

DESIGNING VIET NAM'S CARBON MARKET FOR THE ENERGY SECTOR: INTERACTIONS AMONG THE CARBON PRICE, FREE ALLOCATION, AND NET ETS VALUE PASS-THROUGH INTO ELECTRICITY PRICES

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Abstract: The design of an emissions trading system (ETS) for the energy sector depends jointly on the carbon price, the free allocation rate, and the extent to which the electricity sector's net ETS value is reflected through the electricity-price channel. This study extends the static PEP-1-1 computable general equilibrium (CGE) model, calibrated to a 37-account Social Accounting Matrix (SAM) constructed for Viet Nam for 2019, by incorporating sectoral emissions accounting, free allocation, and an ETS accounting balance for a regulated electricity sector. A grid of 126 scenarios combines seven carbon prices (50,000-2,500,000 VND/tCO₂), three free-allocation rates (100%, 90%, and 80%), and six pass-through coefficients (0.1-1.0), with each scenario solved independently around the 2019 base equilibrium. Across the grid, real GDP falls by 0.0048%-5.3104%, the consumer price index (CPI) rises by 0.0058%-6.4877%, household consumption falls by 0.0077%-8.6294%, aggregate output falls by 0.4154%-10.6984%, and modelled emissions fall by 0.6793%-16.9257% relative to the baseline. The sensitivity results indicate a diminishing incremental emission response as the carbon price rises. In the specified local slices, reducing α from 100% to 80% produces larger changes in aggregate outcomes than varying ϑ from 0.1 to 1.0; because the parameters have different units and ranges, this comparison is not an absolute ranking of parameter importance. FIN_GAP_ELEC , which represents the share of the electricity sector's net ETS value not reflected through the price channel, is zero when pass-through is complete ($\vartheta = 1$) and ranges from -VND 48,447 billion to +VND 4,552 billion on the model's accounting scale. It is not an observed corporate cash flow or government fiscal flow. The analysis is confined to the comparative-static grid; the three-period quasi-dynamic extension is excluded because it lacks a period-specific non-ETS baseline. The study does not identify an optimal policy configuration or make legal recommendations; the findings are conditional on the model's data, structure, closure, and assumptions.

Keywords: Carbon market, emissions trading system, free allocation, net ETS value, electricity-price pass-through, computable general equilibrium model.

1. Introduction

Viet Nam has moved from establishing the legal basis for a domestic carbon market toward pilot implementation. The Law on Environmental Protection 2020 [1] and Decree No. 06/2022/ND-CP [2], as amended and supplemented by Decree No. 119/2025/ND-CP [3] and Decree No. 83/2026/ND-CP [4],

provide the core framework for greenhouse-gas mitigation, allowance allocation, carbon-credit use, and ETS compliance. Decision No. 232/QD-TTg sets out the roadmap for establishing and developing the domestic carbon market [5], while Decree No. 29/2026/ND-CP provides for the domestic carbon exchange [6]. Decree No. 112/2026/ND-CP establishes the framework for the international exchange of greenhouse-gas mitigation outcomes and carbon credits [7]. Decision No. 42/2026/QD-TTg, issued on

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10 August 2026 and scheduled to take effect on 25 September 2026, updates the list of sectors and greenhouse-gas-emitting facilities required to conduct greenhouse-gas inventories [8]. This evolving framework makes it important to assess how alternative ETS design configurations affect emissions, output, prices, household consumption, and the allocation of net ETS value across model accounts.

In the early phase of market formation, electricity generation holds a pivotal position because it is a major emissions source and electricity is an essential input to nearly all sectors. ETS-related values arising in electricity generation can propagate through electricity prices, production costs, consumer prices, and household consumption via inter-industry linkages [9]. Viet Nam's electricity sector, however, remains subject to substantial state price regulation. When electricity prices do not fully reflect the sector's net ETS value, the untransmitted share remains outside the price channel and is recorded elsewhere under the model's accounting closure [10]. This feature motivates the explicit treatment of partial pass-through.

Three design parameters are therefore central to the analysis: the carbon price (P_C), the free-allocation rate (α), and the pass-through coefficient (θ). They perform distinct functions in the model. P_C sets the monetary scale of the ETS signal; α changes the net ETS value after free allocation; and θ determines the share of the electricity sector's net ETS value reflected through the price channel. The parameter α is stylised and does not directly equal the share of allowances that every facility must purchase, while θ is not an estimate of the actual increase in retail electricity prices.

