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Environmental Policy Implications of Carbon Tax Implementation Using Natural Language Processing

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ABSTRACT

One of the adopted policies to contribute to this effort is the carbon tax policy, which is being implemented in several countries. However, its effectiveness remains heavily affected by public perceptions and reactions. Therefore, this paper explores the environmental policy implications of carbon tax implementation in Indonesia using a Natural Language Processing (NLP) approach. As seen, the data were directly surveyed from 377 respondents and analyzed using the BERT model. After analysis, most respondents feel positive about the carbon tax, stating that with a policy like that, levels of pollution will be reduced in a green economy. Word clouds of text data bring to the fore important keywords on carbon tax — 'emission', 'climate change', and 'green economy'- pointing to the actual gist on which the public discourse is centered. The correlation analysis also shows a strong relationship between perceptions of the carbon tax with views on economic and environmental impacts. The implications are useful for policymakers to come up with a communication strategy optimization and an implementation of the carbon tax in Indonesia, considering public concerns and expectations.

1. INTRODUCTION

Climate change has today taken over and is the most predominant global challenge, causing impacts on the environment, economy, and social life worldwide. According to the most recent report by the Intergovernmental Panel on Climate Change (IPCC), without sharp mitigation actions, global temperatures are likely to rise by more than 1.5℃ in the coming decades, which would seriously threaten ecosystems and human societies. This global urgency necessitates localized action, and for Indonesia-a major emitter of greenhouse gases-balancing developmental priorities with global climate commitments presents a complex challenge. Data from the Ministry of Environment and Forestry shows that the largest sources of carbon emissions in Indonesia are in the energy and land sectors. The Indonesian government has, therefore, committed itself to reducing greenhouse gas emissions by 29% on its own or up to 41% with international support by the year 2030 in line with the Paris Agreement.

One of the cornerstone strategies proposed to achieve these targets is the implementation of a carbon tax. It is believed that the imposition of this tax will result in alterations in industry and societal behavior toward more environmentally friendly actions because firms will be motivated by economic reasons to reduce their emissions. However, the success of the implementation is highly contingent on public acceptance and perception. A national research institute has recently surveyed and found that 70% of the polled people support this initiative, but 45% expressed fear of its negative impact on the economy, particularly in sectors sensitive to policy changes.

The Indonesian government placed the carbon tax as one of the tools necessary to reach high targets for emission reductions proposed under the Paris Agreement. Under an environmental political-economic agenda, a carbon tax is believed to make industries internalize the costs of negative externalities in the hope that economic behavior will be steered to ensure more environmentally sustainable practices. Underscores the potential of carbon taxation, particularly when complemented by supportive measures like energy subsidies and incentives for energy efficiency [1, 2]. The carbon tax in Indonesia is seen to bring emission reduction but also induce a structural transition into the green economy, in which investments with clean technologies and in renewable energy will become attractive to potential investors.

However, the success of the carbon tax policy in Indonesia heavily depends on public and business acceptance. Public support for a carbon tax is also highly sensitive to public perceptions of the economic impact of the policy. Research in Indonesia revealed that the primary worries of public respondents are associated with rising prices of goods and services, potentially exacerbating inequality [3]. The last national survey shows that although 70% of them support the implementation of the carbon tax, almost half express concern over how this will affect their purchasing power, especially in energy-sensitive industries. These are concerns that manifest from earlier findings that show that policy on carbon taxing

has to take into consideration social equity for more considerable support.

To address these challenges, analyzing public sentiment becomes crucial. This study leverages Natural Language Processing (NLP), specifically the BERT model, to analyze sentiments and opinions expressed in a national survey. NLP offers significant advantages over traditional methods by enabling in-depth, contextual analysis of large-scale textual data, capturing nuanced public perceptions [4]. Natural Language Processing (NLP) methodologies are effective in identifying patterns in public sentiment and may offer valuable insights for the development of policies that are more responsive to the needs and concerns of the public [5]. As such, this study does not focus solely on the understanding of public perceptions but is also directed toward providing policy recommendations that can increase the effectiveness and acceptance of carbon tax policy in Indonesia.

