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Impact of Coal Power Plant Emissions on Indonesia's Carbon Tax Rates

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Abstract

Indonesia, as one of the top ten global carbon emitters, largely due to its heavy reliance on coal-fired power plants, has introduced a carbon tax policy to address the environmental impacts and mitigate carbon emissions. This study investigates the dynamic effects of coal power plant emissions on Indonesia's carbon tax rates by applying a system thinking approach utilizing a Causal Loop Diagram (CLD). The CLD is used to map the complex interactions between carbon emissions, economic factors, and regulatory policies, focusing on Indonesia's carbon tax policy framework from its inception in 2021 through its early implementation stage in 2022, with projections extending to 2025. The CLD analysis identifies three key feedback loops : a reinforcing loop where economic growth and electricity demand increase coal consumption and CO2 emissions, a balancing loop where carbon tax revenues stimulate renewable energy investments to reduce fossil fuel dependency, and a policy feedback loop that strengthens fiscal capacity for climate mitigation efforts. Scenario analysis suggests that increasing the carbon tax rate from IDR 30/kg CO2e to IDR 150/kg CO2e could significantly reduce emissions while maintaining economic stability, particularly in the energy sector, if accompanied by targeted subsidies and incentives for renewable energy. The findings contribute new policy insights on how carbon taxes can be optimized to achieve environmental conservation goals while minimizing negative economic impacts and promoting a sustainable energy transition in Indonesia.

Keywords: Carbon Tax, Coal-Fired Power Plants, Emissions, System Thinking.
JEL Classification: Q52, Q58, H23, Q48

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1. INTRODUCTION

Global warming and extreme climate change, particularly the increase in global temperatures, have emerged as prominent subjects of contemporary public discourse. In

2022, global temperatures were recorded as the sixth highest since 1880, exhibiting an average increase of 0.86°C relative to the 20th-century mean. (National Centers for Environmental Information (NCEI), 2022). Numerous factors contribute to the rise in temperatures, both nationally and internationally, with carbon emissions being a significant contributor among greenhouse gases. These emissions mainly originate from human activities and daily routines, particularly from combustion processes such as power generation and industrial activities. China is responsible for approximately 27% of global carbon emissions, representing a 174% increase in emissions between 1990 and 2010. Developed nations, including the UK, Australia, and the USA, contribute substantially to global carbon emissions and bear considerable responsibility for their mitigation. (Abeydeera et al., 2019).

Indonesia, being among the top ten global contributors to carbon emissions, encounters substantial challenges in reducing its greenhouse gas emissions, especially due to the predominance of coal-fired power plants in its energy sector. In response, the Indonesian government introduced its carbon tax policy in 2021, with limited implementation beginning in April 2022 targeting coal-fired power plants through a cap-and-tax mechanism. This initial phase represents an early and partial step toward a more comprehensive carbon pricing system currently under development.

It is essential to recognize that the responsibility for global carbon emissions does not rest exclusively with the highest-emitting nations. These emissions largely result from the production of industrial goods driven by international demand. Developed nations, which consume a significant portion of these goods, indirectly contribute to emissions generated in manufacturing hubs. This interconnected dynamic highlights the need for shared accountability. Both producing and consuming countries must implement policies to reduce emissions collectively. A comprehensive approach, including sustainable production practices and responsible consumption, is essential to address the global carbon crisis effectively. International trade and economic activities create complex interdependencies, as countries and industries influence each other's carbon emissions. Therefore, carbon emissions represent a shared global responsibility that requires international cooperation to develop effective emission reduction solutions.

Some socially responsible companies voluntarily take on the responsibility of reducing emissions. In contrast, profit-oriented companies may lack the incentive to do so, as emission reductions often incur higher costs. Government regulations on carbon reduction often serve to restrict their carbon emissions. At present, carbon taxes and carbon quotas are two widely implemented instruments for achieving emission reductions. (Wang et al., 2023).

Indonesia, as a large country, contributes significantly to carbon emissions. Based on World Bank data from 2019, Indonesia's per capita carbon emissions reached 2.30 tons of CO2e, reflecting a steady increase since 2013. Therefore, the increasing volume of carbon emissions poses a significant threat to national welfare. Notable consequences include climate change and the potential for substantial economic losses. It is thus essential for the Indonesian government to address these risks through effective policies, for instance, through the adoption of a carbon taxation system.

According data from Global Carbon Atlas Team (2023), global carbon dioxide emissions reached approximately 36,000 metric tons ($MtCO_2$) in 2021. Indonesia contributed 615.93 $MtCO_2$, equivalent to about 1.72 percent of total global carbon emissions, placing it as the 10th highest carbon-emitting country in the world. In 2022, this share increased to 1.96 percent of global carbon emissions.

According to information provided by the Ministry of Environment and Forestry, economic impact projections indicate that climate change in Indonesia could hinder the fulfillment of basic citizen needs by 0.66% to 3.45% of the National Gross Domestic Product (GDP), with the average estimated impact reaching 2.87% of the National GDP by 2030. This analysis considers the impact of disasters on key sectors, such as the spread of diseases due to floods, landslides, and droughts, as well as the impact on agriculture from floods, while the impact on infrastructure is calculated separately. The sustainability of sectors essential to human life heavily depends on their ecosystem conditions, and disasters can threaten the sustainability of these ecosystems. If ecosystem damage and disasters are considered, potential losses could reach IDR 4,328.38 trillion.

