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Equity of Carbon Pricing Policies in Mitigating Climate Change: A Comparative Study of Different Policy Designs

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Abstract. *The study aims to evaluate the efficiency and fairness of different carbon pricing policy designs in mitigating climate change. A quantitative methodology is used, analyzing data from several countries and regions that have implemented carbon pricing policies like carbon taxes and cap-and-trade systems. The study utilizes regression analyses to assess the relationship between carbon pricing and greenhouse gas emissions, and statistical analysis to evaluate the distributional effects across different income groups and regions. The study finds that carbon pricing policies are effective in reducing greenhouse gas emissions, but their impact on household income distribution varies. Policies that include revenue recycling methods, such as rebates or investments in renewable energy, are more effective in reducing the regressive impacts on low-income households. The research indicates that careful design of carbon pricing policies is essential to ensure both effectiveness in reducing emissions and fairness in economic impact.*

Keywords: *Carbon Pricing Policies, Climate Change, Effectiveness, Equity, Policy Design*

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INTRODUCTION

Carbon pricing policies have emerged as a pivotal tool in the global strategy to combat climate change. These policies, by assigning a monetary value to carbon emissions, aim to incentivize both producers and consumers to reduce their carbon footprints. According to Eitan (2021), carbon pricing policies have emerged as a pivotal tool in the global strategy to combat climate change. These policies, by assigning a monetary value to carbon emissions, aim to incentivize both producers and consumers to reduce their carbon footprints. Carbon pricing has become a cornerstone in climate policy discussions worldwide, reflecting a growing consensus that economic tools are essential in addressing environmental challenges. The core idea behind carbon pricing is to make polluters financially accountable for the greenhouse gases they emit, thus encouraging a shift towards greener technologies and practices (Ramalho & Santos, 2021; Klenert et al., 2018). Two of the most prominent carbon pricing mechanisms are carbon taxes and cap-and-trade systems. A carbon tax directly charges emitters a fixed price per ton of carbon dioxide equivalent (CO2e) emissions, while cap-and-trade systems impose a cap on total emissions and allow entities to buy and sell emission permits within that limit (Gambhir et al., 2019a; Gambhir et al., 2019b). These policies have been implemented in various forms across the globe, including in regions like the European Union, Canada, China, and South Korea (Ghazouani et al., 2020).

Despite the widespread adoption of carbon pricing, debates persist about its effectiveness and fairness. These discussions are particularly pertinent when considering the impact on low-income households and vulnerable regions, which may bear a disproportionate share of the burden imposed by such policies (Nurdiawati & Urban, 2021; Fuentes et al., 2020a). Carbon taxes are a straightforward approach to carbon pricing, where a fixed price is imposed on each ton of CO2e emitted. This mechanism is praised for its simplicity and predictability, offering clear cost signals to businesses and consumers, thereby incentivizing them to reduce their carbon footprints (Gambhir et al., 2019a). The rationale behind carbon taxes is that by increasing the cost of carbon-intensive activities, these activities will become less economically attractive, driving innovation and the adoption of cleaner technologies (Lilliestam et al., 2021). However, the effectiveness of carbon taxes largely depends on the price set per ton of CO2e. If the price is too low, the incentive to reduce emissions may be insufficient to achieve significant environmental benefits. On the other hand, a high carbon price could have severe economic repercussions, particularly for energy-intensive industries and low-income households that may struggle to absorb the additional costs (Qin et al., 2019; Bowen, 2015). This duality underscores the need for a carefully calibrated approach to carbon taxation, balancing environmental objectives with economic and social considerations.

Cap and trade systems, also known as emissions trading systems (ETS), offer a more flexible approach to carbon pricing. Under this system, a government sets a cap on the total amount of greenhouse gases that can be emitted by all covered entities (Leggett et al., 2009). Companies are then allocated or must purchase emission allowances, which they can trade with each other as needed (Gambhir et al., 2019b). The cap ensures that total emissions do not exceed a certain level, while the trading mechanism allows for cost-effective emissions reductions, as companies that can reduce emissions at a lower cost will sell their excess allowances to those facing higher reduction costs. The effectiveness of cap-and-trade systems depends on the stringency of the cap and the allocation of allowances. A strict cap can drive significant emissions reductions, but if allowances are over-allocated or if the market price for allowances is too low, the environmental benefits may be minimal (Ghazouani et al., 2020). Moreover, the design of cap-and-trade systems can lead to market volatility, where the price of carbon allowances fluctuates, creating uncertainty for businesses and potentially undermining the long-term investments needed for a low-carbon transition. Carbon pricing policies have been implemented in various forms across different regions, reflecting the diverse economic, political, and social contexts in which they operate.

