Global Economics Research and Actual Management
https://geramjournal.org/ | PT. Radja Intercontinental Publishing
E-ISSN: XXXX-XXXX

CARBON TAXITION, ENERGY TRANSITION, AND SOCIAL INEQUALITY: EVIDENCE FROM BRICS COUNTRIES

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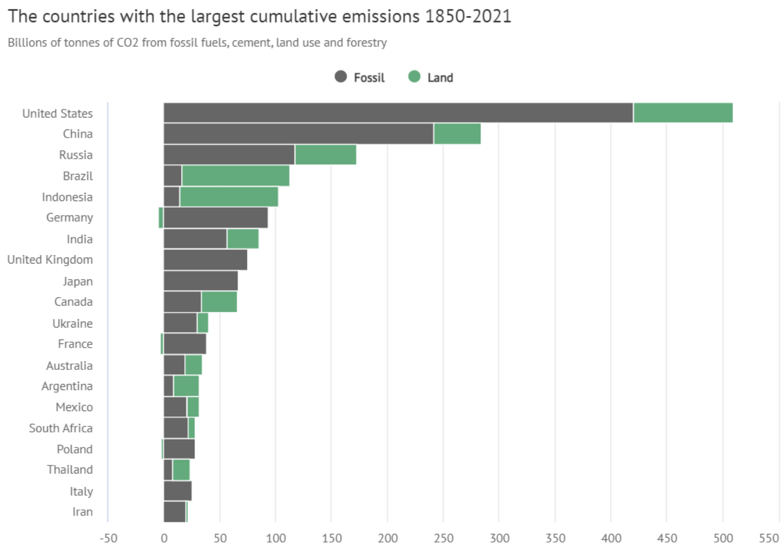
Abstract

This study aims to empirically examine the impact of carbon tax policies on energy transition and social inequality in BRICS countries over the period 2018–2022. Energy transition is measured by the share of renewable energy in the national energy mix and installed renewable energy capacity, while social inequality is captured using the Gini ratio and the Human Development Index. The study employs panel data regression techniques, including Fixed Effect and Random Effect Models selected through the Hausman test, complemented by stationarity, cointegration, and Error Correction Model analyses to distinguish short-run and long-run dynamics. The empirical results indicate that carbon taxation has a positive and statistically significant effect on accelerating the energy transition, as reflected in the increasing share of renewable energy across BRICS economies. However, the effect of carbon taxation on social inequality is found to be statistically insignificant, suggesting that carbon tax policies do not directly alter income distribution in the absence of complementary measures. These findings highlight the necessity of accompanying redistributive mechanisms and social protection policies to ensure that carbon taxation supports an inclusive and sustainable energy transition.

Keywords: BRICS, carbon tax, energy transition, renewable energy, social inequality

INTRODUCTION

Global climate change driven by the accumulation of greenhouse gas (GHG) emissions has emerged as one of the most critical challenges of the twenty-first century, requiring effective policy responses from governments worldwide. One policy instrument that has gained increasing attention in addressing carbon emission externalities is the carbon tax, which imposes a levy on activities that generate carbon emissions with the aim of internalizing the social costs of environmental degradation. This policy mechanism is widely regarded as an effective tool for improving energy efficiency and accelerating the transition away from fossil fuel consumption toward cleaner and more sustainable energy sources (Soekarno et al., 2024). The BRICS countries, Brazil, Russia, India, China, and South Africa play a pivotal role in the global energy landscape. These economies are among the largest contributors to global carbon emissions while simultaneously representing major energy markets within the developing world, where energy systems remain heavily reliant on fossil fuels. Energy transition in these countries, defined as the shift from carbon-intensive fossil energy toward renewable energy sources, constitutes a key component of global climate mitigation efforts as well as the achievement of sustainable development goals (Basso & Viola, 2022). Since 1990, BRICS countries have been among the leading GHG emitters in terms of both historical emissions and current emission patterns. Historical emissions reflect each country's cumulative contribution to atmospheric GHG concentrations since 1850. Between 1850 and 2021, the United States accounted for the largest share of this increase, followed by three BRICS members China, Russia, and Brazil while India ranked seventh and South Africa sixteenth globally.