The enactment of Law Number 7 of 2021 marked the initial step in introducing a carbon tax, aiming to harmonize tax regulations while incorporating carbon tax provisions. Currently, the government is developing the framework for determining and applying the carbon tax. The implementation of carbon trading, including technical details and the operationalization of the carbon tax, is anticipated to commence around 2025. Globally, countries employ various methods and policies to limit carbon emissions, which are closely linked to the development of carbon trading markets. One common application in carbon trading markets is the Cap and Trade mechanism, where each company is allocated a cap represented by permits or quotas for their carbon emissions within a specific period.

This mechanism involves verifying a company's carbon emissions after one year of operation to determine whether it exceeds or does not exceed the allocated carbon emission permits. If a company’s total carbon emissions exceed the allocated permits, the company must compensate for the excess emissions by reducing them by the difference between the generated emissions and the number of permits held. Conversely, if a company's total carbon emissions are below the permits, the surplus can be traded on the carbon exchange, regulated by the government (Irama, 2020).

In the context of cap-and-trade implementation, the carbon trading market enables the exchange of emission allowances both domestically among companies and internationally across countries. This complexity has led to the creation of the European Union Emissions Trading System (EU ETS), a significant multinational carbon trading framework. Nations participating in transactions through the EU ETS include the United Kingdom, France, and Finland. Nevertheless, this approach may not be fully sufficient to achieve substantial reductions in global carbon emissions, highlighting the need for carbon taxes as an additional measure to enhance emission control within the trading market. At present, Indonesia has not yet introduced a carbon tax; therefore, no direct effects of such a tax, particularly in relation to coal-fired power plants, have been observed.

In the meantime, the Director of Electricity Technical and Environmental Affairs at the Ministry of Energy and Mineral Resources of the Republic of Indonesia held a webinar on the Application of Carbon Economic Value in the Electricity Sector, outlining several key points. The carbon tax is implemented based on the carbon tax roadmap established by the government and/or the carbon market roadmap. This tax applies to individuals or entities that purchase carbon-intensive products or conduct activities resulting in carbon emissions. The revenue generated from the carbon tax may be directed toward climate change mitigation programs, as stipulated by Government Regulation and subject to approval by the Indonesian House of Representatives (DPR RI) during the State Budget (RAPBN) formulation. The carbon tax rate is set at a minimum of IDR 30.00 per kilogram of CO_2 equivalent (CO_2e). Since April 1, 2022, the carbon tax has been applied to the coal-fired power plant sector under a cap-and-tax mechanism.

Therefore, This research is crucial in supporting government efforts to limit carbon emissions in Indonesia, particularly in coal-fired power plants. The initiative has significant potential to contribute to carbon emission reduction efforts. The results of this study may provide a useful reference for the government in projecting carbon tax revenues and supporting global environmental preservation initiatives. The insights provided by this study are expected to be useful in shaping effective policies for sustainable energy practices.

Anthropogenic and Natural Radiative Forcing (Forster et al., 2007), As outlined in the Intergovernmental Panel on Climate Change (IPCC) report, which discusses the role of CO_2 from human activities in driving climate change, human actions are identified as the primary factor behind the rising concentrations of greenhouse gases (GHGs). Over the past century, the combustion of fossil fuels like coal and oil has significantly elevated carbon dioxide levels. This occurs as burning these fuels results in the combination of carbon with atmospheric oxygen, generating CO_2. Furthermore, to a lesser extent, activities such as agricultural land clearing, industrial operations, and other human-driven actions also contribute to the increase in greenhouse gas concentrations. (NASA, 2024).

Coal-fired power plants represent a significant source of carbon emissions within Indonesia's energy sector, where the release of carbon from coal combustion leads to various adverse environmental consequences, such as climate change and air pollution. In response, Indonesia has introduced a carbon tax policy to mitigate these challenges. The rise in CO_2 concentrations, which drives global warming, remains one of the most pressing global concerns. The forestry and energy sectors are the two primary contributors to national emissions, with deforestation and electricity generation being major sources. The predominant use of oil and coal fuels has been identified as a key driver of CO_2 emissions in Indonesia. (Cahyono et al., 2022). The complexity of the interaction between various variables influencing the implementation of carbon tax policies necessitates a comprehensive explanation and evaluation of these policies.

Carbon emissions describe the discharge of carbon into the atmosphere occurring within a particular geographical region and during a specified timeframe. (Ministry of Energy and Mineral Resources, 2020). The global increase in carbon emissions can be attributed to various factors, including economic growth, fossil fuel consumption, and population expansion (International Energy Agency, 2020). Examples of carbon emissions include carbon dioxide (CO_2), nitrogen oxides (N_2O), methane (CH_4), sulfur hexafluoride (SF_6), and various other compounds (Zhang et al., 2008). These emissions, commonly referred to as greenhouse gases (GHGs), are major contributors to global warming (Organisation for Economic Co-operation & (OECD), 2023)

By the end of 2021, Indonesia had risen to the fifth position among the largest cumulative carbon emission contributors globally (Mutia, 2022). This reflects a concerning trend, especially when compared to earlier data from 2011. In response, and in line with its commitment to the Paris Agreement in 2015, Indonesia has demonstrated its dedication to reducing its carbon footprint and combating global climate change.

