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Research Article

The Impact of Carbon Tax on Agricultural Output, Employment, and Rural Income in Indonesia: Insights from an Energy Input-Output Model

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Abstract: The agricultural sector in Indonesia is crucial for the national economy, contributing significantly to Gross Domestic Product (GDP) and sustaining the livelihoods of millions in rural areas. In light of increasing global environmental concerns, this study examines the potential impacts of a proposed carbon tax on agricultural production, employment, and rural household income in Indonesia. Utilizing the Miyazawa energy input-output model, this research integrates data from the 2016 Indonesian input-output table with carbon emissions profiles to evaluate both direct and indirect effects of a carbon tax set at Rp 30 per kg CO2e. The findings indicate that the implementation of this tax could lead to a substantial decline in agricultural production, estimated at IDR 16.37 billion in a cross-sector scenario, particularly affecting the non-food crops and forestry subsectors. Employment losses could reach approximately 17,884,082 jobs, predominantly impacting rural households highly dependent on agriculture for their livelihood. Moreover, the analysis reveals regressive effects on income distribution, where lower-income households experience a greater intensity of income reduction compared to higher-income groups. This inequality underscores the necessity for effective mitigation strategies to protect vulnerable populations from the adverse consequences of carbon taxes. The study recommends recycling tax revenues to support affected households and investing in subsidies for sustainable agricultural practices. These measures are essential to ensure a just transition that balances environmental goals with economic stability, thereby promoting resilience in the agricultural sector. In conclusion, while a carbon tax represents a significant step toward reducing greenhouse gas emissions, its implications for agricultural output, employment, and income distribution require careful consideration and proactive policy design to preserve social and economic stability in rural Indonesia.

Keywords: Agricultural, Carbon Tax, Employment, Input-Output Model, Policy, Greenhouse Gas Emissions, Rural Income, Forestry

Introduction

One of the biggest problems in the world is climate change, with global warming set to take hold in the 21st century. The main driver of gas emissions is the acceleration of economic growth, which leads to uncontrolled gas loads due to the expansion of the agricultural sector and industrialization (Chen *et al.*, 2023). Climate change is an endless phenomenon and requires a lot of serious concern as it has already started to affect biodiversity.

Specifically, climate encompasses many issues, such as rising temperatures, extreme weather conditions, and the well-being of all living organisms found on the planet. It is currently notable that the entire globe is taking initiatives at an increasing pace to ensure that the level of carbon emitted into the atmosphere is reduced. The release of gases is causing life-threatening situations. Many countries are working on adopting new emission reduction policies to get the scenario under control and prove effective in the future. This is where the carbon tax program comes in. The carbon tax is a

universal program that is currently gaining attention and is trying brilliantly to reduce carbon emissions. This is achieved by imposing a carbon tax on industries, companies and individuals, targeting those that emit more carbon.

This text provides an overview of the global scenario of carbon emissions, while taking into account the increase in global temperatures due to the release of gases. It focuses on how the world is trying to reverse the negative impact of industry on biodiversity loss. It also examines emission reduction policies and their effectiveness in addressing the impact of biodiversity loss (Chen *et al.*, 2023). The aim is to achieve a more scientific approach to emissions policies in companies and industries that would reduce carbon emissions across the country.

Emission reduction policies are an important factor in determining the impact of biodiversity loss. There are also additional goals, such as increasing carbon sinks and protecting forests from greenhouse gases. The roots of this entire program are to ensure that evidence is collected against biodiversity and climate change. The aim is to verify the implementation of carbon capture and storage programs that will provide tangible positive results on climate change to save the planet while keeping biodiversity in check.

Indonesia, a developing country committed to the Paris Agreement, an international climate control treaty, is very urgent in shaping climate policy. Indonesia has also set an unconditional target of reducing its greenhouse gas emissions by 31.89% by 2030, with a conditional target of up to 43% (Chen *et al.*, 2022a-b). They also aim to reduce this further with conditions. These targets mark Indonesia's efforts to combat global warming while also maintaining its economic development. However, these goals require extensive groundwork, especially in the agricultural sector, which is the backbone of the country's economy and supports the livelihoods of millions of people, especially in economically disadvantaged areas.

