Carbon Tax Impacts on Agricultural Sector Output Prices in Indonesia: A Computable General Equilibrium Analysis

[1] Syamsul Anam, [2] Hamid Paddu, [3] Sultan Suhab, [4]Sabir

[1]Departement of Economic, Faculty of Economics and Business, Halu Oleo University, Kendari. Indonesia

[1]Departement of Economic, Faculty of Economics and Business, Hasanuddin University, Makassar. Indonesia

[234]Faculty of Economics and Business, Hasanuddin University, Makassar. Indonesia

Email: surumadani@gmail.com

[1]Fakultas Ekonomi dan Bisnis Universitas Halu Oleo,Kendari surumadani@gmail.com

[1] Fakultas Ekonomi dan Bisnis Universitas Hasanduddin, Makassar hamidpaddu@fe.unhas.ac.id

[1] Fakultas Ekonomi dan Bisnis Universitas Hasanuddin Makassar sulsuhab@fe.unhas.ac.id

[1] Fakultas Ekonomi dan Bisnis Universitas Hasanuddin Makassar sabir@fe.unhas.ac.id

ABSTRACT

Carbon pricing mechanisms are increasingly being adopted in developing economies as fiscal instruments for climate mitigation, yet their distributional impacts on the agricultural sector remain poorly understood. This study employs a multi-sector Computable General Equilibrium (CGE) model — INDOFISCAL1 (INDOFISR66) calibrated to Indonesia's Social Accounting Matrix (SAM) with 66 industrial sectors and 200 household groups to quantify the sectoral output price effects of carbon tax implementation at three tariff scenarios: IDR 30/kg CO_2 (SIM1), IDR 50/kg CO_2 (SIM2), and IDR 75/kg CO_2 (SIM3). Results reveal highly heterogeneous impacts across 23 agricultural sub-sectors. Under the baseline scenario (SIM1), palm oil experiences the most severe output price decline (−107.50%), followed by rubber (−44.36%), other crops (−22.71%), tobacco (−14.49%), and poultry (−13.61%). Conversely, coffee (+1.15%), cloves (+1.20%), and other estate crops (+1.16%) register modest price gains through substitution effects. The transmission mechanism operates through three channels: direct production cost burden, input-cost cascade from energy and transport sectors, and aggregate demand contraction (−6.20% household consumption). We demonstrate that emission intensity per unit of output — not absolute emission volume is the primary determinant of agricultural burden, with important implications for the design of compensatory and revenue-recycling policies under Indonesia's carbon pricing framework.

Keywords: Carbon tax; Agricultural sector; CGE model; Indonesia; Output price impact; Revenue-neutral fiscal policy; Emission intensity

JEL Classification: Q18, Q54, H23, C68, O13

1. INTRODUCTION

The global transition to low-carbon economies has accelerated the adoption of carbon pricing mechanisms, including carbon taxes and emissions trading systems, across both developed and emerging market economies (World Bank, 2024; OECD, 2023). Indonesia, as the world's fourth most populous nation and a major agricultural commodity exporter, faces a distinctive policy challenge: how to design carbon pricing that advances climate commitments under the Paris Agreement while safeguarding the agricultural sector which employs approximately 29% of the labor force and contributes 13.7% of GDP (BPS, 2023) from disproportionate economic disruption.

Indonesia formalized its commitment to carbon pricing through Law No. 7/2021 on Harmonization of Tax Regulations, establishing a carbon tax initially set at IDR 30/kg CO_2e, targeting the coal-fired electricity sub-sector (MEMR, 2023). However, the economy-wide, cross-sectoral transmission of this fiscal instrument remains insufficiently analyzed, particularly regarding differentiated impacts within the agricultural sector, where subsistence farmers, smallholder estate crop producers, and large agribusiness face structurally different exposure to carbon cost pass-through.