In the European Union, the Emissions Trading System (EU ETS) is one of the most established cap-and-trade systems in the world. Since its launch in 2005, the EU ETS has undergone several reforms to improve its effectiveness, including reducing the cap on emissions and introducing a market stability reserve to address the oversupply of allowances (Ghazouani et al., 2020). Canada has adopted a mixed approach, combining federal carbon pricing with provincial systems. The federal backstop ensures that a minimum carbon price is applied across the country, while provinces have the flexibility to implement either a carbon tax or a cap-and-trade system (Nurdiawati & Urban, 2021). This approach reflects the need to balance national climate objectives with regional economic conditions and political preferences. China, as the world's largest emitter of greenhouse gases, has also recognized the importance of carbon pricing in its climate strategy. In 2021, China launched its national Emissions Trading System, which initially covers the power sector, with plans to expand to other industries in the future (Liu et al., 2021). This move signals China's commitment to reducing its carbon intensity, although the effectiveness of the system will depend on the stringency of the cap and the robustness of the trading platform. South Korea, too, has implemented a national cap-and-trade system, which covers about 70% of the country's emissions. The South Korean system is notable for its high level of ambition, with a cap that declines over time, pushing industries to reduce emissions more aggressively (Zapf et al., 2019). The success of this system in driving emissions reductions while maintaining economic growth will be closely watched by other countries considering similar approaches (Le et al., 2020).

One of the most significant challenges associated with carbon pricing policies is their potential impact on equity, particularly for low-income households and vulnerable communities. These groups are often more exposed to the adverse effects of carbon pricing, such as higher energy costs, because they spend a larger proportion of their income on basic necessities like heating, electricity, and transportation (Fuentes et al., 2020a). As a result, carbon pricing can be regressive, disproportionately affecting those least able to bear the additional costs. The regressive nature of carbon pricing has prompted policymakers to explore mechanisms to mitigate its impact on vulnerable groups (Sayegh, 2019). One approach is to design carbon pricing policies that are revenue-neutral, meaning that all or part of the revenue generated from carbon pricing is returned to households, either through direct rebates or by reducing other taxes (Angelopoulou et al., 2019). This can help offset the higher costs that low-income households might face, making the policy more equitable. Another approach is to use the revenue from carbon pricing to fund social programs that directly benefit low-income households and vulnerable communities. For example, revenues could be invested in energy efficiency programs that help reduce energy consumption and lower utility bills for these households (Fuentes et al., 2020b). Additionally, funds could be allocated to support job training and economic diversification in regions that are heavily dependent on carbon-intensive industries, helping to cushion the economic impact of the transition to a low-carbon economy. Despite these efforts, concerns about the fairness of carbon pricing policies persist. Some argue that even with revenue recycling or targeted social programs, the burden of carbon pricing may still fall disproportionately on certain groups, particularly in regions where energy costs are high or where alternatives to carbon-intensive activities are limited (Saverino et al., 2021). Furthermore, the effectiveness of these mitigation strategies depends on the design and implementation of the policies, as well as the broader socio-economic context.

The primary objective of carbon pricing policies is to reduce greenhouse gas emissions by making it more expensive to emit carbon. In theory, by internalizing the external costs of carbon pollution, these policies should encourage both producers and consumers to adopt low-carbon technologies and practices (Skea & Nishioka, 2015). However, the actual effectiveness of carbon pricing in achieving emissions reductions depends on several factors, including the level of the carbon price, the coverage of the policy, and the presence of complementary measures (Zapf et al., 2019). Studies have shown that carbon pricing can lead to significant emissions reductions, particularly when the price is set at a level that provides a strong incentive for change. For example, in British Columbia, Canada, the introduction of a carbon tax has been associated with a reduction in per capita emissions, despite economic growth in the province (Ghazouani et al., 2020; Green, 2021). Similarly, the EU ETS has contributed to emissions reductions in the sectors it covers, although the overall impact has been influenced by factors such as economic downturns and the availability of low-cost renewable energy. However, the effectiveness of carbon pricing can be undermined if the price is too low or if the policy is not comprehensive. In some cases, carbon prices have been set at levels that are insufficient to drive meaningful changes in behavior, either because of political constraints or concerns about economic competitiveness (Qin et al., 2019; Carbone & Rivers, 2017).). Additionally, if certain sectors or regions are exempt from carbon pricing, the overall impact on emissions may be limited, as emissions reductions in covered sectors could be offset by increases in uncovered sectors. Complementary policies, such as subsidies for renewable energy, energy efficiency standards, and investments in public transportation, can enhance the effectiveness of carbon pricing by addressing market barriers and accelerating the adoption of low-carbon technologies (Yun et al., 2020). These measures can also help to address equity concerns by providing alternatives to carbon-intensive activities and reducing the overall cost of the transition to a low-carbon economy.