Existing CGE studies of carbon pricing in Viet Nam generally allow prices to adjust to input costs and do not explicitly represent partial pass-through in a regulated electricity sector [9], [11]. Much of the literature focuses on the carbon price while simplifying or holding constant free allocation and pass-through. As a result, the relative roles of these three parameters, and their implications for both

macroeconomic outcomes and the electricity sector's untransmitted net ETS value, remain insufficiently explored. An earlier study by the authors examined 13 scenarios combining carbon price and pass-through but did not treat free allocation as an independent policy axis [12]. The present study extends that analysis to a full 126-scenario grid.

The paper's contribution is to model the three parameters jointly within one CGE framework and to link changes in modelled emissions and macroeconomic outcomes with the allocation of the electricity sector's net ETS value between the price channel and `FIN_GAP_ELEC`. This shifts the analytical focus from a single carbon-price choice to the interaction among price, allocation, and pass-through. Under regulated electricity pricing, the same nominal carbon price can produce different outcomes depending on the free-allocation rate and the share of the electricity-sector balance that enters the price channel.

The objective of this study is to assess the separate and interacting effects of the carbon price, the free-allocation rate, and the electricity-price pass-through coefficient on modelled emissions, GDP, the CPI, household consumption, aggregate output, and the electricity sector's ETS accounting balance in Viet Nam. Three questions guide the analysis: (i) How do the three parameters separately and jointly affect emissions and macroeconomic outcomes; (ii) How do local responses differ across the one-at-a-time sensitivity slices for the carbon price, α , and θ ; and (iii) How does θ change the allocation of the electricity-sector balance between the price channel and `FIN_GAP_ELEC`? The remainder of the paper is organised as follows. Section 2 describes the data and the extended PEP-1-1 model. Section 3 presents the results and discussion. Section 4 concludes and states the study's limitations.

2. Data and methods

2.1. Model and data sources

The study uses the PEP-1-1 static, single-country CGE model as its quantitative core [13]. PEP-1-1 was selected because its transparent

and modular single-country static structure can be calibrated directly to the study's 2019 SAM and extended at equation level to represent ETS accounting and partial electricity-price pass-through. This structure is consistent with the comparative-static objective of the study, which is to isolate economy-wide responses to alternative ETS design parameters rather than to model intertemporal investment or detailed power-sector technologies. Producers minimise cost under nested constant elasticity of substitution (CES) production functions; households maximise a Stone-Geary utility function; domestic and imported goods are combined under the Armington assumption; and output is allocated between domestic sales and exports through a constant elasticity of transformation (CET) specification. The model is solved as a system of simultaneous non-linear equations. The principal dataset is Viet Nam's 2019 input-output table [14]. Structural ratios from an earlier SAM and supplementary household, labour, tax, trade, and institutional data are used for components not separately identified in the input-output table, as documented in the underlying dissertation [15]. The resulting 37-account SAM contains five production activities, six commodity groups, two labour types, capital and land, four household groups, firms, government, the rest of the world, tax accounts, export accounts, investment, and inventory change. Electricity is retained as a separate activity and commodity. The balanced SAM satisfies row-column equality with a maximum residual below 0.01% and contains no negative entries.

The nominal exchange rate serves as the model numeraire. The current-account balance and aggregate supplies of labour and capital are fixed in each static simulation, while wages, returns to capital, relative prices, trade volumes, and sectoral factor allocation adjust endogenously. Government saving absorbs changes in government income and the modelled ETS accounting flows, and aggregate investment is savings-driven. The results are therefore conditional on this macroeconomic closure, including the selected treatment of TCO2T and FIN_GAP_ELEC.