A carbon tax represents a type of levy applied to fossil fuel consumption, aiming to minimize pollution and mitigate adverse effects such as climate change and air pollution. (Ratnawati, 2016). Fossil fuels such as oil, coal, and natural gas are non-renewable hydrocarbon resources. Imposing a carbon tax on these fuels raises their market prices, thereby discouraging overconsumption. This tax is primarily applied to fossil fuels utilized in energy generation, with the amount calculated based on the volume of carbon dioxide released during combustion. The tax predominantly targets industries responsible for greenhouse gas (GHG) emissions, aiming to promote the adoption of cleaner, more environmentally sustainable technologies within the industrial sector. (Stern, 2007).

Following the implementation of the HPP Law, Indonesia requires that the carbon tax rate be set at a level equal to or higher than the market value of carbon per kilogram of carbon dioxide equivalent (CO2e). The primary objective of the carbon tax is to reduce GHG emissions by obligating individuals and businesses to offset the carbon footprint associated with goods and services that have not yet achieved full carbon neutrality. Furthermore, the carbon tax may contribute to national economic growth and enhance public welfare. (Pamungkas & Haptari, 2022).The core principle behind the carbon tax is to minimize the negative impacts caused by consumption of carbon-intensive goods and services. Moreover, the carbon tax provides potential benefits such as promoting economic growth and enhancing public welfare (Investor Daily, 2021). The revenue generated from this tax can be allocated to support sectors that directly impact people's lives and promote technological advancement. As global carbon emissions continue to rise, carbon taxation plays a crucial role in compensating for the environmental costs associated with high-carbon activities. This mechanism not only supports emission reductions but also strengthens the national economy and fosters sustainable development (Investor Daily, 2021).

As one of the power plants in Indonesia, Coal-Fired Steam Power Plants (PLTU) are relied upon by the Government for electricity supply (Sabubu, 2020). Coal-fired PLTUs fall into the category of steam power generation facilities, which are thermal and fossil fuel-based, using coal as their primary fuel source. The process of generating electricity from coal-fired steam begins with the selection of the type of coal to be used at the facility. The selected coal is then fed into a boiler to start the steam production process. The generated steam is used to drive steam turbines, which in turn drive electricity generators. Steam is produced under high-temperature conditions, typically around 570°C, and at a pressure of about 200 bar.

Carbon emissions are a textbook example of market failure, where private actors do not internalize the full social costs of their activities, leading to excessive pollution. From a microeconomic perspective, this represents a negative externality, which justifies government intervention through taxation (Pigou, 1920). The Pigouvian tax theory suggests that the ideal carbon tax should correspond to the marginal social cost associated with carbon emissions, thus internalizing external costs and aligning private decisions with social welfare. From a macroeconomic standpoint, carbon taxes not only address environmental degradation but also generate fiscal revenues that can be recycled to support green investments, reduce other distortionary taxes, and stimulate economic growth (the so-called double dividend hypothesis). This theoretical framework forms the basis for our analysis of Indonesia's carbon tax policy using a system thinking approach.

However, it is important to recognize that the use of coal-fired steam power plants has significant environmental impacts, particularly in the form of environmental pollution. These plants produce waste, primarily in the form of fly ash, which spreads toxic and potentially deadly pollutants into the environment. In contrast, some developed countries have found innovative ways to utilize fly ash, using it as a construction material in concrete and cement production.

2. RESEARCH METHODS

System thinking, according to Thwink.org (2014), It involves both the art and science of drawing dependable conclusions about behavior through a comprehensive understanding of the fundamental structures. System thinking also employs a causal framework to explain the interdependent relationships among variables and systems. (Suryani et al., 2022). Since it presents conceptual dynamics of variables, system thinking offers a powerful and efficient way of thinking, enhancing awareness, precision, and intelligence. Therefore, system thinking is not just a technique but also an effective and efficient discipline of thought (Prahasta, 2018). Over time, the paradigm of system thinking has become increasingly recognized and utilized by various groups, serving as a foundation for designing impactful and sustainable policies across multiple fields. As such, mastering system thinking is crucial for various stakeholders, including academics, public officials, and the general public (Sarasi et al., 2021). Based on its definition and components, the following are some features of system thinking (Acaroglu, 2017):

a. Interconnectedness:
System thinking requires the ability to shift from linear to circular (non-linear) thinking, incorporating loops or feedback. This shift allows all components or variables to become interconnected.

b. Synthesis:
Synthesis refers to the combination of components (variables) to form something new (emergence) and interconnected as a whole. In system thinking, the goal is similar understanding the components, relationships, and connections that form overall

dynamics. Essentially, synthesis is the ability to see how the system's components work together.