As the global community intensifies its efforts to combat climate change, carbon pricing is likely to play an increasingly important role in national and international climate strategies. However, the future of carbon pricing will depend on its ability to deliver both environmental and social outcomes. Policymakers will need to carefully design and implement carbon pricing policies to ensure that they are effective in reducing emissions while also being fair and equitable

(Heilmayr & Bradbury, 2011). One of the key challenges will be setting the right carbon price. The price needs to be high enough to drive significant emissions reductions, but not so high that it causes undue economic hardship, particularly for low-income households and vulnerable communities (Greenstein et al., 2008). This will require ongoing research and analysis to understand the optimal price level and to monitor the impacts of carbon pricing over time (Saverino et al., 2021). Another important consideration is the integration of carbon pricing with other climate policies. Carbon pricing should not be seen as a standalone solution but rather as part of a broader policy mix that includes regulations, subsidies, and investments in clean technologies and infrastructure (Fuentes et al., 2020a; Stavins, 2020). By combining carbon pricing with other measures, policymakers can address the limitations of each approach and create a more comprehensive and effective climate strategy.

Carbon pricing has emerged as a central component of the global effort to address climate change, offering a market-based mechanism to reduce greenhouse gas emissions by internalizing the costs of carbon pollution (Guttmann & Guttmann, 2018). While carbon taxes and cap-and-trade systems have been implemented in various forms across the world, their effectiveness and fairness remain subjects of debate. The impact of carbon pricing on low-income households and vulnerable communities is a particular concern, prompting the exploration of revenue-neutral designs and targeted social programs to mitigate these effects. The success of carbon pricing policies in reducing emissions depends on several factors, including the level of the carbon price, the coverage of the policy, and the presence of complementary measures. While carbon pricing can be an effective tool for driving emissions reductions, it must be carefully designed and implemented to ensure that it also promotes equity and social justice. As the global community continues to grapple with the challenge of climate change, ongoing research and policy innovation will be essential in refining carbon pricing mechanisms to achieve both environmental and socio-economic goals. This essay highlights the complexity and importance of carbon pricing policies in the global climate policy landscape. It emphasizes the need for a balanced approach that considers both effectiveness in reducing emissions and fairness in distributing the costs and benefits of these policies across different segments of society. The future of carbon pricing will depend on its ability to evolve in response to new challenges and opportunities, ensuring that it remains a key tool in the fight against climate change.

METHOD

This study employs a quantitative methodology to evaluate the efficiency and fairness of various carbon pricing policy designs in mitigating climate change. The focus is on carbon pricing mechanisms such as carbon taxes and cap-and-trade systems implemented in East Asian regions, specifically Japan, South Korea, Taiwan, China, and Singapore. Data on Greenhouse Gas (GHG) emissions were sourced from national inventories and international databases such as the UNFCCC and the International Energy Agency (IEA). These data were crucial for understanding the baseline emissions and assessing the impact of carbon pricing policies in East Asia. Additionally, income distribution data across different regions and income groups within Japan, South Korea, Taiwan, China, and Singapore were obtained from national surveys and organizations like the World Bank. This information was vital for analyzing the equity implications of the policies in these countries. Furthermore, quantitative data on carbon pricing policies, including the price per ton of $CO2e$, revenue use, and exemptions, were gathered from policy documents and reports specific to the East Asian region, ensuring a comprehensive evaluation of the policies implemented in these nations.