As with many other sectors, Indonesia's agricultural landscape is heavily dependent on fossil fuels, which further complicates the challenges of climate change. Attempts to modernize Indonesia's agriculture to increase productivity and efficiency have backfired as they increase carbon emissions. This creates a paradox because, on the one hand, the agricultural sector is driving the economy, accounting for a significant portion of the country's Gross Domestic Product (GDP), while on the other hand, growing environmental concerns are putting enormous pressure on reducing carbon emissions (Chen *et al.*, 2021). Reliance on energy-intensive agricultural practices, such as the use of fertilizers and fuel for agricultural equipment, makes the sector one of the main sources of greenhouse gas emissions in the country.

Implementing a carbon tax in Indonesia's agricultural sector is not easy and requires extensive research, taking into account the socio-cultural and economic factors associated with the sector (Grainger & Kolstad, 2010). The carbon tax is intended to provide an incentive and, as a result, help farmers and agribusinesses to adopt low-carbon practices in their businesses. Unfortunately, this shift poses some challenges, especially for Indonesia's dominant agricultural class. These supporting businesses are known to have weak market competitiveness and low adaptive capacity; thus, they are more susceptible to disastrous policies such as carbon taxes (Zou *et al.*, 2014a).

Furthermore, research has identified a particularly worrying equity flaw in carbon taxes: Lower-income households bear the brunt of these policies more than others, as they are unable to cope with the additional costs of carbon pricing (Kamil *et al.*, 2023). For example, in Indonesia, where many rural households depend on subsistence agriculture, the negative consequences of a carbon tax are likely to exacerbate existing economic inequalities (Kay & Jolley, 2023). There is, therefore, a growing need to understand the complex effects of carbon tax policies on the agricultural sector, job creation and income levels of rural populations.

This article aims to address the understudied implications of carbon tax policies for the agricultural sector in developing countries, particularly Indonesia (Khanna & Bakshi, 2010). Using Miyazawa's energy input-output model, the study attempts to conduct a more nuanced analysis that links different sectors regionally and illustrates how it would affect different income groups of rural residents, albeit with different measures (Lingling *et al.*, 2012). The study focuses primarily on certain non-food crops and forestry, which have long been neglected but form an integral part of Indonesia's agricultural economy.

The innovation in the analytical approach allows for the assessment of the differential impact of a carbon tax on different economic levels and social groups. It is equally important to address the broader implications of such a tax and understand whose livelihoods are most at risk. The aim is to identify these impacts as precisely as possible and to develop useful recommendations for decision-makers.

The implications of the results are likely to focus on the revenue generated by a carbon tax and how it helps to reduce adverse social problems. Policies that target tax revenues to those most affected through direct payments or energy subsidies would help mitigate the impact of the tax while contributing to the promotion of sustainable agriculture (Sun *et al.*, 2020). These policies not only seek to mitigate the blunt repressiveness of taxation but also contribute to a just transition to low-carbon agricultural practices that support rural livelihoods.

The main objective of this research is to improve understanding of the implementation of carbon taxes in the agricultural sector by developing economically efficient and environmentally sustainable practices. It aims to contribute to the development of effective environmental policies that adequately take into account the socioeconomic realities of developing countries such as Indonesia (Ma *et al.*, 2021). The study aims to address one of the key gaps in the social considerations of carbon taxes, with the aim of fostering a constructive debate on how to achieve Indonesia's climate goals while ensuring the sustainability and resilience of its agricultural sector.