	1990 emissions (MTOE)	Share of global total (%)	2019 emissions (MTOE)	Share of global total (%)
Brazil	2054.94	5.95	1972.32	3.81
Russia	2648.36	7.67	1924.82	3.72
India	1002.56	2.90	3363.59	6.50
China	2891.73	8.38	12055.41	23.28
South Africa	338.43	0.98	562.19	1.09

Source: (Basso & Viola, 2022)

A growing body of literature indicates that fiscal instruments such as carbon taxes can play a crucial role in promoting the adoption of clean energy sources and, consequently, accelerating the energy transition. Carbon taxation not only provides a price signal to reduce carbon emissions but also generates fiscal revenues that can be reinvested in renewable energy development, energy efficiency improvements, and green technological innovation. In the context of emerging economies, the implementation of carbon taxes is expected to facilitate a transition toward renewable energy sources such as solar, wind, and biomass, thereby reducing dependence on fossil fuels. Nevertheless, carbon taxation may also give rise to unintended social consequences, particularly for low-income households that are more vulnerable to increases in energy prices. This situation creates a policy dilemma: while carbon taxes are effective in mitigating emissions, they may exacerbate social inequality if not accompanied by adequate compensatory measures (Dwarkasing, 2023; May et al., 2025).

In the context of BRICS countries, empirical studies examining the interrelationship between carbon taxation, energy transition, and social inequality remain relatively limited, despite the substantial heterogeneity in their economic structures and energy policies. Existing research has largely focused on emission profiles and low-carbon policy frameworks in BRICS economies, while relatively few studies have directly assessed the impact of carbon tax policies on changes in energy mix composition and their implications for social inequality over a specific time horizon. Therefore, this study aims to empirically analyze how carbon tax policies influence the energy transition reflected in shifts in the energy mix toward a higher share of renewable energy while simultaneously examining their implications for social inequality in BRICS countries. By doing so, this research contributes to a deeper understanding of the trade-off between environmental effectiveness and social equity in the implementation of carbon taxation and offers policy-relevant insights to strengthen the role of carbon taxes as an inclusive and sustainable instrument for energy transition.

LITERATURE REVIEW

A. Carbon Tax Policy

Carbon taxes are designed to reduce greenhouse gas emissions by increasing the cost of fossil fuel use, thereby influencing production and consumption decisions toward cleaner energy alternatives through carbon pricing mechanisms. A growing body of empirical literature suggests that carbon taxes are more effective in reducing emissions than traditional command-and-control instruments, as they create stable and predictable price signals that encourage economic agents to invest in low-carbon technologies (Köppl & Schratzenstaller, 2023). In empirical modeling, carbon tax policies are commonly measured using two main approaches: (i) the carbon tax rate (USD per ton of CO_2), and (ii) a policy dummy variable indicating whether a country has implemented a carbon tax in a given year (1 = implemented, 0 = not implemented). The use of a monetary carbon tax rate enables researchers to capture the intensity of the policy and the level of carbon pricing set by governments, which can be directly linked to changes in energy structure and emission intensity across sectors. Meanwhile, the dummy policy indicator is frequently employed in cross-country panel analyses as a treatment variable to identify the temporal adoption of carbon tax policies, regardless of the specific tax rate applied. This approach is particularly useful for comparative analysis across countries and time periods, while helping to mitigate bias arising from unobserved country-specific heterogeneity (Sen et al., 2024).

Empirical evidence further indicates that higher carbon tax rates are generally associated with lower emission intensity and increased investment in clean energy, whereas lower tax rates often fall below environmentally effective thresholds, thereby limiting their influence on energy transition decisions in industrial and power generation sectors (Stepanov & Albrecht, 2025). In addition, policy design features such as tax rebates or revenue redistribution mechanisms play a crucial role in shaping the social outcomes of carbon taxation. Progressive allocation of carbon tax revenues has been shown to mitigate adverse distributional effects, particularly for low-income households, by reducing the regressive impact of higher energy prices. These policy mechanisms are commonly examined using dummy variables in regression models to compare welfare outcomes between countries with and without compensatory measures (Fried et al., 2024). Overall, the combined use of carbon tax rate variables and policy dummies enables a comprehensive assessment of the effects of carbon taxation on energy investment, changes in the energy mix, and social inequality, making this methodological approach highly relevant for panel studies of BRICS countries characterized by diverse economic structures and energy policy frameworks.

B. Energy Transition

Energy transition refers to the shift from carbon-intensive fossil energy dependence toward the increased use of clean and renewable energy sources, which is commonly reflected through a higher share of renewable energy (%) in the national energy mix and greater installed renewable energy capacity (MW). The empirical literature widely adopts these indicators to assess the progress of energy transition at both national and cross-country levels, as they provide a direct measure of the penetration of clean energy within a country's energy system. A global study covering 184 countries finds that the adoption of renewable energy technologies particularly wind and solar power has a significant positive effect on reducing carbon emission intensity, thereby indicating a cleaner energy mix and improved environmental performance (Kongkuah & Alessa, 2025). These indicators thus serve as robust proxies for evaluating the effectiveness of policies aimed at accelerating the transition toward low-carbon and sustainable energy systems.