2.2. ETS accounting equations

The model is extended with sectoral emissions accounting, a free-allocation rule, and a net ETS accounting equation. For each sector j , modelled emissions E_j are linked to sectoral output through a stylised emission-intensity coefficient $emisJ_j$, expressed in tCO₂ per unit of the model's accounting output: $emisJ_ELEC = 1.0$ and $emisJ_IND = 0.5$, while the remaining sectors are assigned zero within the ETS-covered block. These coefficients are maintained modelling assumptions used to represent the electricity sector's comparatively higher exposure to the ETS signal; they are not measured sector-specific emission factors. With intensity fixed, modelled emissions change only through output and the sectoral output mix, not through fuel switching or technological change within a sector. Compliance is assumed to be complete, and the model does not represent MRV costs, transaction costs, enforcement, market liquidity, or speculative behaviour.

$$E_j = emisJ_j \times XST_j \quad (1)$$

Where XST_j is the volume of sectoral output. The quota allocated free of charge, $QUOTA_FREE_j$, is a fraction α of baseline emissions, evaluated at the base-year output level $XST0_j$:

$$QUOTA_FREE_j = \alpha \times emisJ_j \times XST0_j \quad (2)$$

The sectoral ETS compliance balance, ETS_BAL_j , values the gap between modelled emissions and free allocation at the carbon price P_c :

$$ETS_BAL_j = P_c \times (E_j - QUOTA_FREE_j) \quad (3)$$

A positive ETS_BAL_j means that modelled emissions exceed free allocation under the accounting convention; a negative value means that free allocation exceeds modelled emissions. For non-electricity sectors, this net value enters the sectoral production-value identity and affects the equilibrium through relative prices, intermediate demand, and final demand. The model does not separately

represent allowance trading among firms or the opportunity value of freely allocated allowances.

$$FIN_GAP_ELEC = (1 - \vartheta) \times ETS_BAL_elec \tag{4}$$

The parameter ϑ is an exogenous institutional scenario parameter specified by the modeller; it is not an econometric estimate of actual pass-through behaviour in Viet Nam, and the model does not estimate asymmetric responses to cost increases and decreases [16], [17]. Modelled emissions E_j are internal quantities used for comparisons on a common model scale and are not national greenhouse-gas inventory estimates. $TCO2T$ is the sum of sectoral net ETS values, while FIN_GAP_ELEC is the untransmitted share of the electricity-sector balance. Under the selected closure, these variables are offset through government income and saving; neither is equivalent to auction revenue, observed fiscal receipts, or corporate cash flow [15].

2.2.1. Interpretation of the pass-through and allocation parameters

In an actual ETS, freely allocated allowances may have opportunity value. The present model does not separately represent that opportunity cost, strategic allowance trading, or differences between grandfathering and output-based benchmarking. It records only the net ETS value after free allocation under the equations above. A negative ETS_BAL is therefore a model-accounting position and does not establish that marginal incentives to reduce emissions have disappeared. Similarly, θ is a scenario parameter describing the accounting treatment of the electricity-price channel, not an estimate of the sector’s behavioural response.

2.3. Scenario design

The simulation grid combines seven carbon prices, three free-allocation rates, and six pass-through coefficients, yielding $N = 7 \times 3 \times 6 = 126$ scenarios. Each scenario is solved independently as a comparative-static deviation from the 2019 base equilibrium. Table 1 summarises the scenario parameters.

Table 1. Simulation grid parameters

Parameter	N	Values
Carbon price (thousand VND/tCO ₂)	7	50; 100; 250; 500; 1,000; 2,000; 2,500
Free-allocation rate α	3	100%; 90%; 80%
Pass-through coefficient θ	6	0.1; 0.2; 0.3; 0.5; 0.7; 1.0

Source: Authors’ simulation results

Table 1 summarises the full factorial design of 126 independently solved equilibria. Outcomes are reported as percentage deviations from the baseline, $\Delta Y_s = [(Y_s - Y_{BAU}) / Y_{BAU}] \times 100$, for GDP, the CPI, household consumption, aggregate output, and modelled emissions, together with ETS_BAL , $TCO2T$, and FIN_GAP_ELEC . One-at-a-time sensitivity slices isolate local responses to each parameter while holding the other two fixed; descriptive interactions are examined by comparing cells across the full factorial grid. The paper is confined to the 126-scenario comparative-static analysis. The underlying dissertation also contains an illustrative three-period quasi-dynamic extension for 2025-2030,

but it is not reported here because the sequential runs lack a period-specific non-ETS baseline and therefore do not separate the ETS effect from the concurrent updating of factor endowments and productivity [15].

For practical context, Hanoi Stock Exchange trading records for the pilot allowance code VN2025 show observed prices of VND 130,000-136,000/tCO₂e in the initial market. This range lies between the VND 100,000 and VND 250,000 scenario points, which therefore bracket the initial observed price signal. The wider price grid is retained for sensitivity analysis and should not be interpreted as a forecast of market prices [18].