Materials and Methods

This study utilizes several key materials to evaluate the impact of carbon tax policies on Indonesia's agricultural sector and rural household income distribution. The primary data sources include the 2016 Input-Output Table of Indonesia, which provides the structural framework for analyzing sectoral interdependencies and simulating policy shocks. Household-level data are obtained from the National Socioeconomic Survey (Susenas), which offers comprehensive information on income and expenditure, and from the National Labour Force Survey (Sakernas), which supplies employment and labor force details essential for assessing job impacts within the agricultural sector. Carbon emissions data are integrated from Indonesia's environmental satellite accounts to calculate sector-specific CO_2e outputs. The analytical framework is built upon Miyazawa's energy input-output model, implemented using the General Algebraic Modeling System (GAMS) for scenario simulation and optimization. Microsoft Excel is used for data preprocessing, tabulation, and result visualization. These materials collectively provide the empirical and computational foundation necessary to analyze the direct and indirect effects of a carbon tax on sectoral output, employment, and household income distribution.

The study uses a quantitative approach using Miyazawa's energy input-output model to assess the impact of carbon tax policies on Indonesia's agricultural sector and household income distribution. The main components of the research methodology include input-output analysis to examine how the carbon tax affects both the agricultural sector and household income distribution and statistical analysis to assess the robustness of the results as assumptions and parameters vary.

The modelling uses General Algebraic Modeling System (GAMS), which is adept at solving complex mathematical optimization problems, and Microsoft Excel is used to manage the data and visually present the results. The data analysis process involves several key steps, including data cleaning and preparation, model implementation in GAMS, model calibration to fit the Indonesian economy, scenario analysis to examine the impacts of changing carbon tax rates, and clear interpretation and presentation of the results.

The study focuses on a carbon tax rate of IDR 30 per kilogram of CO2e. The dependent variables analyzed in relation to this tax include agricultural sector output, employment opportunities, and rural household income. Given its ability to provide nuanced sectoral insights and adapt to different policy scenarios, from Figure (1) Miyazawa's energy input-output model is particularly effective for assessing the impact of carbon tax policies in this context.

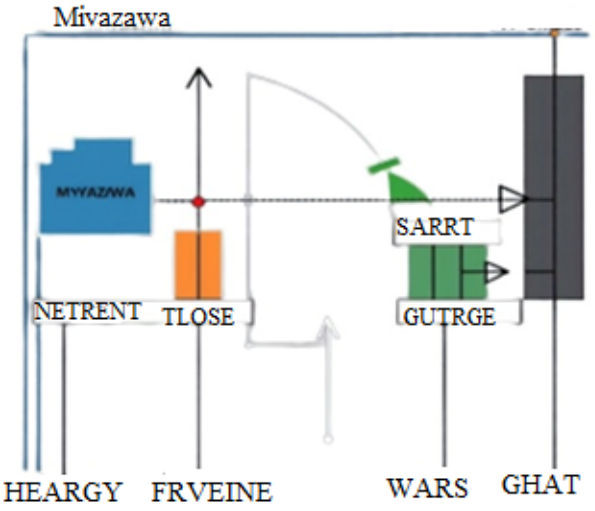

Fig. 1: Miyazawa Energy Input-Output Model

Independent Variable

The independent variable for this study is the carbon tax rate; in this case, the tax is IDR 30 per kilogram of CO2e. This value is determined in order to investigate the impact of a carbon tax on the agricultural industry and income redistribution within households.

Dependent Variables

The scope of this study is limited to the following dependent variables:

1. Agricultural sector output: Refers to the value-added of the agricultural sector in the Indonesian economy
2. Employment opportunities: Refers to the number of jobs and positions available in the agricultural sector in relation to the carbon tax
3. Rural household income: Refers to the income of rural residents in Indonesia who are directly or indirectly affected by the carbon tax in terms of their employment, commodity prices, etc

Identification of Variables

To identify the scope of the work, the existing literature on the use of carbon taxes in the agricultural

sector was assessed. In this case, a carbon tax rate of 30 IDR per kilogram of CO2e was chosen because it is relatively close to Indonesia's potential carbon tax rate. The dependent variables were chosen in relation to the research problem and the impact of the carbon tax. The units of analysis consist of subsectors within the agricultural sector identified using Indonesia's 2016 Input-Output Table. The primary focus is on 73 economic sectors, with special emphasis on agricultural subsectors that significantly contribute to the national economic structure.