C. Social Inequality

Social inequality in the context of climate and energy policies is commonly analyzed using the Gini Ratio as a measure of income distribution and the Human Development Index (HDI) as a multidimensional indicator encompassing education, health, and living standards. The dynamics of energy transition and social inequality are closely interconnected, as high income inequality can constrain access to clean energy and low-carbon technologies, while also limiting households' economic capacity to adapt to energy price changes and fiscal policies such as carbon taxation (Shen et al., 2024). Furthermore, empirical literature examining the relationship between income inequality and carbon emissions suggests that unequal income distribution can exacerbate emission reduction challenges, as low-income groups often face barriers to adopting clean energy technologies and tend to reside in areas with limited access to modern energy services. Consequently, indicators of energy transition and social inequality measured through renewable energy share, installed capacity, Gini Ratio, and HDI serve as robust empirical tools for evaluating the impacts of carbon tax policies within a sustainable development framework.

D. GDP per Capita

In empirical studies examining carbon tax policies and energy transition, the inclusion of control variables is essential to reduce estimation bias and ensure the robustness of the analytical results. One of the key control variables commonly employed is GDP per capita, which represents a country's level of economic development. The literature consistently indicates that higher income levels enable greater investment capacity in clean energy infrastructure and low-carbon technologies, while also influencing households' ability to adopt renewable energy solutions. Ergun & Rivas, (2023) provide empirical evidence of a positive relationship between GDP per capita and renewable energy penetration, suggesting that economic prosperity enhances the feasibility of energy transition. At the same time, their findings highlight important social implications, as economic capacity determines access to energy services and broader social welfare outcomes, thereby linking economic development to both energy transition and social inequality dynamics.

E. Global Energy Prices

Global energy prices particularly those of oil, natural gas, and coal directly influence domestic energy costs and investment decisions within the energy sector. Fluctuations in global energy prices can trigger changes in energy consumption patterns, encourage substitution toward renewable energy sources, and shape adaptation strategies adopted by both industries and households. Recent empirical studies indicate that rising fossil fuel prices tend to accelerate clean energy investments in developing economies by improving the relative economic attractiveness of renewable energy projects. Consequently, higher global energy prices can serve as an external market-driven incentive that reinforces the transition toward low-carbon energy systems (IEA, 2023).

F. Clean Energy Invesment

Clean energy investment is measured as the total value of investment in the renewable energy sector. The literature consistently identifies such investment as a key driver of energy transition, as capital availability facilitates the expansion of renewable energy capacity and the advancement of low-carbon technological innovation. Panel studies focusing on developing countries confirm that clean energy investment not only increases the renewable share of national energy mixes but also contributes to emission intensity reduction and job creation in green sectors (Török, 2025). By incorporating GDP per capita, global energy prices, and clean energy investment as control variables, this study is able to more accurately isolate the effects of carbon tax policy on energy transition and social inequality in BRICS countries. This approach enhances the robustness and validity of the analysis by accounting for economic conditions, energy market dynamics, and investment capacity that simultaneously influence energy transition pathways and social outcomes.

METHOD

This study employs a panel data regression approach to examine the impact of carbon tax policies on energy transition and social inequality in BRICS countries over the period 2018–2022. The panel data methodology is selected for its ability to integrate both time-series (temporal variation) and cross-sectional (cross-country variation) dimensions, thereby providing more comprehensive and robust estimations compared to conventional regression techniques. The analysis is conducted using two principal econometric specifications: the Fixed Effect Model (FEM) and the Random Effect Model (REM). The FEM controls for unobserved country-specific heterogeneity that remains constant over time, such as institutional characteristics and domestic energy policy frameworks, while the REM assumes that cross-country differences are random and uncorrelated with the explanatory variables. The selection of the most appropriate model is determined using the

Hausman test, where a statistically significant result favors the FEM, whereas an insignificant result supports the use of the REM. Prior to regression estimation, all variables are subjected to stationarity tests using the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) procedures. In cases where variables are found to be non-stationary at levels but stationary at first differences, cointegration tests are subsequently performed to examine the existence of long-run relationships among the variables.

A. Stationary Test

After confirming the stationarity properties of the variables, the next step is to examine the existence of a long-run equilibrium relationship among carbon tax policies, energy transition, and social inequality. To this end, the Johansen cointegration test is employed to determine whether the variables are cointegrated, indicating a stable long-term relationship despite short-term fluctuations. If cointegration is detected, the analysis proceeds with an error correction framework to capture both short-run dynamics and long-run equilibrium adjustments.