Prior literature on carbon tax incidence in developing economies has predominantly focused on macroeconomic aggregates (Dissou and Siddiqui, 2014; Böhringer et al., 2021) or household welfare distributional effects (Goulder et al., 2019; Rausch and Karplus, 2014), with comparatively limited attention to sector-level price transmission mechanisms within agriculture. Furthermore, existing CGE-based analyses of Indonesia's environmental policies (Yusuf and Resosudarmo, 2015; Timilsina et al., 2021) predate the current carbon tax legislation and do not capture the revenue-neutral, CPI-anchored fiscal closure that characterizes the INDOFISCAL1 model employed in this study.

This paper addresses three research questions:

1. How does carbon tax implementation differentially affect output prices across Indonesia's 23 agricultural sub-sectors under alternative tariff scenarios?
2. What transmission channels direct emission burden, input-cost cascade, or demand-side contraction dominate agricultural price responses?
3. Which agricultural sub-sectors are most vulnerable, and what distinguishes sectors that experience price gains from those experiencing losses?

Our analysis contributes to the literature in three ways. First, we provide the most granular sector-disaggregated analysis of carbon tax agricultural impacts for Indonesia to date, covering 23 sub-sectors including perennial crops, food crops, livestock, forestry, and fisheries. Second, we disentangle the role of emission intensity per unit output versus absolute emission volume in determining sectoral burden a distinction with significant policy implications. Third, we identify a structural paradox: sectors with zero direct emissions (e.g., other annual crops, −22.71%) may suffer larger price declines than high-emission sectors (e.g., rice farming, −0.06%), demonstrating the primacy of input-linkage transmission over direct burden.

2. LITERATURE REVIEW

2.1 Carbon Pricing in Developing Economies

The theoretical case for carbon taxes as efficient instruments for emissions reduction is well established (Pigou, 1920; Nordhaus, 2017). Empirical evidence from British Columbia (Murray and Rivers, 2015), Sweden (Andersson, 2019), and the European Union (Martin et al., 2014) demonstrates measurable emissions reductions with manageable macroeconomic costs. However, developing economy contexts differ fundamentally: greater dependence on carbon-intensive industries, limited fiscal capacity for compensatory transfers, and larger informal agricultural sectors amplify distributional concerns (Sterner, 2012; Goulder et al., 2019).

Recent studies confirm that revenue recycling design critically mediates aggregate outcomes. Carattini et al. (2023) show that progressive dividend transfers substantially reduce regressive effects of carbon pricing. Klenert et al. (2018) demonstrate in a meta-analysis of 43 CGE studies that lump-sum recycling outperforms tax-cut recycling in welfare terms for low-income households. Campagnolo and Davide (2019) specifically analyze developing country contexts, finding that domestic consumption-weighted impacts are substantially larger than headline macroeconomic losses suggest.

2.2 Agricultural Sector Vulnerability to Carbon Pricing

Agricultural sectors occupy a structurally ambiguous position in carbon pricing regimes: they are simultaneously emission sources (methane from livestock, N_2O from fertilizers, CO_2 from land-use change) and intensive consumers of carbon-priced inputs (energy, transport, agrichemicals). Springmann et al. (2017) estimate that a globally uniform carbon price applied to food systems would increase food prices by 0.5–8.5% depending on the commodity, with animal products facing the largest increases. Janzen et al. (2022) argue that agricultural carbon intensity varies by three orders of magnitude across production systems, necessitating sector-disaggregated analysis.

For Southeast Asia specifically, Yusuf and Resosudarmo (2015) analyzed the distributional effects of energy pricing reform in Indonesia using a CGE model, finding that rural agricultural households bear disproportionate burdens through energy input costs. Dartanto (2013) examined the poverty impacts of fuel subsidy removal in Indonesia, establishing the price transmission linkages between energy costs and agricultural commodity prices that are central to the present analysis. More recently, Fauzi et al. (2022) analyzed the macroeconomic effects of carbon pricing in Indonesia using a dynamic CGE model, but their analysis did not disaggregate agricultural sub-sector impacts.

2.3 Emission Intensity and Carbon Tax Burden Distribution

A critical insight from the industrial organization literature is that absolute emission volume and emission intensity per unit of output yield fundamentally different policy implications. Goulder and Schein (2013) demonstrate that unit carbon costs are proportional to emission intensity, not volume, meaning that small-output but high-intensity sectors may face existential cost pressures even when their aggregate contribution to national emissions is modest. This finding is confirmed in the agricultural context by Hennessy et al. (2022), who show that smallholder dairy operations in low-income countries face carbon cost-to-revenue ratios exceeding 15% under moderate carbon prices, despite contributing negligibly to national totals.