The study groups participants into income classes based on deciles, with the lowest decile representing the poorest 10% of the population and the highest decile representing the wealthiest 10%. The study groups participants into income classes based on deciles, which is a common approach in income distribution analysis. This choice is justified for several reasons: Past studies have shown that decile grouping is a useful way to capture income inequality and analyze the impact of policy interventions on different income groups; deciles provide a nuanced understanding of how different income groups are affected by carbon tax policies, allowing for a more detailed analysis of the distributional impacts; and grouping participants into deciles also facilitates the analysis and presentation of results, making it easier to compare and contrast the impacts across different income groups.

Participants in this study are rural households grouped into 10 income classes (deciles), as reflected in the data from the National Socioeconomic Survey (Susana's) and the National Labor Force Survey (Sekeras).

Decile Grouping Justification

The study groups participants into income classes based on deciles, which is a common approach in income distribution analysis. This choice is justified for several reasons: Past studies have shown that decile grouping is a useful way to capture income inequality and analyze the impact of policy interventions on different income groups; deciles provide a nuanced understanding of how different income groups are affected by carbon tax policies, allowing for a more detailed analysis of the distributional impacts; and grouping participants into deciles also facilitates the analysis and presentation of results, making it easier to compare and contrast the impacts across different income groups.

Data are gathered from various sources, including carbon emission information from the input-output tables and the expenditure frameworks based on the National Socioeconomic Survey (Susena) and the National Labour Force Survey (Sakerna).

Data Sources

The data for this survey were obtained from the Susenas and Sakernas surveys conducted by the BPS. These surveys are reliable and complete data sources on the socioeconomic and labour force parameters of the country.

National Socioeconomic Survey

- Sample size: The sample size of the Susenas survey is usually around 200,000 households or one million people
- Demographic information: It covers age, gender, occupation and education
- Scope: The survey covers income and expenditure, education, health and even housing

National Labour Force Survey (Sakernas)

- Sample size: The sample size of the Sakernas survey is usually 100,000 households or five hundred thousand people:
- Demographic information: It covers age, gender, occupation and education
- Scope: The survey examines labour force characteristics such as employment status, occupation, industry, income level

Reliability and Validity

Both surveys are assumed to be reliable and valid because they are conducted according to established procedures, and a predefined methodology is used for sample selection. The information obtained from these surveys is available to researchers, policymakers, and other stakeholders to enhance evidence-based decision-making and policy formulation, which encompass energy consumption across economic sectors and household consumption structures from Susana and Speakers. Data integration processes are conducted to link carbon emission information with household expenditure patterns, enabling the analysis of the carbon tax impact by income class.

Data analysis is conducted using the input-output model, where the carbon tax is applied as a "shock" to the economic system to project its impact on agricultural sector output, employment opportunities, and rural household income. This technique allows for the evaluation of both the direct and indirect effects of the carbon tax policy. Additionally, a sensitivity analysis is performed to understand the extent to which changes in variables influence the research outcomes. Data validation is carried out by comparing the projected results with relevant national economic data to ensure consistency and accuracy.

The approach employed in this study offers several key advantages. First, the model facilitates detailed cross-sectoral impact measurement, providing in-depth insights into intersectoral relationships. Second, the research integrates an analysis of tax burden distribution across income classes, enabling an evaluation of the regressive impact of the carbon tax on low-income

households. Third, this approach allows for a comprehensive assessment of both direct and indirect impacts of the carbon tax policy on various economic dimensions, particularly those relevant to the agricultural sector and the sustainability of rural households. This methodology is designed to make a significant contribution to understanding carbon mitigation policies in the agricultural sector, with implications that are highly relevant for formulating more equitable and effective policies.