3. Results and discussion

3.1. Range of outcomes across the 126-scenario grid

Across all 126 scenarios, real GDP declines by 0.0048%-5.3104% relative to the baseline; the CPI rises by 0.0058%-6.4877%; household consumption declines by 0.0077%-8.6294%; aggregate output declines by 0.4154%-10.6984%; and modelled emissions decline by 0.6793%-16.9257%. The lower bound of each range occurs under the mildest configuration (50,000 VND/tCO₂, $\theta = 0.1$, $\alpha = 100\%$), while the upper bound occurs under the most stringent configuration (2,500,000 VND/tCO₂, $\theta = 1.0$, $\alpha = 80\%$). The ranges show that the three parameters jointly determine both environmental and macroeconomic responses. They do not, by themselves, support a universal ranking because the indicators move differently across configurations.

3.2. Sensitivity to the carbon price

Table 2 reports the sensitivity of GDP, the CPI, and modelled emissions to the carbon

price when the pass-through and free-allocation parameters are held at $\theta = 0.3$ and $\alpha = 100\%$.

As reported in Table 2, holding α and θ constant, Δ GDP and Δ CPI respond in a near-linear fashion to the carbon price over this range, while the emission-reduction response is concave. The incremental reduction between 50,000 and 100,000 VND/tCO₂ is 1.5546 percentage points per 100,000 VND, compared with 0.1613 percentage points per 100,000 VND between 2,000,000 and 2,500,000 VND/tCO₂. GDP changes by approximately 0.0133 percentage points per 100,000 VND over the same slice. This is an internal general-equilibrium response under fixed emission intensities: additional price increases produce smaller incremental emission reductions through changes in output and sectoral composition. Figure 1 further illustrates that the GDP response becomes larger as θ increases at each carbon-price level when $\alpha = 100\%$. It should not be interpreted as direct evidence of a technology-specific marginal abatement cost curve or as proof that low-cost technologies are sequentially exhausted.

Table 2. Sensitivity to the carbon price ($\theta = 0.3$; $\alpha = 100\%$)

Price (VND/tCO ₂)	Δ GDP (%)	Δ CPI (%)	Emission reduction (%)
50,000	-0.0067	+0.0081	0.7534
100,000	-0.0133	+0.0163	1.5307
250,000	-0.0333	+0.0407	3.6141
500,000	-0.0666	+0.0814	6.2323
1,000,000	-0.1332	+0.1627	9.4408
2,000,000	-0.2664	+0.3254	12.4468
2,500,000	-0.3329	+0.4068	13.2532

Source: Authors' simulation results

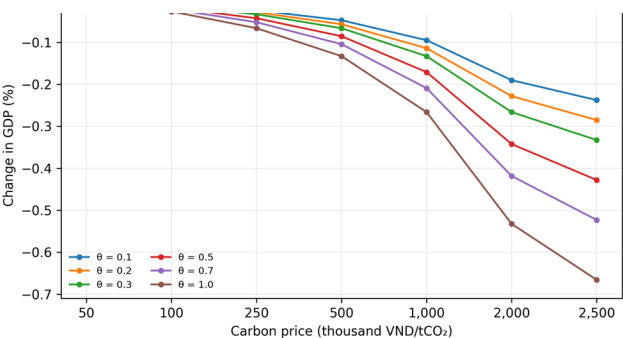


Figure 1. Change in GDP by carbon price and pass-through coefficient ($\alpha = 100\%$). Source: Authors' simulation results

3.3. The role of free allocation

At a carbon price of 250,000 VND/tCO₂ and $\theta = 0.5$, reducing α from 100% to 80% increases the modelled emission reduction from 3.9033% to 12.7722%, the GDP reduction from 0.0428% to 0.3414%, the CPI increase from 0.0523% to 0.4171%, and the household-consumption reduction from 0.0696% to 0.5547%. The intermediate $\alpha = 90\%$ case gives a 9.8609% emission reduction, a 0.1712% GDP reduction, a 0.2092% CPI increase, and a 0.2782% household-consumption reduction. The two

10-percentage-point steps are therefore not symmetric. These results are conditional on the model's stylised free-allocation rule, which does not separately represent the opportunity cost of freely allocated allowances; α is not a literal estimate of the share that each facility would purchase in an operating ETS [10], [19], [20].