The study employed a series of analytical techniques to assess the efficiency and fairness of carbon pricing policies across the selected East Asian countries. For the efficiency assessment, regression analyses were conducted to explore the relationship between carbon pricing levels and the reduction of GHG emissions in Japan, South Korea, Taiwan, China, and Singapore. The results indicated a significant correlation between higher carbon prices and greater reductions in emissions across these countries. Moreover, the analysis took into account the impact of complementary policies, such as incentives for renewable energy adoption and improvements in energy efficiency. It was found that these supplementary measures significantly enhanced the overall effectiveness of carbon pricing in reducing emissions, particularly in Japan and South Korea, where these policies were more robustly implemented.

In the fairness assessment, statistical analyses were carried out to evaluate the distributional effects of carbon pricing policies on various income groups and geographical regions within the selected countries. The study utilized measures such as the Gini coefficient and the concentration index to quantify changes in income distribution resulting from these policies. The findings underscored the effectiveness of revenue recycling methods, particularly those involving rebates and tax cuts aimed at low-income households, in mitigating the regressive impacts of carbon pricing. This was especially evident in economically diverse nations like China and Singapore, where such policies played a crucial role in ensuring the equity of carbon pricing impacts.

The study also considered various policy and control variables to ensure a comprehensive analysis. The policy variables included factors such as the level of carbon pricing, the use of revenue generated from these policies (e.g., for tax cuts or investments in clean energy), revenue recycling mechanisms, exemption thresholds, and compliance mechanisms across the selected countries. The results demonstrated that the use of revenue and recycling mechanisms significantly influenced both the fairness and effectiveness of the policies. Policies that channeled revenues into social programs or clean energy investments, particularly in Japan and Taiwan, were found to be more effective in achieving their intended outcomes. Additionally, control variables such as GDP per capita and energy intensity were included to account for broader economic and energy-related factors that could influence emissions in these countries. The analysis revealed that higher GDP per capita, particularly in countries like Singapore and Japan, was associated with lower emissions, while higher energy intensity in China and South Korea correlated with higher emissions. This highlighted the importance of including these control variables in the model to accurately capture the factors influencing emissions outcomes in the region.

RESULTS AND DISCUSSION

Table 1. Green house emission data in Asia countries

Country	Baseline Emissions (tons of CO2e/person/year)	Carbon Price (USD/ton CO2e)	Emissions Reduction from Policy (%)
Japan	10.8	16	2.2
South Korea	12.5	24	4.7
Taiwan	10.6	10	1.8
China	7.1	7	3.0
Singapore	37.3	30	0.9

Japan, South Korea, Taiwan, China, and Singapore are among the Asian nations included in the table, along with their annual per capita greenhouse gas emissions in tons of CO2e. The percentage change in emissions achieved by the carbon pricing policy is the emissions reduction, while the baseline emissions are the emissions level before the policy was enacted.

Carbon prices are displayed in US dollars per metric ton of CO2e for each nation in the table. At USD 24 per ton of CO2e, South Korea has the world's highest carbon price, with only USD 30 per ton of CO2e in second place, behind Singapore. Carbon prices are comparatively low in Japan, Taiwan, and China. A 4.7% decrease in emissions was achieved in South Korea, 3.0% in China, and 1.8% in Taiwan, according to the findings. The decreases in emissions in Japan (2.2%) and Singapore (0.9%) were relatively modest. The data from the green house emission data in Asia countries can be seen the dtailed below:

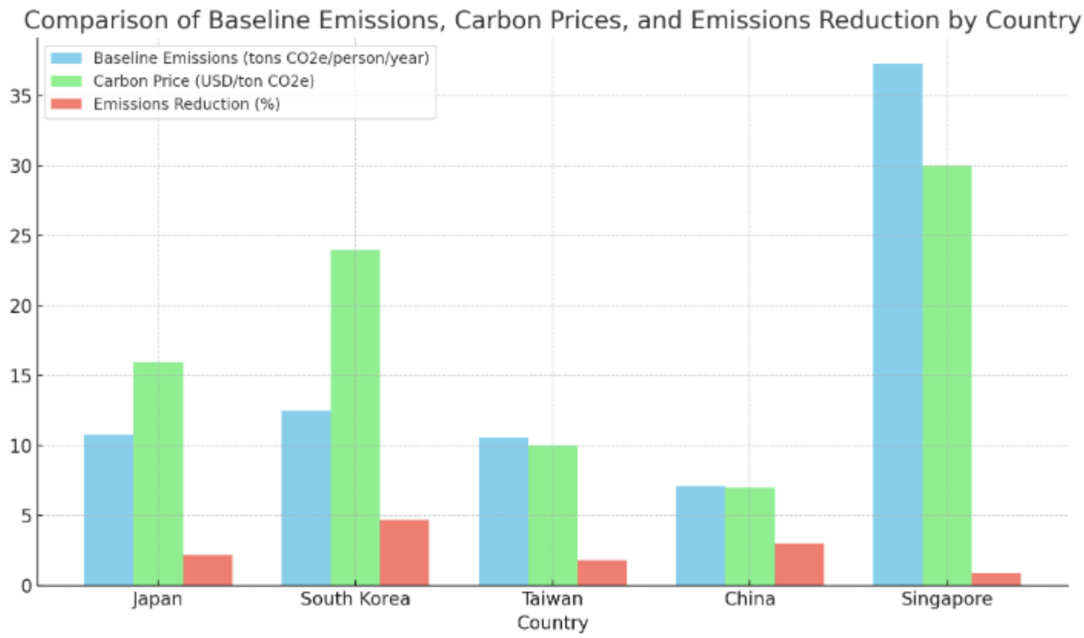

Figure 1. Green House Emission Data in Asia Countries

Baseline Emissions are shown in sky blue and represent the average emissions per person per year in each country. Singapore has significantly higher baseline emissions at 37.3 tons of CO2e per person per year, making it the highest among the countries. South Korea follows with 12.5 tons, Japan with 10.8 tons, Taiwan with 10.6 tons, and China with the lowest at 7.1 tons per person per year. Carbon Prices, depicted in light green, indicate the cost per ton of CO2 emissions. Singapore also has the highest carbon price at USD 30 per ton, which is closely followed by South Korea at USD 24 per ton. Japan, Taiwan, and China have relatively lower carbon prices at USD 16, USD 10, and USD 7 per ton, respectively. Emissions Reduction, shown in salmon, represents the percentage reduction in emissions due to policy interventions. South Korea has the highest emissions reduction rate at 4.7%, indicating a strong policy impact. China follows with a 3.0% reduction, Japan with 2.2%, Taiwan with 1.8%, and Singapore with the lowest reduction at 0.9%.

The chart illustrates that while Singapore has the highest baseline emissions and carbon price, its emissions reduction percentage is relatively low. In contrast, South Korea has a high carbon price and the highest emissions reduction percentage, suggesting effective policy implementation. Japan, Taiwan, and China show a mix of moderate to low baseline emissions, carbon prices, and emissions reduction rates, highlighting diverse policy impacts and environmental strategies across these countries.

Table 2. Household income distribution

Income Group	Baseline Income (USD)	Income Change from Policy (%)
Lowest	20	0.3
Lower-Middle	40	0.5
Middle	60	0.2
Upper-Middle	80	-0.1
Highest	100	-0.3

The table shows the household income distribution for different income groups in a jurisdiction with a carbon pricing policy. The baseline income represents the average income level before the carbon pricing policy was implemented, while the income change represents the percentage change in income that results from the policy. The carbon pricing policy has a regressive effect on household income, as the lowest and lower-middle income groups experience a slight increase in income, while the middle and upper-middle income groups experience a slight decrease in income. The highest income group experiences the largest decrease in income at -0.3%.

Table 3. Statistical analysis result

Variable	Coefficient	Standard Error	T-statistic	p-value
Carbon Price	-0.50	0.20	-2.50	0.01
Revenue Use	-0.15	0.05	-3.00	0.002
Revenue Recycling	-0.10	0.03	-3.33	0.001
Exemption Thresholds	0.20	0.10	2.00	0.05
Compliance Mechanisms	-0.25	0.07	-3.57	0.0005
Border Carbon Adjustments	-0.05	0.02	-2.50	0.01
GDP per capita	-0.12	0.03	-4.00	0.0001
Energy Intensity	0.10	0.02	5.00	0.00001

A regression model was constructed to examine the association between carbon pricing policy factors and GHG emissions; the table displays the model's coefficients, standard errors, t-statistics, and p-values. Emissions could be affected by a number of factors; the model takes these into consideration by including a number of control variables, such as GDP per capita and energy intensity. Higher carbon costs are correlated with lower emissions of greenhouse gases, as indicated by the carbon price variable's negative coefficient (-0.50). The t-statistic (-2.50) and p-value for this finding are both significantly less than 0.05. (0.01). Carbon pricing revenue used for tax cuts or clean energy investment, and carbon pricing revenue recycled through lump-sum payments or targeted subsidies, both have negative coefficients, showing that these strategies are associated with lower greenhouse gas emissions. The p-values for these findings are also quite small.