2. METHOD

2.1 Survey methodology

The target population of this study consisted of individuals in Indonesia who have an understanding of and interest in carbon tax policies. A purposive sampling method was used to ensure respondents represented diverse socio-economic, educational, and professional backgrounds, which would provide varied insights into the topic. While the mixed-method approach-combining online and manual distribution of questionnaires-helped achieve broader coverage, potential biases were identified. These include an overrepresentation of individuals with access to digital platforms and a possible self-selection bias, where respondents with strong opinions were more likely to participate. To mitigate these biases, manual distribution was employed to reach participants without reliable internet access, and neutral messaging was used to encourage broader participation, ensuring the inclusion of a diverse set of perspectives.

2.2 BERT approach and implementation

The BERT-Base Uncased model approach, introduced by Devlin's, is applied in this study to analyze the sentiment of open survey responses regarding the carbon tax policy in Indonesia [6]. The model consists of 12 transformer layers, 768 hidden units, and 12 attention heads, with a total of 110 million parameters. The model allows for training on large corpora, including BooksCorpus and English Wikipedia. The BERT model also effectively captures contextual relationships in text, making it highly suitable for nuanced sentiment analysis. For this research, the survey dataset was divided into 80% training data and 20% testing data, with sentiment categories labeled as positive, negative, or neutral. Text preprocessing includes tokenization using the BERT tokenizer, normalization, and attention mask creation to ensure compatibility with the model. The fine-tuning process uses categorical cross-entropy loss and the AdamW optimizer to refine the pre-trained weights for the sentiment analysis task.

The Hyperparameter Configuration is specifically tasked with fine-tuning the BERT model as follows:

- Learning Rate: 2e-5
- Batch Size: 16
- Epoch: 4
- Dropout Rate: 0.1

These configurations ensure optimal performance during training, preventing overfitting while allowing the model to effectively generalize across various sentiment categories. Finally, the model evaluation uses accuracy, precision, recall, F1-score, and confusion matrix to assess classification performance and identify classification errors. The BERT model successfully captured complex public sentiment, such as positive opinions accompanied by economic concerns or negative opinions acknowledging environmental benefits. These insights provide actionable recommendations to improve the design and communication of carbon tax policies in Indonesia.

3. RESULTS

3.1 Data pre-processing

Data pre-processing is important for observing how text processing affects analysis outcomes and ensuring that the data utilized in subsequent analyses appropriately represents the respondents' original message (Figure 1).