c. Emergence:
From a systems perspective, larger phenomena emerge from what are considered small elements, resulting from the synergy of these interrelated small elements.

d. Feedback:
Because of the interconnectedness, systems typically contain elements that form feedback loops. After understanding the system, interventions can be made through its feedback loops if necessary. There are two types of feedback: reinforcing and balancing. Reinforcing loops do not always lead to beneficial outcomes; when a component becomes dominant (too strong), it may not need further reinforcement, as its growth tends to become exponential, similar to human, flora, and fauna populations under certain conditions. Conversely, in balancing loops, the components continuously balance the system (through natural predators, specific constraints, or deliberate regulations). However, if a population (component) is excessively reduced due to balancing processes, another population may potentially explode (reinforcing) in the future.

e. Causality:
As part of system thinking, causality can explain everything in terms of mutual influence within a system. Understanding this provides a deeper perspective on the agents (variables) involved, feedback, connections, and relationships, all of which are part of system mapping.

f. System Mapping:
System mapping is one of the tools in system thinking. The principle involves identifying and mapping each component (variable) to understand how they relate, interact, and collaborate within a system. However, to intervene or implement policies (which will dramatically alter the system's behavior/dynamics), more in-depth research is still needed.

The following is the research framework developed to address the study being conducted:

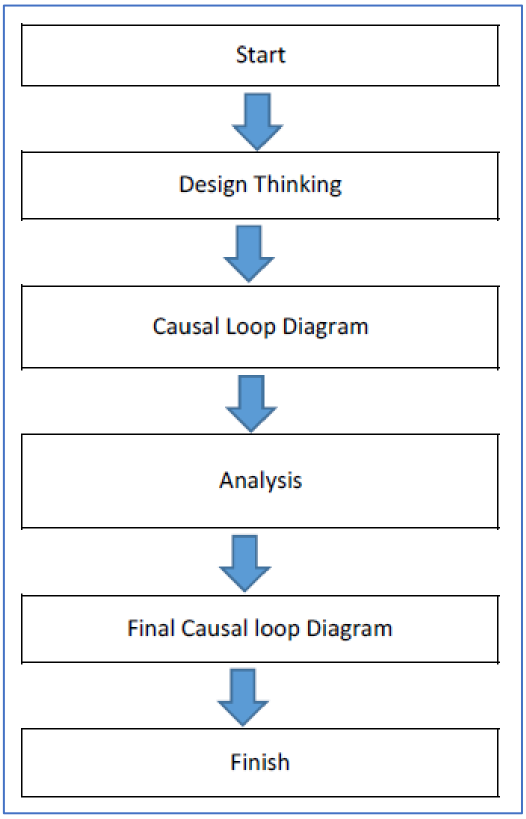

Figure 1. Research Framework

This research framework begins with the initial stage, where the research process related to carbon tax policy is clearly formulated, including the research objectives and the scope of the issues to be investigated. This stage is crucial to ensure that the entire research process has a clear direction and is focused on the objectives to be achieved. Next, the process moves into the Design Thinking phase, where the methods used aim to deeply understand the problem and identify the needs of various stakeholders involved. In this stage, data collection and literature review are conducted to gain a comprehensive understanding. This process involves steps such as understanding the problem's context, defining the problem specifically, generating solution ideas, and creating an initial model of the proposed solution.

The subsequent phase involves the creation of a Causal Loop Diagram (CLD), which maps the cause-and-effect relationships between various factors related to carbon tax policy. This diagram helps visualize the complexity of the system under investigation by identifying potential positive and negative feedback loops. Once the CLD is completed, an analysis phase is conducted to ensure the diagram's accuracy and relevance to real-world conditions. The analysis involves triangulation of sources by delving into insights from three groups: internal stakeholders, external stakeholders, and academics, as well as further investigation into the carbon tax policy. This process aims to test the reliability and validity of the developed model, ensuring that all identified causal relationships accurately reflect reality.

The next stage is the Final Causal Loop Diagram, where the validated diagram is updated and refined based on findings from the validation phase. These revisions result in a final diagram that is more accurate and representative of the system being studied. This final diagram then serves as the basis for formulating more effective and efficient policy recommendations. Finally, the research process concludes with the compilation of research findings, including the final CLD, and policy recommendations based on the conducted analysis. These recommendations are intended to guide policymakers in designing and implementing carbon tax policies that are more effective in reducing carbon emissions and their negative impacts on the environment, while also considering their effects on industry and society. Overall, this research framework provides a systematic and comprehensive approach to understanding and developing carbon tax policies, involving in-depth analysis and empirical validation to ensure that the resulting policies are truly effective and practically applicable.

Data for this study were collected from both secondary and primary sources. Secondary data included peer-reviewed literature, government policy documents, statistical databases (e.g., Global Carbon Atlas, IEA, and national statistics), and relevant academic publications. Primary data collection involved semi-structured interviews and focus group discussions (FGDs) with policymakers (Ministry of Finance), academics, and private sector representatives.