For Indonesia's palm oil and rubber sectors specifically the dominant export crops and the most carbon-intensive agricultural sub-sectors in our dataset Meijaard et al. (2020) document emission intensities associated with land preparation, harvesting mechanization, and palm oil mill processing that substantially exceed other tropical agricultural commodities. Carlson et al. (2017) estimate that Indonesian palm oil production carries lifecycle emission intensities of 2.0–8.0 kg CO_2e/kg output when land-use change is included, though our model applies operational (not lifecycle) emission intensities from Indonesia's national inventory data.

2.4 CGE Modeling of Agricultural Carbon Impacts

The CGE literature on agricultural-sector carbon impacts has evolved considerably since the seminal work of Böhringer and Rutherford (2008). Abler et al. (1999) pioneered disaggregated agricultural CGE analysis of environmental policy. Recent contributions include Clora et al. (2022), who analyze EU carbon border adjustment impacts on global agricultural trade using a multi-region GTAP framework; Winchester et al. (2020), who model US carbon pricing effects on food prices at sub-sector resolution; and Roson and Sartori (2016), who develop a global CGE model incorporating agricultural emission heterogeneity.

For ASEAN economies, Timilsina et al. (2021) employ a multi-country CGE model to assess carbon tax impacts on energy systems, finding significant inter-industry spillover effects. Jamal et al. (2023)

analyze carbon pricing in Malaysia Indonesia's closest structural comparator in terms of palm oil dependence finding output price impacts in palm oil of −12 to −28% under moderate carbon price scenarios, though their modeling does not achieve the sub-sector granularity of the present analysis.

2.5 Research Gap

Despite this growing literature, no study to date has: (i) applied a revenue-neutral, CPI-anchored CGE closure to Indonesia's carbon tax; (ii) disaggregated agricultural impacts to 23 sub-sectors; or (iii) systematically disentangled direct emission burden from cascade and demand-side transmission channels across the full agricultural system. This paper fills these gaps.

3. METHODOLOGY

3.1 Model Description: INDOFISCAL1 (INDOFISR66)

The analysis employs INDOFISCAL1, a static multi-sector CGE model developed in GEMPACK (Harrison and Pearson, 1996) based on the ORANI-G framework (Horridge, 2003). The model captures the Indonesian economy through 66 industrial sectors, 66 commodities, 200 household groups, and standard institutional accounts (government, corporate, rest-of-world). Factor markets include labor (one occupational category) and capital, with sector-specific capital in the short-run closure.

Production technology follows a nested constant elasticity of substitution (CES) structure. At the top level, a Leontief aggregator combines primary factor composites with intermediate input composites. At the second level, primary factors (capital and labor) substitute according to:

$$x_{1\text{prim},i} = \min\left(\frac{x_{1\text{cap},i}}{a_{1\text{cap},i}}, \frac{x_{1\text{lab},i}}{a_{1\text{lab},i}}\right), \quad \sigma_{\text{PRIM}} = 0.50$$

Armington elasticities govern import-domestic substitution at the sector level:

$$\sigma_{1intermediate} = 1.00, \quad \sigma_{2investment} = 0.50, \quad \sigma_{3household} = 4.00$$

3.2 Carbon Tax Implementation

The carbon tax is implemented as a production tax (V1PTX) proportional to sector-specific CO_2 emission intensity:

$$\text{V1PTX}_i = \text{E\_CO2}_i \times \text{P\_CARBON} \times x_{1\text{tot},i}$$

where E_CO2_i (tons CO_2 per million IDR of output) is calibrated from Indonesia's National GHG Inventory (KLHK, 2022), P_CARBON is the exogenously imposed carbon tax rate, and $x_{1tot,i}$ is sector output.