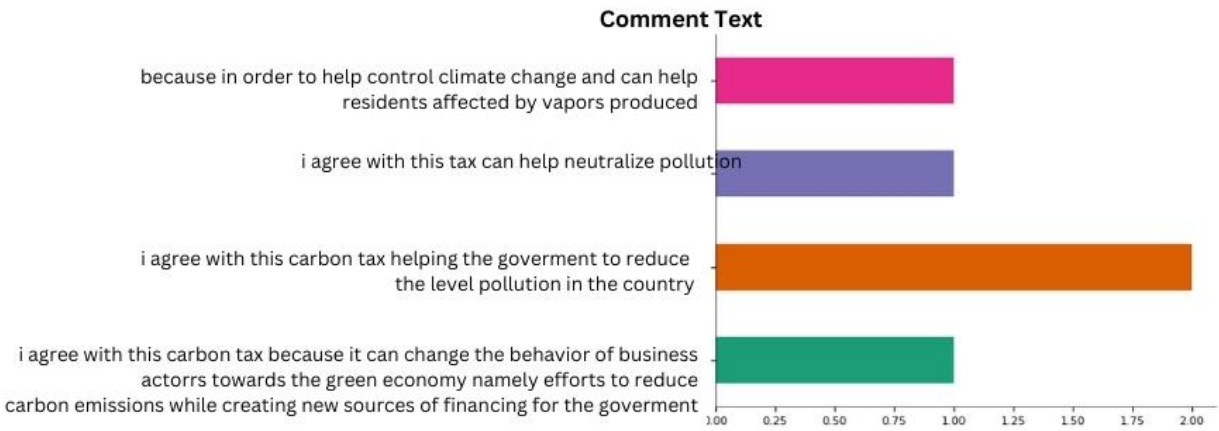

Figure 1. Categorical distributions

First Chart

This chart shows the original text from respondents regarding the carbon tax. Each line of text is evaluated to see how frequently various reasons or justifications for supporting or opposing the carbon tax policy are mentioned. The color and length of the bars indicate the frequency or proportion of each reason that appears in the original text.

Second Chart (Cleaned Text)

This chart shows text that has been cleaned up, which may involve the removal of punctuation, stopwords, and irrelevant words. The idea is to capture the key message without distractions from non-essential text elements. The end output is typically cleaner and concentrates on significant keywords or phrases.

Third Chart (Lemmatized Text)

This chart depicts the outcomes of text that has been lemmatized, which entails translating words in the text to their base form (lemma). For example, verbs in various forms (such as “running” and “ran”) are reduced to their base form “run”. This procedure helps to normalize the text, making the analysis more accurate and consistent.

3.2 Sentiment analysis

The sentiment analysis of the survey data conducted using the BERT model provides a clear picture of how the carbon tax policy in Indonesia is received by the public. Out of a total of 376 texts analyzed, 96.28% (or 362 out of 376 texts) showed neutral or positive sentiment towards this policy, represented by LABEL_0. Conversely, only 3.72% (or 14 out of 376 texts) showed negative sentiment, represented by LABEL_1, as shown in Table 1.

Table 1. Sentiment propositions

Sentimen	Count	Propositions
Label_0 (Positive Sentiment)	362.000000	96.276596
Label_1 (Negative Sentiment)	14.000000	3.723404
Total Text	376.000000	100.0
Average Text Length (words)	16.468085	-

Furthermore, it is shown that the average length of the analyzed texts is approximately 16.47 words per text. This indicates that respondents generally provide brief yet concise responses, which are sufficient for the BERT model to capture the sentiment within them. These results suggest that the majority of respondents have a neutral or positive view towards the carbon tax, indicating a relatively high level of public acceptance. Conversely, the proportion of negative sentiment is relatively small. This analysis is important to highlight the presence of certain concerns or resistance to the policy, which can be further examined through in-depth analysis. Furthermore, the table visualization is supported by Figure 2.

This statistic indicating that more than 96% of respondents are either neutral or positive towards the carbon tax is quite significant. It indicates that the policy is not significantly unpopular, but it may be contentious among specific groups where it may face criticism. Potential advantages of such a policy were readily apparent to respondents: its direct

contribution to the reduction of carbon emissions and the mitigation of climate change, as well as its indirect influence on enhancing environmental quality. By contrast, a mere 3.72% of all responses conveyed unfavorable attitude; nonetheless, it is important to consider this in context. The expression of negative attitude by individuals may be attributed to certain issues, such as the economic ramifications of the carbon tax, its influence on the cost of living, or uncertainties regarding the efficacy of the policy. These concerns may indicate opposition to policy implementations that impact energy and manufacturing expenses, which will eventually be transferred to consumers.

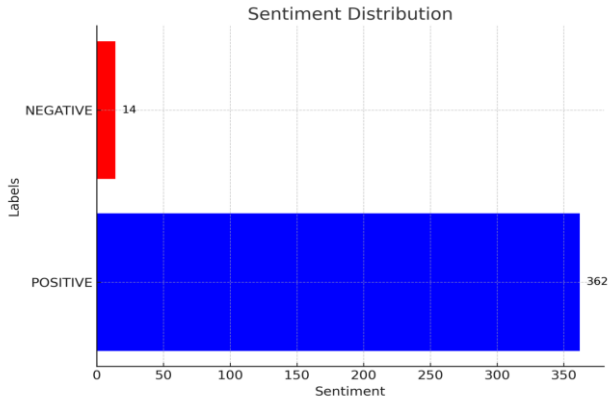

Figure 2. Distribution of sentiment

Furthermore, the sentiment intensity distribution analysis in Figure 3 shows the distribution of sentiment intensity measured from the analyzed texts. Sentiment scores typically range from -1 (very negative) to 1 (very positive), with 0 being neutral.