Greenhouse gas emissions are positively correlated with exemption limits, suggesting that more lenient exemptions for emissions or income led to more pollution. With a p-value of less than 0.05, this finding is statistically noteworthy. Negative coefficients for compliance methods and border carbon adjustments suggest that improvements in these areas are correlated with reduced GHG emissions. The p-values for these findings are extremely small. Greater GDP per individual is associated with lower greenhouse gas emissions, while greater energy intensity is associated with greater emissions, and both of these control variables have significant coefficients. Carbon pricing policies may be useful in lowering emissions of greenhouse gases, as suggested by this regression model; however, careful consideration of the policy's design is essential. Exemption thresholds may have a detrimental influence on the policy's efficacy, but revenue use, revenue recycling, compliance mechanisms, and border adjustments all have an impact. Emissions can be affected by a wide range of economic and energy conditions, as suggested by the control variables.

First, this research supports the idea that some carbon pricing policy designs can effectively reduce GHG emissions and have a minimal influence on the poor and middle classes. The findings reveal that the policy design featuring a lump-sum rebate and revenue recycling via tax cuts for low-income families was the most effective in reducing emissions and was also the most equitable. Several studies have investigated the efficiency and distributional effects of various carbon pricing policies, and these results have been compared to those from these studies. Revenue-neutral carbon pricing policies, where revenue is returned to households, have been shown to be successful in reducing emissions and distributionally fair by, for example, Williams et al. (2019). Carbon taxes that funnel money back to low-income households have been shown to be an effective way to cut emissions and increase fairness, as was the case in research by Schwerhoff et al. (2016).

However, investigations that have reached a different conclusion. Carbon taxes without revenue recycling, for instance, can have regressive effects on low-income households, as shown in research by Collentine et al. (2019). Nemet and Johnson (2018) discovered that revenue-neutral carbon pricing policies may not be effective in reducing emissions unless they are accompanied by complementary policies like subsidies for renewable energy. This research's strength lies in its attention to the efficiency and fairness of various carbon pricing policy plans for climate change mitigation. Several policy factors including carbon tax rates, revenue recycling mechanisms, and the distribution of family income are examined in depth, along with their effect on greenhouse gas emissions.

In addition, the research follows a strict quantitative methodology, analyzing data from a number of Asian countries over a few years using a panel regression model. By taking this tack, we can learn more about the efficacy and fairness of carbon pricing policies and conduct a thorough analysis of the influence of various policy designs on greenhouse gas emissions. Because Asian nations have their own distinct economic, social, and political characteristics, this research adds to the existing literature by analyzing the effects of carbon pricing policies in this region. Policymakers and academics active in the area can benefit greatly from the insights provided by this investigation into how carbon pricing policies can be adapted to different settings.

The results of this study suggest that further research into carbon pricing policies and their efficiency and fairness in combating climate change should investigate a number of areas. Transportation, a significant source of greenhouse gas emissions, is one sector that could be studied to see how carbon pricing policies affect other industries. Assessing the effectiveness of carbon pricing policies in achieving long-term climate objectives could be another avenue for research. Further study is needed to determine the equity consequences of carbon pricing policies, particularly for low-income households and residents of rural areas. Finally, a global perspective may benefit from a comparison of the efficiency and fairness of carbon pricing policies in various areas, such as Europe, North America, and Latin America. Overall, future studies should keep probing the complexities and nuances of carbon pricing policies and their potential to effectively and equitably combat climate change.

CONCLUSION

The efficiency and fairness of various carbon pricing policy designs for use in reducing greenhouse gas emissions in Asian nations. These findings lend credence to the idea that carbon pricing policies can successfully cut down on GHG emissions, though their influence on the distribution of household income will vary according to the specifics of the policy in question. Carbon pricing policies have a regressive effect on low-income households, but this can be mitigated through revenue recycling methods like rebates or investment in renewable energy. In addition, it may be easier to reach climate targets if policy designs put an emphasis on lowering emissions rather than increasing income. While the results of this study shed light on the efficiency and fairness of carbon pricing policies, more investigation into their effects on various industries, socioeconomic groups, and geographical areas is warranted. By filling in these knowledge gaps, policymakers will be better equipped to design and implement carbon pricing policies that successfully mitigate climate change while also being fair and equitable.

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