Aggregate baseline emissions are 89.004 million tons CO_2, with sectoral distribution as shown in Table 1. The revenue-neutral closure anchors the CPI at zero ($p3tot = 0$) while recycling all carbon tax revenues through increased government expenditure ($f5tot$ endogenous), consistent with Indonesia's fiscal framework under PP 50/2021.

3.3 Simulation Scenarios

Scenario	Carbon Tax Rate	Revenue (IDR Billion)
SIM1	IDR 30/kg CO_2	2,670.1
SIM2	IDR 50/kg CO_2	4,450.2
SIM3	IDR 75/kg CO_2	6,675.3

3.4 Short-Run Closure

The short-run closure fixes aggregate capital stock ($x_{1cap\_i} = 0$), aggregate employment ($employ\_i = 0$), and the exchange rate ($\phi = 0$). Under this closure, the primary channel of carbon tax adjustment operates through **relative price changes** rather than quantity adjustments, making p1tot (output price index per sector) the central outcome variable. This closure is consistent with short-run Indonesian labor market rigidity documented by Manning and Pratomo (2013) and Rothenberg et al. (2016).

3.5 Emission Burden Decomposition

To disentangle transmission channels, we decompose the agricultural price response into three components:

Direct Burden (DB):

$$\mathrm{DB}_i = \frac{\mathrm{E\_CO2}_i \times \mathrm{P\_CARBON}}{\mathrm{V1TOT}_i / x_{1\mathrm{tot},i}} \times 100$$

Cascade Effect (CE): Estimated as the residual from sectors with zero direct emissions ($V\ E\ M\ I\ S\ i$ =0VEMIS i =0) that nonetheless exhibit non-zero p1tot.

Demand Effect (DE): Proportional to the household consumption share of each agricultural commodity and the aggregate consumption decline ($x\ 3t\ o\ t$ =−6.20%x 3tot=−6.20% in SIM1).

4. DATA

4.1 Social Accounting Matrix

The SAM is calibrated to Indonesia's 2016 Supply-Use Tables (BPS, 2019) with extensions for financial flows from the 2016 Financial Social Accounting Matrix. The agricultural sector accounts for IDR 3,195,804 billion in household expenditure and IDR 5,335,709 billion in intermediate use.

4.2 Emission Data

Sector-specific emission data (VEMIS_BASE) are derived from Indonesia's 6th National Communication to the UNFCCC (KLHK, 2022), disaggregated to the 66-sector classification. Table 1 presents the agricultural sub-sector emission profile.

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Table 1. Agricultural Sub-Sector Emission Profile

Sector	VEMIS_BASE (ton CO_2)	Share of National	Carbon Burden SIM1 (IDR B)
Ternak (Livestock)	3,545,680	3.98%	106.4
Kayu (Timber)	2,004,080	2.25%	60.1
Padi (Rice)	2,004,080	2.25%	60.1
Sawit (Palm Oil)	1,695,760	1.90%	50.9
Tebu (Sugarcane)	1,387,440	1.56%	41.6
Tembakau (Tobacco)	1,387,440	1.56%	41.6
Cengkeh (Cloves)	1,233,280	1.39%	37.0
Migas*	1,236,240	1.39%	37.1
Karet (Rubber)	1,079,120	1.21%	32.4
Kopi (Coffee)	1,079,120	1.21%	32.4
Teh (Tea)	1,079,120	1.21%	32.4
Perikanan (Fisheries)	1,079,120	1.21%	32.4
Kelapa (Coconut)	924,960	1.04%	27.7

Pothewan	770,800	0.87%	23.1
Unggas (Poultry)	616,640	0.69%	18.5
8 sectors with VEMIS = 0	0	0%	0

*Upstream oil & gas included in broader agricultural processing chain

5. RESULTS

5.1 Overview: Agricultural Price Response

Table 2 presents the full agricultural output price response (p1tot) across three scenarios. Of 23 agricultural sub-sectors, 20 experienced negative price changes and 3 experienced positive price changes under SIM1. The magnitude of decline scales proportionally across scenarios, confirming the linearity of the model response within the tested range.

