proceeds to promote equity and economic efficiency. From an equity standpoint, regressive transfers tend to result in milder welfare impacts across income groups and support better overall macroeconomic outcomes than progressive transfers. However, progressive transfers are effective in offsetting the regressive burden of carbon taxation on the lowest-income households and play a compelling role in reducing income inequality. This finding aligned with that of Zhao et al. (2022). This scenario especially adds to their suitability when equity is a primary policy objective.

In terms of efficiency, progressive transfers align with Turner et al. (2022) and Combet et al. (2025) who emphasize the effectiveness of such allocations in protecting low-income households. However, they tend to deliver weak GDP performance over time. Income tax reductions show mixed results. Under the BAU pathway, they mirror the negative macroeconomic effects of direct transfers. Under the NDC pathway, however, they become GDP-neutral, reflecting improved efficiency when accompanied by structural and behavioral adjustments such as fuel switching. Government spending performs well across both pathways. Under BAU, it leads to milder economic impacts; under NDC, it yields neutral-to-positive GDP effects, avoids placing burdens on specific groups, and causes only modest investment declines. Although less studied, this approach proves promising in balancing economic and social goals.

Overall, the literature suggests the absence of a one-size-fits-all solution. Hybrid approaches, such as combining tax cuts with targeted transfers, may offer a better balance between equity and efficiency. These findings underscore the need for integrated climate-fiscal strategies that adapt to different economic pathways and support long-term sustainability.

6. Conclusions

This study assesses the economic and environmental impacts of carbon taxation in Thailand using a Computable General Equilibrium (CGE) model. It examines three tax base scenarios, covering all fuels, liquid fuels, and gasoline across two emission pathways: the Business-as-Usual (BAU) and the Nationally Determined Contribution (NDC), which target a 40% emission reduction by 2030. The model also evaluates three revenue-recycling options: direct transfers, income tax cuts, and increased government spending.

A broader tax base not only captures additional emissions and generates higher revenues but also yields strong macroeconomic impacts. The liquid fuel base, reflecting Thailand's current structure, is used as the reference case. Under BAU, GDP and household consumption decline, whereas investment rises. Conversely, the NDC pathway yields milder economic effects, supported by behavioral shifts such as fuel switching. Emission reductions are slightly lower under NDC but remain significant.

The effectiveness of recycling revenue depends on policy priorities. Proportional transfers ease welfare losses across all income groups and support better macroeconomic outcomes. Progressive transfers are effective in reducing inequality and protecting low-income households, but come at a high economic cost. Income tax cuts perform poorly under BAU but become GDP-neutral under NDC. Government spending proves to be the most balanced option, especially under NDC, where it delivers neutral-to-positive GDP effects, directly avoids burdening households, and maintains stable investment.

These findings lead to several policy implications. First, carbon taxation can stimulate green investment and government incentives, such as subsidies for renewable energy, which can enhance this effect. Second, revenue recycling through targeted public spending may offer the most balanced strategy, especially if focused on energy efficiency or low-carbon infrastructure. Third, hybrid strategies that combine tax reductions with targeted transfers could effectively balance equity and efficiency goals, offering flexibility under uncertain economic conditions.

However, this study has limitations. The Social Accounting Matrix used is based on older data and would benefit from updates to reflect current economic conditions. Additionally, the model does not explicitly include technological innovation, which could significantly shape long-term outcomes. Future research should incorporate these factors to provide a comprehensive assessment of the role of carbon taxation in Thailand's low-carbon transition.

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Appendix

Appendix 1. The relation to existing literature.

Author (Year)	Country	Tax rate	Tax base	Tax revenue (proportion to GDP)	Effect on GDP	Effect on household consumption
This paper finding	Thailand	200 baht per ton	Energy used	0.21% (BAUpath), 0.11% (NDCpath)	-0.05% (BAU), 0.03% (NDC)	-0.89% (BAU), 0.80% (NDC)
Puttanapong et al. (2015)	Thailand	227.75, 445.49, 683.23 baht per ton	Energy used		-0.56%, -1.02%, -1.47%	-0.47%, -1.02%, -1.58%
Mengistu et al. (2019)	Ethiopia	Increase from $5 per ton in 2018 to $30 per ton in 2030	Energy used		-0.38%	Urban (-0.16%), rural (-0.013%)
Jia et al. (2023)	China	Increase from 31.1 to 133.7 CNY/tCO_2	Energy type		-1.6%, -1.610%, -1.616%, -0.729%	urban (-4.71%), rural (-4.87%),
Alonso and Kilpatrick (2022)	China	$50 per ton	Energy used	1.70%		-3.4%
	Indonesia			1.70%		-7%
	Mongolia			4.50%		-10%
	India			2.50%		3.4%
	Kiribati			0.70%		2.7%
	Myanmar			1%		1.2%
	Philiphines			0.90%		2.1%
Octaviano et al. (2016)	Brazil	$10/$tCO_2$, $50/$tCO_2$	Fossil fuel combustion and industrial sources		Loss 0-4%	
	Mexico				Loss 1-11%	
Landa Rivera et al. (2016)	Mexico	US$100(in 2030), US$700 (in 2050)		5-6% in 2050	Decline more than 4% after 2040	-10% by 2050
Calderón et al. (2016)	Columbia	$50/$tCO_2$ (growth at 4%/year)	Fossil fuel combustion		Loss 2.3-3.4% by 2050	Loss 2.2-4.7% by 2050
Alton et al. (2014)	South Africa	$3/$tCO_2$ in 2012	Fossil fuel combustion		-1.2% by 2025	-0.63% by 2025
Nong (2018)	Vietnam	33.33%, 50% increase in tax rate	Fossil fuel used	3.91% (Petroleum), 1.98% (Coal)	-1.99% (Petroleum), -0.51% (Coal)	-0.5% (Petroleum), -0.51% (Coal)

Appendix 1. The relation to existing literature. (Cont.)

Author (Year)	Country	Tax rate	Tax base	Tax revenue (proportion to GDP)	Effect on GDP	Effect on household consumption
Nguyen (2023)	Vietnam	$1, $5, and $10 per ton of tCO_2	Fossil fuel used		Loss 0.247%-2.306%	Loss 0.51%-4.772%
Nurdianto and Resosudarmo (2016)	Vietnam	$10/$tCO_2$	Energy used	0.69%	-5.77%	-1.58%
	Thailand			0.68%	-2.33%	-0.75%
	Singapore			0.42%	-0.95%	-0.22%
	Philippines			0.64%	-2.99%	-0.63%
	Malaysia			0.82%	-4.06%	-1.12%
	Indonesia			0.75%	-3.76%	-1.11%

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