Results

Potential Carbon Tax Revenue and Its Impact on the Agricultural Sector

The research findings indicate that the total potential carbon tax revenue in Indonesia across all economic sectors amounts to IDR 5,025,641,983,076. However, the contribution from the agricultural sector is relatively small, amounting to only around IDR 418,242,180 or 0.000105% of the sector's total output. This suggests that carbon emissions from the agricultural sector are still relatively low compared to other sectors, such as manufacturing. The simulation of carbon tax scenarios reveals two primary impact patterns:

1. Scenario I: The tax is applied only to the agricultural sector. The output of this sector decreases by IDR 2.17 billion.
2. Scenario II: The tax is applied across all economic sectors. The decline in agricultural sector output increases significantly to IDR 16.37 billion, highlighting substantial cross-sectoral impacts (653.50%)

The most significant decline in output is observed in the non-food crops subsector, which decreases by 24.77%, followed by the forestry subsector with a 22.77% decline. In contrast, the rice subsector experiences the smallest impact, with its output decreasing by only 12.47%.

Table 1: Differences in impact between the two scenarios on the non-food crops and forestry subsectors

Subsectors	Scenario I (IDR Million)	Scenario II (IDR Million)	Difference (%)
Rice	-5.02	-2,040.64	40,582.66
Non-Food Crops	-81.00	-4,053.98	4,905.22
Forestry	-305.68	-3,726.55	1,119.09
Other Food Crops	-210.37	-2,686.75	1,177.16

Table (1) illustrates the differences in impact between the two scenarios, with the non-food crops and forestry subsectors experiencing the highest levels of impact in both scenarios. These results indicate that the implementation of a carbon tax has a greater impact when applied across sectors compared to being limited to a specific sector. Therefore, mitigating the effects on the most affected subsectors, such as non-food crops and forestry, should be a priority.

Estimated Reduction in Employment Opportunities in the Agricultural Sector Due to Carbon Tax

The implementation of a carbon tax shows a significant impact on employment opportunities in the agricultural sector, with the following results:

1. Scenario I: The tax is applied only to the agricultural sector, resulting in the loss of 30,056 jobs
2. Scenario II: The tax is applied across all economic sectors, with job losses rising drastically to 17,884,082 jobs. This difference represents an increase of 59,402.92%, indicating that cross-sectoral effects play a significant role.

Most Affected Subsectors Based on Scenarios:

1. Scenario I: The livestock subsector experiences the largest reduction in employment opportunities, with a loss of 15,015 jobs (49.96% of the total)
2. Scenario II: The non-food crops subsector is the most affected, with a loss of 5,656,805 jobs (31.63%)

Table (2) illustrates a comparison of the impacts between Scenario I and Scenario II, highlighting a significant surge in job losses, particularly in the non-food crops subsector. The greatest impact is observed in subsectors heavily reliant on other sectors for inputs, such as non-food crops. Scenario II demonstrates that the cross-sectoral effects of the carbon tax are far greater compared to its direct application solely to the agricultural sector.

Table 2: Employment impact due to carbon tax across agricultural sub-sectors by scenario

Subsectors	Scenario I (People)	Scenario II (People)	Difference (%)
Rice	-1,470	-4,936,353	335,742.89
Non-Food Crops	-2,304	-5,656,805	245,442.74
Forestry	-1,515	-113,114	7,365.47
Livestock	-15,015	-1,298,076	8,545.13

Impact of Carbon Tax on Income Based on Income Classes

The implementation of a carbon tax significantly affects rural household incomes. The impact is analyzed through two scenarios:

1. Scenario I: The tax is applied only to the agricultural sector. The total decline in rural household income amounts to IDR 249.30 million.

2. Scenario II: The tax is applied across all economic sectors. The income decline increases drastically to IDR 26,656.76 million, representing a 10,592.73% increase compared to Scenario I

The decline in income is more significant for higher-income classes in absolute terms, but the relative impact is greater on lower-income classes:

- Lowest Income Class (Class 1): Income decreases by IDR 10.78 million in Scenario I, rising to IDR 685.41 million in Scenario II
- Highest Income Class (Class 10): Income experiences the largest absolute decline of IDR 8,819.13 million in Scenario II

Table 3 highlights a pattern where the absolute income decline is higher for upper-income classes while the relative impact is greater for lower-income classes. The income reduction is progressive in nominal terms but regressive in its intensity. Lower-income classes experience a proportionally larger decrease compared to higher-income classes. This underscores the importance of mitigation strategies to protect low-income rural households.