Peak at Neutral Sentiment Score

The largest peak in this graph occurs at a sentiment score of 0, suggesting that the majority of respondents have a neutral attitude toward the presented issue. This could indicate that many respondents do not have strong opinions (positive or negative) about the carbon tax, or that they have neutral attitudes or are unaffected by the legislation.

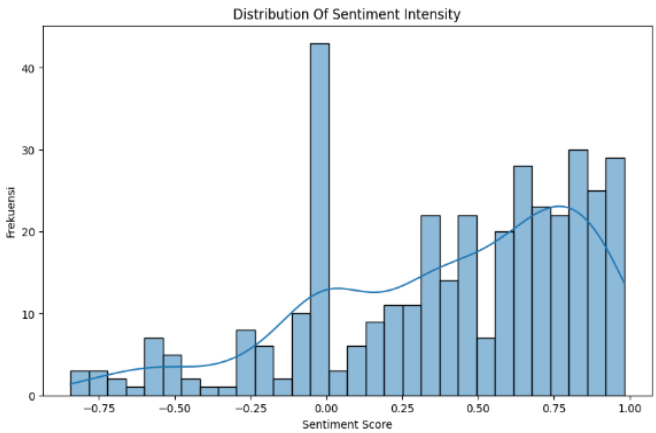

Figure 3. Distribution of sentiment intensity

Positive Sentiment Distribution

Most positive sentiment scores range from 0.25 to 1, with a fairly even distribution but tending to increase towards higher scores. This indicates a stronger tendency towards positive sentiment among respondents. Another significant peak is observed around 0.75, indicating that many respondents have a strongly positive view of the policy.

Negative Sentiment Distribution

On the other hand, negative sentiment scores range from -0.75 to 0, with a few small peaks around -0.5 and -0.25. However, the frequency of negative sentiment is lower compared to positive sentiment, suggesting that although there are some respondents who disagree or have negative views, their numbers are relatively smaller.

General Trend

The trend curve displayed in this graph provides an overview that despite variations in sentiment responses, the general trend leans towards neutral to positive sentiment. This is consistent with previous findings indicating that the carbon tax policy is, overall, well-received by the public.

3.3 Word cloud analysis

The word cloud generated from the text analysis shown in Figure 4 provides a visualization of the most frequently occurring words related to public perceptions of the carbon tax policy. Words displayed in larger sizes indicate higher frequency in the processed text, while words in smaller sizes appear with lower frequency.

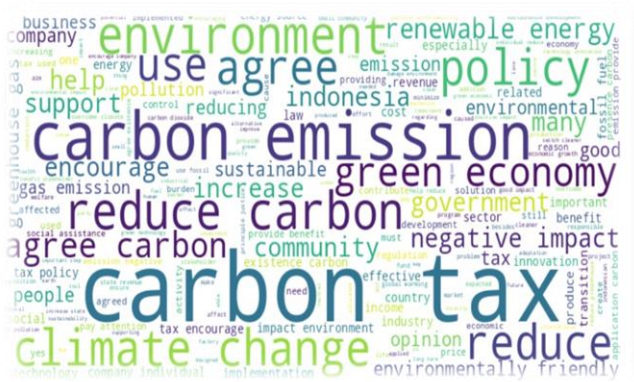

Figure 4. Word cloud chart

Target the topics of "Carbon" and "Tax"

The prevalence of the terms "carbon" and "tax" in this Word Cloud suggests that public discourse on this policy mostly centers around the fundamental elements of the regulation. These findings indicate that the participants regularly link the policy with its main objective of decreasing carbon emissions by means of taxation methods. Furthermore, the prevalence of these terms also indicates a distinct public comprehension of the essence of this program.