3.4. The role of the pass-through coefficient

Table 3 reports sensitivity to the pass-through coefficient at a carbon price of 250,000 VND/tCO₂ and $\alpha = 100\%$.

Table 3. Sensitivity to the pass-through coefficient (carbon price = 250,000 VND/tCO₂; $\alpha = 100\%$)

θ	Δ GDP (%)	Δ CPI (%)	Emission reduction (%)
0.1	-0.0238	+0.0291	3.3148
0.2	-0.0285	+0.0349	3.4657
0.3	-0.0333	+0.0407	3.6141
0.5	-0.0428	+0.0523	3.9033
0.7	-0.0523	+0.0639	4.1827
1.0	-0.0666	+0.0814	4.5841

Source: Authors' simulation results

As Table 3 shows, increasing θ from 0.1 to 1.0 raises the GDP reduction from 0.0238% to 0.0666%, the CPI increase from 0.0291% to 0.0814%, and the modelled emission reduction from 3.3148% to 4.5841%. Over the specified parameter ranges, these changes are smaller than those obtained when α is reduced from 100% to 80% in Section 3.3. Figure 2 illustrates the joint movement of GDP and CPI across the 12 representative scenarios. This is a descriptive comparison of two different sensitivity slices, not an absolute ranking of parameter importance because α and θ have different units and ranges. The principal role of θ

in the model extension is to determine how much of the electricity sector's net ETS value enters the price channel. Because FIN_GAP_ELEC is also linked to government saving under the selected closure, θ affects the general equilibrium through both the price channel and the savings-investment channel; it is not solely a distributional parameter [10], [16], [21].

3.5. Household consumption

Household consumption falls in every scenario because lower factor income and a higher consumer price level jointly reduce real purchasing power.

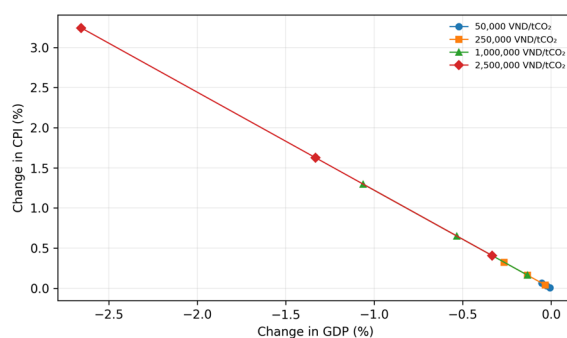


Figure 2. Relationship between changes in GDP and CPI in 12 representative scenarios ($\theta = 0.3$; $\alpha = 100\%$, 90%, and 80%)

At a carbon price of 250,000 VND/tCO₂ and $\theta = 0.3$, household consumption falls by 0.0541% when $\alpha = 100\%$ and by 0.4315% when $\alpha = 80\%$. The corresponding GDP reductions are 0.0333% and 0.2655%, while the CPI increases are 0.0407% and 0.3244%. In the representative scenarios, the percentage decline in household consumption is larger than the decline in GDP because income and price effects operate in the same direction. Although the SAM contains four household groups, this paper reports only aggregate household consumption. The results therefore do not support conclusions about distribution across income or location groups.

3.6. Electricity-sector ETS accounting balance

FIN_GAP_ELEC, defined as $(1 - \theta) \times \text{ETS_BAL_elec}$, is zero when $\theta = 1$ by construction because the full electricity-sector balance is then reflected through the price channel. Across all 126 scenarios, it ranges from -VND 48,447 billion at 2,500,000 VND/tCO₂, $\theta = 0.1$, and $\alpha = 100\%$ to +VND 4,552 billion at the same price and θ with $\alpha = 80\%$, on the model's accounting scale. The sign depends on whether the electricity sector's modelled emissions are above or below its free allocation, and the magnitude is further scaled by $(1 - \theta)$. Because the model does not separately represent auction revenue, secondary allowance trading, corporate cash reserves, or company financial statements, FIN_GAP_ELEC must be interpreted strictly as the untransmitted share of net ETS value under the model's closure, not as an observed or forecast financial loss, profit, or fiscal flow [15].