Table 3: Impact of Carbon Tax on Rural Household Income by Income Class and Scenario

Income Class	Scenario I (IDR Million)	Scenario II (IDR Million)	Difference (%)
Class 1	-10,78	-685,41	6,256.43
Class 5	-19,92	-1,815,78	9,014.47
Class 10	-61,01	-8,819,13	14,354.75
Total	-249,30	-26,656,76	10,592.73

Discussion

This study reveals the significant impact of carbon tax policies on Indonesia's agricultural sector (Mardones, 2023). Using simulations based on an energy input-output model, it was found that the implementation of a carbon tax not only affects the overall output of the agricultural sector but also has substantial implications for employment opportunities and the income distribution of rural households (Mardones & Alvial, 2024a). The findings indicate that cross-sectoral impacts are greater than direct impacts, particularly in the non-food crops and forestry subsectors. The findings of this study address the critical question of how carbon tax policies affect the agricultural sector, both directly and indirectly (Mardones & Correa, 2024b). Using the Miyazawa model, this research demonstrates that:

- Agricultural sector output decreases by up to IDR 16.37 billion in the cross-sector scenario
- Employment opportunities are significantly reduced, with the non-food crops subsector losing 5,656,805 jobs
- Rural household income experiences a regressive decline, with the largest absolute impact on higher-income classes but greater intensity on lower-income classes

This study also underscores the importance of cross-sectoral analysis in understanding the impacts of fiscal policies, given the agricultural sector's heavy reliance on inputs from other sectors (Martin & Velázquez, 1994). The experimental design ensures control over confounding variables and validates the reliability of the results obtained.

The findings of this study align with previous literature highlighting the significant impact of carbon tax policies on vulnerable sectors, particularly agriculture (Nakamura & Kondo, 2005). For example, Skirled in Canada demonstrated that farmers face substantial challenges in adapting to carbon taxes, primarily due to their limited ability to influence product prices in global markets. In the Indonesian context, these challenges are even more complex given the dominance of small and medium enterprises in the agricultural sector, which have limited capacity to adapt to such policies (Yuhong & Lin, 2011).

Additionally, this study confirms the view in the literature that carbon taxes can be regressive, with greater impacts on low-income groups (Park *et al.*, 2024); a similar pattern was identified in Indonesia, where the burden of environmental policies tends to fall more heavily on poorer households. This research reinforces those findings by showing that while the absolute impact of carbon taxes is higher for high-income classes, the intensity of the impact is more significant for low-income classes (Renner, 2018).

In the global literature, and the Organisation for Economic Co-operation and Development (OECD) emphasize the importance of cross-sectoral analysis in understanding the full impacts of carbon tax policies. This study expands on those perspectives by incorporating the Miyazawa energy input-output model, enabling an analysis of cross-sectoral interactions and the distributional impacts at the household level (Bartlomiej *et al.*, 2023). By demonstrating that cross-sectoral impacts are far greater than direct impacts on the agricultural sector, this research underscores the critical role of intersectoral linkages in Indonesia's economic structure.

This study contributes to the theory of carbon tax distribution by highlighting the distinction between absolute impacts and impact intensity across income classes (Saelim, 2019). The findings demonstrate that while carbon tax policies appear nominally progressive, an analysis of impact intensity reveals a regressive pattern, aligning with Prasad's perspective on the importance of mitigating the risks of environmental policies for vulnerable groups.

The research also provides additional insights by emphasizing specific subsectors significantly affected,

such as non-food crops and forestry, which have previously received limited attention in the literature (Sánchez-Serrano *et al.*, 2024). Thus, this study not only complements existing research but also broadens the theoretical framework for analyzing the impacts of environmental policies in developing countries.

The study reveals the critical implications of carbon tax policies for Indonesia's agricultural sector (Song *et al.*, 2015). However, there are some limitations to the study that should be considered.