The triangulation process was conducted in three stages: literature triangulation to identify relevant variables, expert triangulation through stakeholder consultations to validate causal relationships, and model triangulation via iterative revisions of the CLD based on expert feedback. To strengthen validity, the CLD structure was partially cross-validated against actual statistical data for key variables such as coal consumption, CO2 emissions, and electricity demand. This consistency check ensured the alignment of the qualitative model with empirical trends, thereby enhancing the model’s credibility.

In application, system thinking is expressed through tools used to model emerging phenomena, such as the Causal Loop Diagram (CLD). The CLD depicts the dynamic interactions among the system’s variables, thereby explicitly revealing the system's structure (Prahasta, 2018). The utilization of system thinking serves as a foundational conceptual study to address complexities, particularly concerning carbon tax policy in Indonesia. This approach enables the clear identification of influencing factors and allows for further analysis based on the developed Causal Loop Diagram model.

3. RESULTS AND DISCUSSIONS

3.1 Results

Various literature related to carbon taxes has been studied, and the factors influencing carbon tax policies can be identified as follows:

Table 1. Factors Related to Carbon Tax Policies

No	Factor	Indicator	Cause-Effect Relationship	Reference
1	Industry	+	Electricity Demand	Determinants of electricity demand in the industrial and commercial sector in Indonesia (Sapta et al., 2024) Jurnal Paradigma Ekonomika Vol.19. No.1, Januari -April 2024.
2	The Population of the Community	+	Electricity Demand	Energy Consumption and Economic Growth in Indonesia (Dat et al., 2020) International Journal of Energy Economics and Policy, 2020, 10(5), 601-607.
3	Electricity Demand	+	Non-Coal-Fired Power Plants (Other Alternatives)	Model conceptualization for policy analysis in renewable energy development in Indonesia by using system dynamics (Hidayatno et al., 2019) International Journal of Smart Grid and Clean Energy
4	Electricity Demand	+	Coal-Fired Power Plant	Indonesia's Electricity Demand and the Coal Sector: Export or meet domestic demand? (Cornot-Gandolphe, 2016).
5	Coal-Fired Power Plant	+	Coal Demand	Multi-objective optimization on total cost and carbon dioxide emission of coal supply for coal-fired power plants in Indonesia (Baskoro et al., 2022)Socio-Economic Planning Sciences.
6	Coal Demand	-	Coal-Fired Power Plant	Multi-objective optimization on total cost and carbon dioxide emission of coal supply for coal-fired power plants in Indonesia (Baskoro et al., 2022) Socio-Economic Planning Sciences.
7	Coal Demand	+	CO2 Emissions	The Causality Between Energy Consumption and Carbon Emission in Indonesia (Lismiyah et al., 2024) Jurnal Riset Ilmu Ekonomi.
8	CO2 Emissions	+	Environmental Pollution	The detrimental effects of dirty energy, foreign investment, and corruption on environmental quality: New evidence from Indonesia (Pujiati et al., 2023) Environmental Economics and Management, a section of the journal Frontiers in Environmental Science.
9	Environmental Pollution	-	Industry	The Impact of Population Density and Economic Growth on Environmental Quality:Study in Indonesia (Wafiq & Suryanto, 2021) Jurnal Ekonomi & Studi Pembangunan.

Table 1. (continued)

No	Factor	Indicator	Cause-Effect Relationship	Reference
10	Environmental Pollution	-	The Population of the Community	The Relationship Between Environmental Degradation, Poverty and Human Quality in Indonesia (Oktavilia et al., 2018) E3S Web of Conferences 73,10020
11	CO2 Emissions	+	Carbon Tax Revenue	The effect of carbon tax on per capita CO2 emissions (Lin & Li, 2011) Energy Policy 39 (2011) 5137–5146
12	Carbon Tax Revenue	+	National Revenue	The Contribution Of Carbon Taxes To Economic Progress In Indonesia (Azis et al., 2023) Jurnal Riset Bisnis Vol 7 (1) (Oktober 2023) hal: 78 – 92
13	Non-Coal-Fired Power Plants (Other Alternatives)	+	National Revenue	The role of renewable energy, tax revenue and women governance in environmental degradation for developing Asian countries (Kuziboev et al., 2024). Energy Nexus 13 (2024) 100262
14	Carbon Tax Revenue	+	Current Tax Rates	Comparative analysis of carbon border tax adjustment and domestic carbon tax under general equilibrium model: Focusing on the Indonesian economy (Ramadhani & Koo, 2022). Journal of Cleaner Production 377 (2022) 134288
15	Current Tax Rates	-	Carbon Tax Revenue	Comparative analysis of carbon border tax adjustment and domestic carbon tax under general equilibrium model: Focusing on the Indonesian economy (Ramadhani & Koo, 2022). Journal of Cleaner Production 377 (2022) 134288
16	Current Tax Rates	+	Tax Costs in Coal-Fired Power Plants	Kebijakan Ketenagalistrikan Di Bidang Perlindungan Dan Pengelolaan Lingkungan Hidup Sejak Berlakunya Undang-Undang Cipta Kerja (Studi Pada PLTU Batubara Tarahan) (Aditama, 2022) Masters Thesis, Univesitas Lampung
17	Tax Costs in Coal-Fired Power Plants	+	Proposal for Reducing Coal Usage	Taxing coal to hit the goals: a simple way for Indonesia to reduce carbon emissions. (Sumarno & Laan, 2021) Winnipeg: International Institute for Sustainable Development (IISD)