3.7. Synthesis

Taken together, the results support three propositions within the model's structure. First, the carbon price sets the monetary scale of the policy shock; along the selected price slice, GDP and CPI respond approximately proportionally, while the incremental emission response diminishes at higher prices. Second, α changes the scale and, in some cases, the sign of net ETS values after free allocation, whereas θ changes the share of the electricity-sector balance that enters the price channel. In the specified local slices, the 100%-80% change in α produces

larger changes in aggregate outcomes than the 0.1-1.0 change in θ , but this does not constitute an absolute sensitivity ranking because the parameter units and ranges differ. Third, θ also affects government saving and investment through the selected closure. The indicators move differently across scenarios, so the study does not identify a universally preferred configuration or rank the full grid.

These propositions extend the authors' earlier 13-scenario study, which combined carbon price and pass-through without treating free allocation as an independent axis [12]. The expanded grid shows that the allocation rule is an analytically important dimension of early-stage ETS design and cannot be inferred from the headline carbon price alone. It also shows that lowering θ does not remove the electricity-sector balance from the system; it changes how that balance is recorded between the price channel and FIN_GAP_ELEC. This is an analytical result within the model, not a recommendation to suppress pass-through or maintain a particular free-allocation schedule.

The emission-reduction results require a further qualification. Because emisJ_ELEC and emisJ_IND are fixed in all scenarios, the reported reductions arise from changes in sectoral output and the output mix under a constant technology structure. They do not represent endogenous fuel switching, investment in abatement technology, or changes in sector-specific emission intensity. The concave response to carbon price should therefore be read as a general-equilibrium output and composition effect within the model, not as direct evidence on a technological marginal abatement cost curve for Viet Nam's power sector.

4. Conclusions

This study extends the static PEP-1-1 CGE model, calibrated to a 37-account SAM constructed for Viet Nam for 2019, with sectoral emissions accounting, a free-allocation rule, and an electricity-sector net ETS accounting equation. It evaluates 126 scenarios spanning seven carbon prices, three free-allocation rates, and six pass-through coefficients. Across the grid,

GDP falls by 0.0048%-5.3104%, the CPI rises by 0.0058%-6.4877%, household consumption falls by 0.0077%-8.6294%, aggregate output falls by 0.4154%-10.6984%, and modelled emissions fall by 0.6793%-16.9257% relative to the 2019 baseline.

Within the model, the carbon price sets the monetary scale of the policy shock. The incremental reduction in modelled emissions diminishes as the price rises, while GDP and CPI respond approximately proportionally along the selected price slice. The α and θ sensitivity slices show different response magnitudes and different channels: α changes net ETS values after free allocation, whereas θ changes the share of the electricity-sector balance entering the price channel. The larger changes observed over the selected α range than over the selected θ range are descriptive of those slices and are not used to rank the parameters absolutely. Through the selected closure, θ also affects government saving and aggregate investment.

Free allocation and pass-through therefore operate through distinct, complementary channels rather than as direct substitutes. Changes in α alter net ETS values across covered sectors, whereas changes in θ reallocate the electricity-sector balance between the price channel and FIN_GAP_ELEC. Because emission intensities are fixed, the emission reductions are generated by changes in output and sectoral composition, not by represented fuel switching

or endogenous technology adoption. The study accordingly does not identify a preferred or optimal configuration of P_C, α , and θ .

These findings are strictly conditional on the 2019 base year, sectoral aggregation, stylised emission coefficients, behavioural elasticities, and macroeconomic closure. Several limitations guide their interpretation. First, the analysis is comparative-static; capital accumulation, endogenous technology adoption, and stranded-asset dynamics are not represented, and the quasi-dynamic extension is excluded because it lacks a period-specific non-ETS baseline. Second, θ is an exogenous scenario parameter rather than an econometric estimate of actual pass-through in Viet Nam. Third, TCO2T and FIN_GAP_ELEC are model-accounting variables and not observed government revenue or corporate cash flow. Fourth, aggregation into five production activities limits conclusions for cement, steel, individual power technologies, and specific covered facilities. Fifth, the results are conditional on a single closure for government saving, investment, the external account, and factor markets. Future research should estimate θ empirically, disaggregate energy and energy-intensive sectors, introduce endogenous technology and fuel switching, test alternative closures, and separately identify allowance auction revenue, compliance expenditure, and secondary allowance trading.

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