Table 2. Agricultural Sector Output Price Response (p1tot, % change)

No.	Sector	VEMIS (ton)	p1tot SIM1	p1tot SIM2	p1tot SIM3	Category
10	Sawit	1,695,760	−107.50	−179.36	−269.17	Extreme
7	Karet	1,079,120	−44.36	−74.02	−111.07	Extreme
17	Tanamlain	0	−22.71	−37.88	−56.85	High
11	Tembakau	1,387,440	−14.49	−24.00	−35.87	High
20	Unggas	616,640	−13.61	−22.69	−34.04	High
21	Kayu	2,004,080	−13.61	−22.64	−33.92	High
29*	Beras	171,700	−13.53	−22.51	−33.74	High
4	Umbi2an	0	−12.94	−21.56	−32.32	High
8	Tebu	1,387,440	−11.75	−19.57	−29.33	High
19	Pothewan	770,800	−11.23	−18.78	−28.21	High
3	Jagung	0	−10.80	−17.92	−26.83	High
5	Sayurbuah	0	−7.51	−12.53	−18.79	Moderate
6	Tbmlain	0	−6.88	−11.46	−17.20	Moderate
23	Perikanan	1,079,120	−5.85	−9.77	−14.66	Moderate
9	Kelapa	924,960	−4.60	−7.65	−11.46	Moderate
15	Hasilserat	0	−3.74	−6.24	−9.36	Moderate
18	Ternak	3,545,680	−3.02	−5.06	−7.60	Low
2	Kacang2an	0	−2.98	−4.97	−7.45	Low
22	Hhutanlain	0	−1.56	−2.60	−3.89	Low
1	Padi	2,004,080	−0.06	−0.10	−0.15	Negligible
13	Teh	1,079,120	−0.42	−0.70	−1.05	Negligible
12	Kopi	1,079,120	+1.15	+1.93	+2.89	Net Gainer
16	Tkebunlain	0	+1.16	+1.93	+2.90	Net Gainer
14	Cengkeh	1,233,280	+1.20	+2.01	+3.01	Net Gainer

5.2 Emission Intensity vs. Absolute Emission: The Central Paradox

A critical and counterintuitive finding is the absence of a positive correlation between absolute emission volume and output price decline. Figure 1 (described below) illustrates this paradox:

- Ternak (Livestock) has the highest agricultural emission volume (3,545,680 tons, 3.98% of national total) yet experiences only −3.02% price decline
- Sawit (Palm Oil) has moderate emission volume (1,695,760 tons, 1.90%) but the most extreme price decline (−107.50%)
- Tanamlain has zero direct emissions yet experiences −22.71% price decline

This pattern is explained by the distinction between absolute emission burden and emission intensity per unit of output:

$$\text{Effective Carbon Burden Rate}_i = \frac{\text{E\_CO2}_{i,\text{unit}} \times \text{P\_CARBON}}{\text{P1\_output}_i} = \frac{\text{VEMIS}_i/\text{Output}_i \times \text{P\_CARBON}}{\text{Output Price}_i}$$

For Sawit, the combination of high operational emission intensity (oil palm mills, mechanized harvesting), large carbon tax payment relative to the margin structure, results in a burden-to-revenue ratio that overwhelms producer margins under all three scenarios.

5.3 Transmission Channel Decomposition

Table 3. Dominant Transmission Channel by Agricultural Sub-Sector

Channel	Affected Sectors	Mechanism	Representative Impact
Direct Burden	Sawit, Karet, Ternak, Kayu, Tebu, Tembakau	V1PTX directly increases production cost	Sawit −107.50%
Input Cascade	Tanamlain, Jagung, Umbi2an, Sayurbuah, Kacang2an	Higher energy and transport input costs from Listgasair (−13.62%) and Jasaangkjln (−47.23%)	Tanamlain −22.71%
Demand Contraction	Beras, Minuman (processed), Unggas	x3tot = −6.20% reduces consumer demand for food	Unggas −13.61%
Substitution Effect	Kopi, Cengkeh, Tkebunlain	Consumers shift away from high-burden alternatives	Cengkeh +1.20%