Table 1. (continued)

No	Factor	Indicator	Cause-Effect Relationship	Reference
18	Proposal for Reducing Coal Usage	-	Coal-Fired Power Plant	Taxing coal to hit the goals: a simple way for Indonesia to reduce carbon emissions. ((Sumarno & Laan, 2021) Winnipeg: International Institute for Sustainable Development (IISD)
19	Coal-Fired Power Plant	+	CO2 Emission Calculation Analysis	Comparing "Carbon Tax" and "Cap and Trade" as Mechanism to Reduce Emission in Indonesia (Putra et al., 2021) International Journal of Energy Economics and Policy, 2021, 11(5), 106-111
20	CO2 Emission Calculation Analysis	+	Carbon Tax Revenue	Carbon Pricing And Its Monitoring System Asa State Revenue (Saputra et al., 2022) Indonesian Treasury Review: Jurnal Perbendaharaan, Keuangan Negara dan Kebijakan Publik

The analysis conducted regarding the factors influencing carbon tax policy, after being examined using system thinking and Causal Loop Diagram (CLD), is as follows:

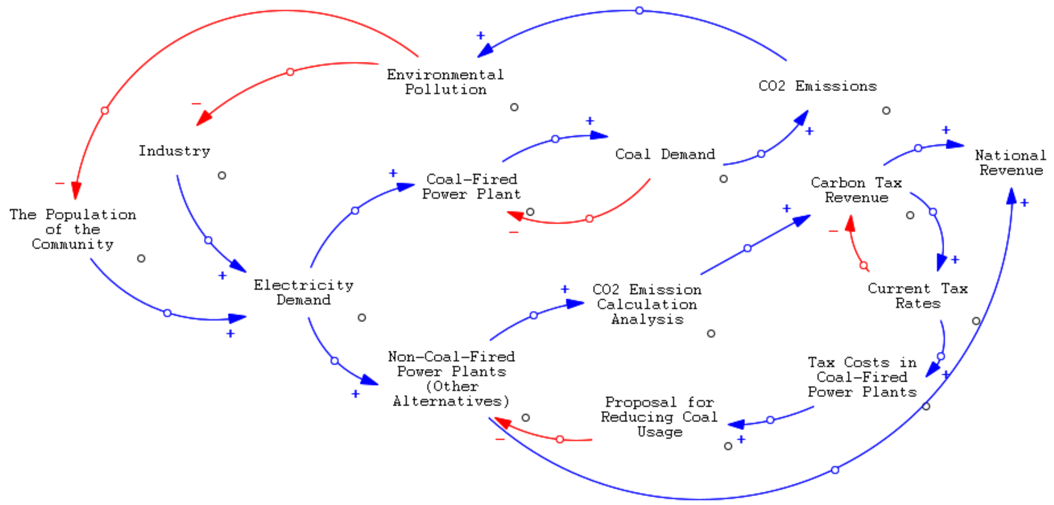

Figure 2. Carbon Tax Causal Loop Diagram

The Causal Loop Diagram (Figure 2) demonstrates the intricate relationships among these variables, highlighting feedback loops that affect the success of carbon tax policies. For example, rising electricity demand leads to greater coal consumption, subsequently increasing CO_2 emissions and environmental degradation. On the other hand, the introduction of carbon taxes and the advancement of alternative energy sources seek to counteract these effects by decreasing coal dependency while generating additional government revenue.

The Causal Loop Diagram (CLD) developed in this study reveals the complex dynamic interactions that shape Indonesia's carbon tax policy. Three primary feedback loops are identified and explained in detail. The first is the Reinforcing Loop : Coal Demand Loop. In this loop, economic growth leads to increasing electricity demand. Since coal-fired power plants remain the dominant energy source in Indonesia, higher electricity demand results in higher coal consumption. Consequently, this drives up carbon dioxide (CO2) emissions, further contributing to environmental degradation. The second is the Balancing Loop : Carbon Tax Revenue Loop. The introduction of the carbon tax imposes additional costs on coal consumption, incentivizing both industries and power producers to shift toward alternative and renewable energy sources. As carbon tax revenue grows, the government gains financial resources that can be reinvested into renewable energy development, improving energy diversification and gradually reducing reliance on coal. The third is the Policy Feedback Loop : Fiscal Capacity Loop. Increased revenue from the carbon tax strengthens the government's fiscal capacity, enabling the implementation of broader climate mitigation programs. This expanded fiscal space allows for greater investment in green infrastructure, public education, and technological innovation that collectively support long-term decarbonization.

To deepen the understanding of the policy implications, a what-if scenario simulation was performed. This analysis assessed the possible outcomes of raising the carbon tax rate from IDR 30/kg CO_2e to IDR 150/kg CO_2e. The findings indicate that a higher carbon tax would significantly decrease both coal consumption and CO_2 emissions. Furthermore, the increased cost of carbon-intensive energy would accelerate investment in renewable energy technologies. While some economic adjustment is expected, especially in carbon-dependent sectors, the negative impacts can be mitigated through targeted government subsidies, fiscal support programs, and transitional assistance for vulnerable industries and low-income households. Overall, the higher carbon tax scenario offers a pathway to achieving significant environmental benefits while maintaining economic stability, provided that supportive policy measures are simultaneously implemented.