Particular focus on "Emission", "Climate Change", and "Environment"

Terminology such as "emission," "climate change," and "environment" also emerge prominently, suggesting that a significant number of participants comprehend and link the carbon price with wider environmental concerns. These findings indicate that there is a significant level of public consciousness of the adverse effects of carbon emissions on climate change and the environment. The majority of respondents are expected to endorse this strategy due to their perception of it as a crucial instrument in addressing climate change and safeguarding the environment.

Definitions of "Green Economy" and "Renewable Energy Technology"

The terminology "green economy" and "renewable energy" suggests that the public associates carbon pricing with the transition to a more ecologically conscious economy. The public seems to recognize that instituting a carbon price might aid in the shift from fossil fuels to renewable energy sources, while also accelerating the adoption of eco-friendly technologies that foster a healthy economy. The findings indicate that the policy is viewed not only as a means of decreasing emissions but also as a catalyst for broader economic reform.

Level of Support and Concerns: "Agree," An Analysis of "Support" and "Negative Impact"

Terminology such as "agree" and "support" denote substantial public endorsement of the carbon price proposal. Nevertheless, the inclusion of terms such as "negative impact" indicates apprehensions regarding the possible adverse consequences of this program. These worries may be associated with economic ramifications, such as the predicted increase in the cost of commodities and services, as also observed in the earlier mood research findings.

Definition and Function of "Government" and "Policy"

The prominent use of the terms "government" and "policy" suggests that the general public considers the government's involvement highly significant in the execution and administration of the carbon price. Moreover, this implies that the policy is perceived as a daring measure taken by the government to tackle climate change. Nevertheless, the general public may also anticipate that the government will guarantee the equitable and efficient implementation of the policy, so resolving the concerns that have emerged about its consequences.

3.4 Word frequency analysis

The bar chart in Figure 5 displays the 20 most frequently occurring words in the texts related to the carbon tax. The frequency of these words provides insights into the main themes and focus of public discussion related to this policy.

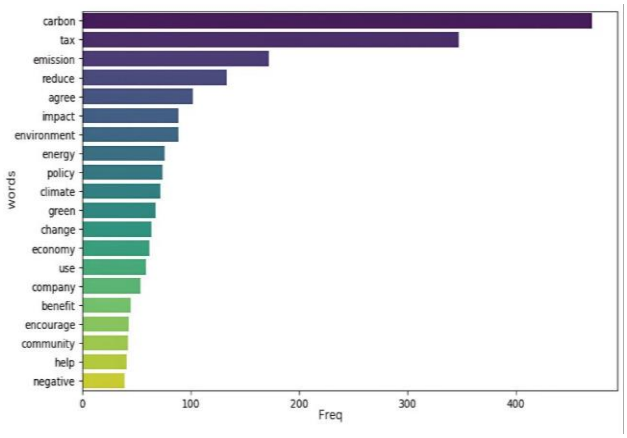

Figure 5. Word frequency

Prevalence of "Carbon" and "Tax"

The terms "carbon" and "tax" are the most commonly featured words in the text. Given that the main subject of the conversation is the carbon price policy, this outcome is somewhat predictable. The prevalence of these terms suggests that almost every participant links their conversation with the fundamental aspect of the policy, specifically the mitigation of carbon greenhouse gas emissions through taxation.

Emphasize the concepts of "Emission" and "Reduce"

Lexical terms such as "emission" and "reduce" also have a high frequency of usage. This indicates that the debate revolves not only on the theoretical framework of the carbon price but also on the primary objective of the policy, which is the mitigation of carbon emissions. The general populace appears to possess a heightened level of consciousness about the consequences of carbon emissions and the significance of their decrease as a measure to alleviate climate change.