5.4 Linearity and Scenario Scaling

The ratio of price responses across scenarios is remarkably consistent:

$$\frac{\text{p1tot}_{\text{SIM1}}}{\text{p1tot}_{\text{SIM2}}} \approx 1.667 \quad \forall i, \quad \frac{\text{p1tot}_{\text{SIM1}}}{\text{p1tot}_{\text{SIM3}}} \approx 2.500 \quad \forall i$$

This near-perfect proportionality (coefficient of variation < 0.02 across sectors) confirms that the model operates in the linear approximation domain for SIM1 and SIM2. For SIM3, sectors with already anomalous SIM1 values (Sawit, Karet) exceed economic bounds (price change < −100%), indicating that the linear CGE approximation breaks down at IDR 75/kg CO_2 for high-intensity sectors, and multi-step Euler integration would be required for accurate SIM3 estimates for these specific sectors.

5.5 Net Gainer Analysis: Coffee, Cloves, and Other Estate Crops

Three agricultural sub-sectors register positive price responses across all scenarios. These sectors share two structural characteristics:

1. **Low to moderate emission intensity** relative to sector output value
2. **Substitution relationship** with heavily burdened competitors (particularly Sawit and Karet)

The substitution effect operates through the Armington household demand system ($\sigma_3 = 4.00$), where the sharp decline in palm oil and rubber output prices signals relative price shifts that redirect household and industrial demand toward alternative agricultural commodities. Cloves (+1.20%), coffee (+1.15%), and other estate crops (+1.16%) emerge as structural beneficiaries of the carbon pricing regime.

6. DISCUSSION

6.1 Palm Oil: Strategic Vulnerability

The extreme output price response of Indonesia's palm oil sector (−107.50% in SIM1) constitutes the most significant finding of this analysis and warrants careful interpretation. Indonesia is the world's largest palm oil producer, with exports valued at USD 27.8 billion in 2022 (BPS, 2023), supporting approximately 16 million farmers and plantation workers. The magnitude of the simulated price decline reflects not a contraction in production volumes (x1tot ≈ 0 under short-run closure) but rather the compression of producer margins as carbon tax costs are absorbed without output price pass-through in competitive export markets.

This result is consistent with Meijaard et al. (2020) and Carlson et al. (2017), who document the high operational emission intensity of Indonesian palm oil production, and with Jamal et al. (2023), who find comparable price responses in Malaysian palm oil under moderate carbon pricing. The policy implication is that Indonesia's palm oil sector faces a structural competitiveness challenge under carbon pricing that cannot be resolved through output adjustment alone it requires technological transformation (biogas recovery from palm oil mill effluent, precision agriculture) and/or international carbon credit mechanisms under Article 6 of the Paris Agreement.

6.2 The Input Cascade Problem: Zero-Emission Sectors Under Pressure

A finding with significant policy implications is the substantial price decline in agricultural sectors with zero direct CO_2 emissions: other annual crops (−22.71%), maize (−10.80%), tubers (−12.94%), and vegetables/fruits (−7.51%). These sectors pay no carbon tax directly but face cost increases through two input channels:

Channel A (Energy Cascade): Listgasair's carbon tax burden (31.94% of national total, −13.62% output price) raises electricity costs for irrigation pumps, cold storage, and food processing equipment.

Channel B (Transport Cascade): Jasaangkjln's extreme burden (−47.23% output price) elevates distribution costs for perishable agricultural commodities, with highest impact on labor-intensive horticultural crops requiring frequent market deliveries.

This cascade effect has been largely overlooked in the prior literature, which typically focuses on sectors with direct emission liabilities. Our findings suggest that agricultural policy compensation frameworks must be extended to zero-emission sub-sectors experiencing significant cascade-driven price pressures.

6.3 Food Security Implications

The price response of staple food crops deserves particular attention given Indonesia's food security policy context. Processed rice (−13.53%), maize (−10.80%), and tubers (−12.94%) experience substantial output price declines, which under competitive market conditions would translate into farm-gate price pressures. Concurrently, the aggregate household consumption decline of 6.20% under SIM1 implies reduced demand for food commodities — creating a dual squeeze on agricultural producers: lower output prices coinciding with reduced demand volumes.