3.2 Discussions

The findings of this research contribute new perspectives to the existing body of literature, as prior studies have not utilized system thinking and causal loop diagrams to examine carbon tax policies within Indonesia's context. This absence highlights the distinctiveness of the present study, which employs dynamic modeling to analyze the intricate relationships between carbon tax policies and multiple economic and environmental variables in Indonesia. Through the application of system thinking, this research generates fresh insights into the possible effects of carbon tax mechanisms — a subject not previously addressed in Indonesian studies. The increasing focus on carbon emissions and the adoption of policies such as carbon taxation reflect a global recognition of the pressing need to address climate change. As one of the leading carbon emitters globally, Indonesia's implementation of a carbon tax, particularly targeting the coal-fired power sector, marks a crucial move toward reducing its environmental footprint. This discussion will further examine the implications of Indonesia's carbon tax policy, evaluating its potential effectiveness, associated challenges, and its broader economic, environmental, and societal impacts.

a. The Effectiveness of Carbon Tax in Reducing Emissions

The main goal of implementing a carbon tax is to lower greenhouse gas emissions by assigning a financial penalty to carbon-intensive activities, thereby motivating both businesses and individuals to transition toward cleaner energy sources and technologies. Ideally, the carbon tax should promote a reduction in coal usage—one of the primary contributors to carbon emissions in Indonesia—in favor of more sustainable energy alternatives. The cap-and-tax mechanism applied to coal-fired power plants, as regulated by the Ministry of Energy and Mineral Resources, seeks to control emissions by establishing a limit on permissible emissions levels and imposing taxes on any emissions that exceed this cap.

However, the effectiveness of the carbon tax in reducing emissions depends on several factors. First, the set tax rate of IDR 30 per kg of CO2e, while a starting point, may not be high enough to significantly deter coal use, especially given the relatively low cost of coal compared to alternative energy sources. Studies suggest that for a carbon tax to be effective, it needs to be set at a level that reflects the true social cost of carbon, which includes the environmental and health impacts of emissions. If the tax rate is too low, it may not provide sufficient economic pressure to drive substantial changes in energy production and consumption.

Second, the effectiveness of the carbon tax is also contingent on the availability of viable alternatives to coal. Indonesia's energy infrastructure is heavily reliant on coal, and transitioning to renewable energy sources requires substantial investment in new technologies, grid modernization, and capacity building. Without significant government support for renewable energy development, such as subsidies, incentives, and investment in research and development, the carbon tax alone may not be enough to prompt a significant reduction in emissions.

b. Economic Impacts and Challenges

The implementation of a carbon tax in Indonesia offers both economic opportunities and challenges. On one side, this tax has the capacity to generate significant government revenue that could be reinvested in various environmental programs, including renewable energy development, reforestation efforts, and climate adaptation strategies. Such investments may yield long-term economic advantages, such as the creation of jobs within the green energy sector, improved public health resulting from lower air pollution levels, and increased resilience to the impacts of climate change.

Conversely, concerns exist regarding the potential economic strain on industries, especially those highly reliant on coal, such as manufacturing and power generation. These sectors may encounter rising operational expenses due to the carbon tax, potentially leading to higher consumer prices, diminished global competitiveness, and possible job losses. To address these concerns, the government may adopt complementary policies, such as offering financial assistance or tax incentives to companies that invest in clean technologies or implement energy efficiency improvements.

An additional challenge lies in the possible financial burden on low-income households, who may experience greater hardship from increased energy costs. To alleviate this, the government could introduce protective measures for vulnerable groups, including subsidies or rebates to offset electricity expenses, as well as investing in energy efficiency programs designed to lower household energy usage..

c. Environmental and Social Implications

The carbon tax has significant environmental implications, particularly in terms of its potential to reduce air pollution and improve public health. Coal-fired power plants are a major source of air pollutants, including particulate matter, sulfur dioxide, and nitrogen oxides, which contribute to respiratory and cardiovascular diseases. By reducing coal consumption, the carbon tax could lead to cleaner air and improved health outcomes for the population.

In addition to its environmental benefits, the carbon tax could also have positive social implications by raising awareness about the need for sustainable energy practices and encouraging behavioral changes. As businesses and individuals become more conscious of the carbon footprint of their activities, they may be more likely to adopt energy-saving measures, such as using public transportation, improving energy efficiency in buildings, and reducing waste.

However, the social acceptance of the carbon tax is crucial for its success. Public resistance to the tax, particularly if it is perceived as disproportionately affecting low-income groups or certain industries, could undermine its effectiveness. Therefore, it is important for the government to engage in transparent and inclusive communication with the public, explaining the rationale behind the tax and its long-term benefits for the environment and society. Public education campaigns and stakeholder consultations could help build support for the carbon tax and ensure its successful implementation.

d. Broader Policy Implications and Recommendations

The implementation of the carbon tax in Indonesia should be considered as an integral component of a comprehensive policy framework designed to achieve sustainable development objectives. To enhance its effectiveness, the carbon tax needs to be coordinated with other environmental measures, such as emissions trading programs, renewable energy requirements, and energy efficiency regulations. For instance, the government may explore the possibility of extending the cap-and-trade system to include additional sectors or adopting a flexible carbon pricing mechanism that adjusts tax rates in response to emission levels and prevailing economic conditions.