Key Significance of "Agree" and "Impact"

The term "agree" signifies that a significant number of participants indicated their concurrence with this policy, therefore corroborating prior research findings on the prevalence of neutral or positive emotion. Conversely, the word "impact" is often mentioned, suggesting that the public is also exhibiting awareness of the effects of this legislation, whether they be beneficial or detrimental.

Emphasize the "Environment" and "Energy"

Lexical terms such as "environment," "energy," and "climate" indicate that the discourse extends beyond the economic dimensions of the carbon price to include environmental and energy concerns as well. This underscores the notion that the policy is perceived as a component of a more comprehensive approach to tackle climate change and facilitate the shift towards cleaner energy sources.

3.5 Bigrams analysis

Figure 6 shows the 20 most frequently occurring two-word combinations (bigrams) in the texts related to the carbon tax. Bigram analysis provides deeper insights into how concepts related to the carbon tax are combined in public discourse. The bigram analysis also shows that public discussion about the carbon tax is highly focused on core issues such as carbon emission reduction, climate change, and the green economy. While most discussions are positive or supportive, there is also attention to the potential negative impacts of this policy. For policymakers, this means it is important to communicate the long-term benefits of the carbon tax while also addressing public concerns about its impacts.

Analysis of the prevalence of "Carbon Tax" and "Carbon Emission"

The figure reveals that the two most prominent bigrams are "carbon tax" and "carbon emission," suggesting that public discussion is closely centered around two key elements of this policy: the mechanism of carbon taxation and the objective of decreasing carbon emissions. This aligns with the core objective of the carbon price program and the overall perception of it by the population.

Emphasize the reduction of emissions and the mitigation of climate risk.

Next most often appearing bigrams are "reduce carbon" and "climate change". This demonstrates that the general population is not only cognizant of the objective of the carbon price to decrease emissions, but also of its intricate link to the mitigation of climate change. The aforementioned statements underscore the significance of this strategy within the

framework of the worldwide climate emergency.

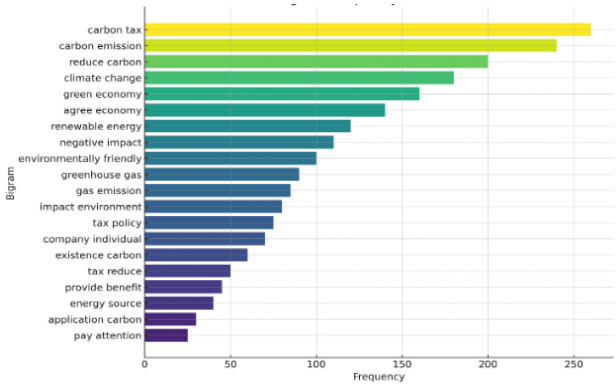

Figure 6. Bigrams chart

Relevance to the Green Economy

The presence of bigrams like "green economy" and "agree economy" implies that the general public also links this strategy with the shift towards a more environmentally friendly and sustainable economy. The general public appears to comprehend that the implementation of a carbon price can significantly stimulate the growth of the green economy by promoting investment in renewable energy and encouraging the adoption of ecologically sustainable corporate practices.

Analysis of Effects and Ecological Concerns

The presence of bigrams like "negative impact" and "environmentally friendly" suggests that there is ongoing debate over the positive and negative consequences of this strategy. Although the prevailing discourse seems to endorse the carbon price as an ecologically sound measure, there are still apprehensions regarding the possible adverse consequences, encompassing both economic and social aspects.

Implementation and Support of Policies

The bigrams "tax policy," "impact environment," and "renewable energy" emphasize facets of policy execution and the public perception of the carbon tax's function in encouraging the adoption of renewable energy. These findings indicate a substantial level of public consciousness regarding the proper implementation of this strategy and the anticipated results.

3.6 PCA and t-SNE visualization

The PCA and t-SNE visualizations shown in Figure 7 provide two different yet complementary perspectives in understanding the structure of topics discussed by the public regarding the carbon tax policy. By combining the findings from these two methods with sentiment analysis, a more comprehensive picture can be obtained of how this policy is received by the public and how various topics within the discourse correlate with positive or negative sentiment.