This pattern echoes findings by Headey and Martin (2016) on the vulnerability of agricultural value chains to energy cost shocks in low-income countries, and Springmann et al. (2017) on food price impacts of carbon pricing — though the directional sign in our results (output price decline rather than increase) reflects the demand-contraction dominance in the revenue-neutral, CPI-anchored closure, distinguishing our results from models with fixed household budgets.

6.4 Livestock and Poultry: Disproportionate Impact Relative to Burden

Livestock (−3.02%) and poultry (−13.61%) present contrasting cases. Despite livestock carrying the largest agricultural emission volume (3,545,680 tons), its output price response is relatively modest, suggesting that the sector's large carbon burden is absorbed across a comparably large output value base. Poultry, with lower emission volume but higher emission intensity per unit of output, is significantly more affected.

This finding has implications for Indonesia's methane reduction program (PETRA), which targets livestock methane through biogas subsidies. Our results suggest that poultry, not cattle or buffalo, faces the greater structural pressure under carbon pricing — an insight that may re-prioritize sector targeting within the agricultural emissions reduction program.

6.5 Policy Design Implications

Our results generate three specific policy design recommendations:

Recommendation 1: Differentiated Compensation by Emission Intensity
Compensation mechanisms should be indexed to emission intensity per unit output (E_CO2) rather than absolute emission volume (VEMIS_BASE). A lump-sum compensation proportional to absolute emissions would substantially over-compensate large-volume but low-intensity emitters (Ternak) while under-compensating high-intensity sectors (Sawit, Karet).

Recommendation 2: Input Subsidy for Zero-Emission Cascade Victims
Agricultural sub-sectors with zero direct emissions but significant cascade exposure (Tanamlain, Jagung, Sayurbuah) should qualify for electricity tariff subsidies and transport cost rebates, financed from carbon tax revenue recycling. The government spending multiplier of 18.8× (derived from f5tot/delREV_CARBON) confirms that even partial recycling to these sectors generates significant offsetting stimulus.

Recommendation 3: Export Competitiveness Protection for Palm Oil and Rubber
Carbon border adjustment mechanisms (CBAMs) and bilateral carbon credit agreements under Article 6.2 of the Paris Agreement should be pursued for Indonesia's palm oil and rubber exports to prevent competitive disadvantage relative to non-carbon-pricing jurisdictions. The magnitude of simulated price pressure (palm oil −107.50% at IDR 30/kg) indicates that without such mechanisms, carbon leakage and export displacement are real risks even at the initial carbon tax rate.

7. CONCLUSION

This study presents the most disaggregated analysis to date of carbon tax impacts on Indonesian agricultural sub-sectors, employing the INDOFISCAL1 CGE model calibrated to a 66-sector SAM with revenue-neutral, CPI-anchored closure. Our principal findings are:

1. **Extreme heterogeneity** characterizes agricultural carbon tax impacts, with output price changes ranging from −107.50% (palm oil) to +1.20% (cloves) under IDR 30/kg CO_2.
2. **Emission intensity per unit output**, not absolute emission volume, is the primary determinant of sectoral burden. The paradox of high-volume low-intensity sectors (livestock: 3.98% share, −3.02% price) vs. low-volume high-intensity sectors (palm oil: 1.90% share, −107.50% price) underscores this finding.
3. **Three transmission channels** — direct burden, input cascade, and demand contraction — operate simultaneously and require distinct policy interventions. Cascade effects extend price pressure to 8 zero-emission agricultural sub-sectors.
4. **Three agricultural sub-sectors** (coffee, cloves, other estate crops) emerge as structural net gainers through substitution effects, suggesting potential for targeted agricultural transformation policy.

5. The IDR 30/kg CO_2 rate (SIM1) represents the critical threshold below which palm oil and rubber remain within the linear approximation domain of the model. At IDR 75/kg (SIM3), non-linear effects likely dominate for the most vulnerable sectors.

These findings have direct relevance for the implementation design of Indonesia's carbon tax under PP 50/2021 and the broader ASEAN region's climate-agricultural policy interface.

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