Limitations and Future Research Directions

The use of the 2016 Input-Output Table for analysis in 2025 may indeed question the applicability of the results to current economic conditions. Economic dynamics, agricultural practices, and external factors influencing the agricultural sector may have changed significantly in the intervening years. Therefore, policymakers and researchers should approach the conclusions with caution, ideally considering more recent data or conducting follow-up studies using updated datasets to validate or challenge the initial findings.

Data Sources and Transparency

The absence of specific citations or references for the 2016 data can further complicate the credibility of the analysis. Without knowing the methodology used to gather or construct the Input-Output Table, it is difficult for readers to assess the robustness of the results. Transparency about data sources aids in verifying the statistical indicators, ensuring that the analysis adheres to rigorous academic and research standards.

Implications for Policy

Given these concerns, any recommendations or conclusions drawn regarding the carbon tax's impact on agricultural output, employment, and household income distribution should be viewed as preliminary. It might be beneficial for future research to incorporate a broader scope, examining additional aspects such as regional differences, policy changes, or technological advancements in agriculture.

The findings indicate that subsectors like non-food crops and forestry are most affected due to their high dependency on other sectors (Sugino *et al.*, 2013). The decline in output and employment opportunities in these subsectors underscores the need for policy designs that account for cross-sectoral interactions.

Moreover, the regressive impact of carbon taxes on low-income households highlights the necessity of mitigation measures, such as recycling tax revenues into direct cash assistance programs or energy subsidies (Sun *et al.*, 2020). These policies can alleviate the burden on vulnerable groups while promoting a transition toward sustainable, low-carbon agricultural practices (Wu *et al.*, 2017).

However, several limitations need to be acknowledged (Yan & Yang, 2021). The use of the 2016 Input-Output Table may not fully reflect the latest economic dynamics, and the carbon tax rate assumption used does not account for potential variations in policy implementation (Zhang *et al.*, 2019). This study is also limited to the agricultural sector, suggesting that a broader analysis encompassing other sectors could provide more comprehensive insights. For future research, focusing on regional contexts and the integration of low-carbon technologies could offer more relevant solutions (Zou *et al.*, 2014b). Additionally, evaluating combinations of mitigation policies, such as energy subsidies and carbon trading mechanisms, would enrich policy recommendations to ensure economic and social sustainability.

Conclusion

This study highlights the significant impacts of carbon tax policies on Indonesia’s agricultural sector, particularly in areas such as reduced output, employment opportunities, and the overall income of rural households. By employing the Miyazawa Energy Input-Output model, our findings indicate that cross-sectoral effects of the carbon tax are more pronounced than direct impacts, with the non-food crops and forestry subsectors experiencing the most substantial declines in both output and employment. Furthermore, the distributional impact of the carbon tax exhibits a regressive pattern, with lower-income households encountering a more intense reduction in their incomes compared to higher-income groups.

These insights are vital as they enrich the existing literature on the distributional implications of environmental policies in developing countries. The evidence underscores the necessity for designing carbon mitigation strategies that are more equitable and effective. For instance, approaches that involve recycling tax revenues to support vulnerable groups or introducing targeted subsidies for low-carbon technologies can help alleviate the adverse effects of these policies on low-income populations.

As policymakers strive to ensure both social and economic sustainability in the implementation of carbon mitigation policies, it is crucial to consider the complexities of income distribution and sectoral interdependencies. Future research should aim to expand the analysis to include regional contexts and evaluate the integration of other environmental policies, which may lead to more holistic and effective solutions for addressing the challenges posed by carbon tax implementation in Indonesia and similar developing nations.

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Author's Contributions

Syahrituah Siregar: Conceived and designed the study, developed the theoretical framework, performed the data analysis, and drafted the manuscript.

Luthfy Fatah and M. Handry Imansyah: Contributed to the development of the model, supervised the research process, and provided critical revisions to the manuscript.

Sunardi: Assisted with data interpretation and provided input on the policy implications of the findings.

All authors contributed to the discussion of results, reviewed, and approved the final version of the manuscript.

Ethics

This article is original and does not involve any ethical issues. The corresponding author certifies that all authors have read and approved the final manuscript and there are no conflicts of interest or ethical contradictions.

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