The PCA visualization reveals that the majority of data points are concentrated in a single region, suggesting that numerous respondents addressed largely analogous themes. The axes in PCA denote the primary components extracted from high-dimensional textual data. These components encapsulate the variance within the dataset, with PC1 (x-axis) accounting for the greatest variance and PC2 (y-axis) denoting the second greatest volatility. In t-SNE visualization, the axes lack direct explanation but represent the relative distances among data points in the reduced two-dimensional space. The clusters displayed using t-SNE relate to distinct topics or sentiment categories. The t-SNE cluster encompasses terms associated with 'positive sentiment,' including 'green economy' and 'environment,' while other clusters represent 'negative sentiment,' featuring terms such as 'economic burden' and 'price increase.' These clusters underscore the predominant societal perceptions on carbon pricing policies.

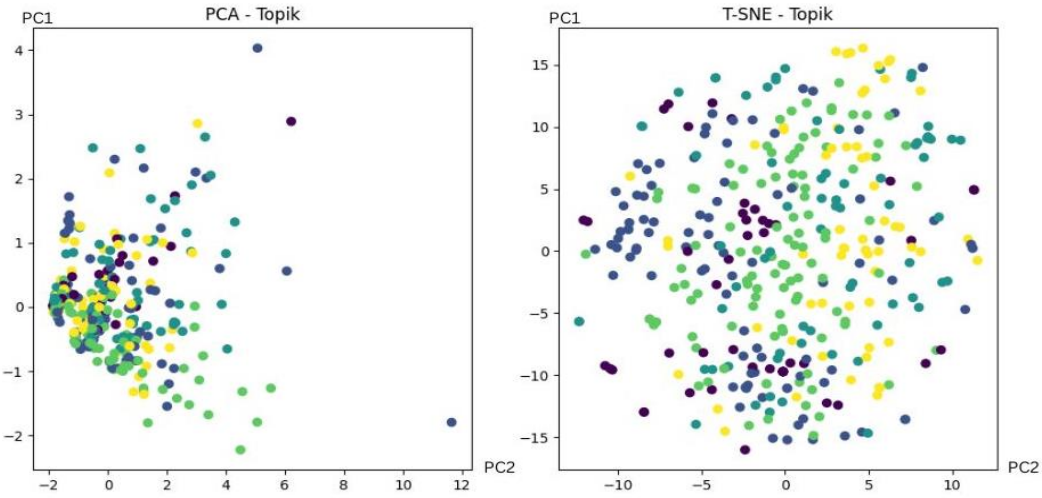

Figure 7. PCA and t-SNE chart

4. IMPLICATIONS OF FINDINGS ON PUBLIC PERCEPTION

The sentiment study revealed that the majority of respondents maintain a neutral to marginally positive perspective on the carbon price policy. This indicates that the environmental and economic benefits it offers are generally recognised by sentiment. Empirical evidence suggests that environmental policies are substantially influenced by robust public support [7]. The propensity to support carbon pricing legislation is positively correlated with an improved public comprehension of environmental issues [8]. The perception

and implementation of carbon pricing can be significantly enhanced through the implementation of effective public awareness campaigns [8]. Additionally, the public's perception of these activities is significantly influenced by the level of environmental consciousness [9]. Public awareness of the consequences of climate change is an indispensable component of obtaining public support for carbon pricing initiatives [10]. These results emphasise the significance of ongoing public participation, emphasising the necessity of educational programs to strengthen this positive sentiment and improve the public's understanding of the long-term benefits.

Negative opinions regarding the carbon pricing strategy were expressed by a small number of participants. The primary cause of this unfavourable sentiment is economic anxieties, particularly among individuals with lower incomes [11]. The rejection is significantly influenced by the perceived economic burden, as evidenced by concerns regarding potential price escalations resulting from the carbon tax [12]. The necessity of employing effective communication strategies and providing financial recompense to at-risk communities to address this issue is underscored by the disparity in tax responsibility distribution [13, 14]. Furthermore, public engagement and transparent tax distribution can promote trust and alleviate economic concerns [15].