In addition, the revenue collected from the carbon tax should be strategically utilized to facilitate the transition toward a low-carbon economy. This may involve investing in renewable energy initiatives, improving public transportation systems, and providing assistance to communities and industries that are most impacted by the shift away from fossil fuel dependence. By directing the revenue toward projects that yield both environmental and societal benefits, the government can ensure that the carbon tax supports the broader pursuit of sustainability.

Finally, ongoing monitoring and evaluation of the carbon tax's impact are essential to ensure its effectiveness and to make necessary adjustments over time. The government should establish a robust framework for tracking emissions, assessing the economic and social impacts of the tax, and soliciting feedback from stakeholders. This will allow for continuous improvement of the policy and help to ensure that Indonesia meets its climate targets.

The implementation of a carbon tax inherently involves important normative trade-offs that need to be carefully addressed. From a microeconomic perspective, carbon emissions represent a negative externality, where private market actors fail to internalize the full social costs of their carbon-intensive activities. In this context, a Pigouvian tax such as the carbon tax serves to correct the market failure by aligning private costs with social costs. However, the imposition of such a tax may also introduce certain inefficiencies if not designed optimally.

One key economic concern is the potential for deadweight loss, as higher energy costs may reduce production, consumption, and overall economic efficiency. This risk can be particularly pronounced if the tax is set at a level that significantly burdens industries with limited capacity to transition to cleaner alternatives. However, empirical studies suggest that when carbon tax revenues are recycled effectively—such as through investment in renewable energy and green infrastructure—these efficiency losses can be mitigated, supporting the double dividend hypothesis. The first dividend comes from reducing environmental externalities, while the second arises from improvements in economic efficiency via revenue recycling.

Another important consideration is the tax incidence and its regressive impact. Carbon taxes tend to disproportionately affect lower-income households, which spend a larger portion of their income on energy-related expenses. Additionally, workers and businesses in the informal sector may lack the resources to adapt to rising energy costs, exacerbating income inequality and social vulnerability. To address these distributional challenges, targeted compensation mechanisms are necessary. These could include direct cash transfers, energy subsidies for low-income households, or financial support for small businesses in the informal sector to facilitate their transition toward greener operations.

Furthermore, broad implementation of carbon taxes may create both incentives and disincentives across various sectors. On the positive side, higher carbon prices encourage investments in energy efficiency, renewable energy, and low-carbon technologies. Conversely, without proper transitional support, high carbon taxes may discourage investment in emission-intensive industries, potentially leading to job losses and economic displacement, particularly in regions dependent on coal and fossil fuel production.

Therefore, the design of carbon tax policy must balance environmental effectiveness with economic and social equity. Gradual tax rate increases, combined with revenue recycling and comprehensive social safety nets, can minimize potential adverse effects while maximizing both environmental and economic benefits. A well-designed carbon tax can thus serve as an effective instrument to simultaneously reduce emissions, promote economic resilience, and ensure inclusive growth.

4. CONCLUSIONS

The introduction of a carbon tax in Indonesia constitutes a pivotal element in the nation's strategy to lower greenhouse gas emissions and address climate change. By assigning a monetary value to carbon emissions, the tax is intended to encourage both businesses and individuals to shift toward cleaner energy sources and adopt environmentally friendly technologies. Nonetheless, the effectiveness of this policy is influenced by several factors, such as the appropriateness of the tax rate, the accessibility of alternatives to coal, and the implementation of complementary supporting policies.

Economically, the carbon tax holds the potential to generate significant government revenue and foster investments in renewable energy and other environmental projects. At the same time, it poses challenges, particularly for coal-dependent industries and low-income households that may experience increased energy expenses. To mitigate these challenges, the government should consider enacting measures that protect vulnerable groups and assist industries in adopting cleaner technologies.

From environmental and social standpoints, the carbon tax may help decrease air pollution, enhance public health, and raise awareness about the necessity of sustainable energy practices. However, public support is essential for the policy's success, requiring the government to engage in open communication and educational initiatives to build public trust and acceptance.

In summary, while the carbon tax offers a promising pathway for emission reduction and sustainability promotion, it should be integrated into a broader policy framework that includes additional environmental regulations and strategies. The government must ensure that the generated revenue is utilized effectively to facilitate the transition toward a low-carbon economy, while regularly reviewing and adjusting the policy to ensure its long-term effectiveness. This approach will enable Indonesia to advance toward its climate objectives and contribute meaningfully to global climate change mitigation efforts. Future studies may explore combining the Causal Loop Diagram method with quantitative System Dynamics or Agent-Based Modeling to conduct more detailed simulations and policy analyses, offering deeper insights into the long-term consequences of carbon tax implementation.

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