Sustained success in the implementation of carbon pricing initiatives is contingent upon transparency and inclusivity. Empirical research suggests that public trust is improved by policy transparency [16]. The implementation of inclusive communication strategies that address public apprehensions and misconceptions may increase the support for these initiatives. Public perception has been improved by providing specific information about the environmental benefits of carbon prices and their role in addressing climate change [8]. Moreover, the public is more likely to endorse initiatives that incorporate social justice factors, such as equitable income distribution and subsidies [17].

Additionally, topic research suggests that the general public is apprehensive about the ecological and social consequences of carbon pricing initiatives, in addition to the economic implications. Public endorsement may be substantially enhanced by aligning carbon price policies with overarching sustainability objectives, such as an equitable energy transition and green innovation. Individuals are more inclined to provide substantial support when they comprehend the correlation between carbon taxes and sustainable development. Investments in renewable energy, in conjunction with policies that prioritise social justice, can promote greater acceptance. As a result, the effective implementation of carbon pricing mandates is contingent upon the incorporation of social justice and green innovation, which ensures that the mandates are in accordance with public expectations and overarching sustainability objectives [18-20].

5. CONCLUSION

This study shows that the majority of respondents have neutral to favorable feelings about the carbon tax policy, indicating strong public support for its ability to decrease carbon emissions and foster a green economy. However, a minority of people remain concerned, mainly about the perceived economic impact on low-income groups. These findings underscore the need of resolving socioeconomic differences in order to guarantee equitable policy adoption across various society sectors.

The application of the BERT model in this work constitutes a methodological improvement, allowing for the detection of complex public perceptions from large-scale textual data. By discriminating between good feelings with concerns and negative sentiments with constructive feedback, the model supplied policymakers with actionable insights. This highlights the model's ability to inform evidence-based environmental policy formulation, thereby closing the gap between public opinion and legislation.

While the study offers useful insights, it has limits. First, the use of purposive sampling may limit the generalizability of findings by overrepresenting digitally connected persons. Second, the success of the BERT model is dependent on the quality of labeled data, which may affect the depth of sentiment analysis. Third, the study's concentration on Indonesia limits the applicability of its findings to other sociopolitical settings.

Future study should address these limitations by using representative sampling methods and broadening the scope to include comparative studies from several nations. Furthermore, including longitudinal analysis could provide more detailed insights into the evolution of public attitude over time. Exploring various NLP models or hybrid approaches may improve the granularity and accuracy of sentiment analysis, providing better insights into public views toward environmental policies.

6. LIMITATIONS

This study offers significant insights into public mood regarding the carbon price policy; yet, certain limitations must be recognized. The dependence on the BERT model for sentiment analysis may introduce biases due to the training data, which might not adequately represent the diversity of public ideas. NLP models additionally encounter difficulties in interpreting intricate emotions, sarcasm, or cultural subtleties, resulting in oversimplification or misclassification of sentiments. The study exclusively utilizes survey text data, potentially overlooking non-verbal cues and broader contextual elements that shape public perception. The results are geographically confined to Indonesia, restricting their relevance to other cultural or socio-economic settings. To mitigate these limitations and foster wider acceptance of carbon tax policies, it is advisable for policymakers to prioritize transparency in revenue distribution, provide targeted economic assistance to at-risk populations, and align the policy with overarching sustainability objectives, including green innovation and social equity. Public communication initiatives must be prioritized to cultivate trust and awareness on the long-term advantages of carbon taxation, while also engaging stakeholders to promote inclusivity in policy formulation. Future study must address NLP biases by utilizing more representative datasets and incorporating qualitative methods, such as interviews, to capture complex public perspectives. Moreover, comparative and longitudinal research across many locations could enhance comprehension of the evolution of public sentiment and guide internationally pertinent policy strategies.

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