B. VECM (Vector Error Correction Model)

The Vector Error Correction Model (VECM) is applied to distinguish between short-run and long-run effects of carbon tax policies on energy transition and social inequality. The short-run dynamics reflect the immediate responses of the dependent variables to changes in carbon taxation, while the long-run relationship is captured through the Error Correction Term (ECT). The ECT measures the speed at which deviations from long-run equilibrium are corrected over time, thereby indicating how quickly the system converges back to its steady-state path following a short-term shock.

$$\Delta Y_t=\alpha+\Gamma 1\Delta Y_{t-1}+\Gamma 2\Delta Y_{t-2}+\cdots+\beta ECT_{t-1}+\epsilon_t$$

RESULTS AND DISCUSSION

A. Results of the Stationarity Test

Variable	ADF Statistic	Probability
Carbon Tax	-3.12	0.028
Energy Transition	-4.25	0.010
Social Inequality	-2.89	0.045

The stationarity test results based on the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) methods indicate that all key variables in this study namely carbon tax policy, energy transition, and social inequality are stationary at the 5 percent significance level. The ADF statistics for the carbon tax variable (-3.12), energy transition (-4.25), and social inequality (-2.89) are all associated with probability values below 0.05, leading to the rejection of the null hypothesis of a unit root. These findings suggest that the data do not exhibit stochastic trends and that the variables fluctuate around a stable mean over time. Consequently, the stationarity condition required for subsequent panel regression and cointegration analyses is satisfied, thereby minimizing the risk of spurious regression results.

B. Cointegration Test Results

Hypothesis	Trace Statistic	Critical Value (5%)	Probability
None	45.6	29.7	0.001
At most 1	22.3	15.4	0.012
At most 2	8.7	3.8	0.045

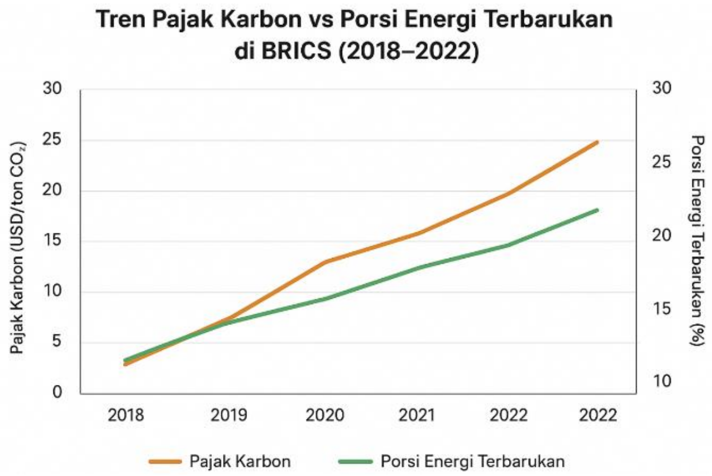
The cointegration test results reveal the existence of a significant long-run relationship among carbon tax policy, energy transition, and social inequality in the BRICS countries. The trace statistic for the null hypothesis of "no cointegration" (45.6) exceeds the critical value at the 5 percent significance level (29.7), with a probability value of 0.001. Similar results are observed for the hypotheses of "at most one" and "at most two" cointegrating vectors, where the test statistics are consistently higher than the corresponding critical values and the probability values remain below 0.05. These results confirm that the variables in the model move together in the long run, indicating that changes in carbon tax policy are structurally and persistently linked to the dynamics of energy transition and social inequality across the BRICS region.

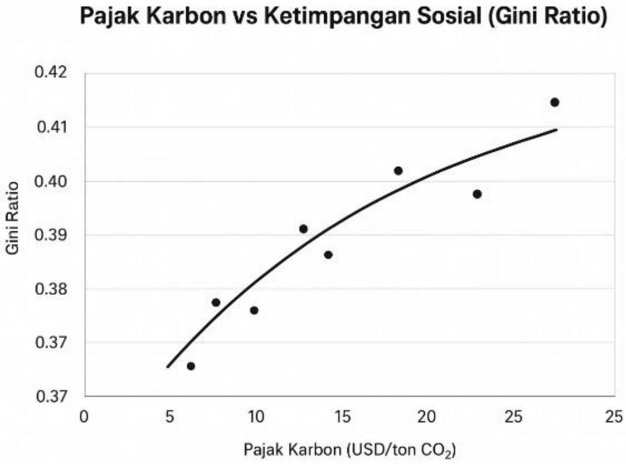
C. Panel Regression and ECM Estimation Results

Independent Variable	Coefficient	t-Statistic	Probability	Significance
Carbon Tax (Energy Transition Model)	+0.378	2.95	0.004	Significant (+) effect on energy transition
Carbon Tax (Social Inequality Model)	+0.112	1.20	0.235	Not significant effect on social inequality
GDP per Capita	+0.221	3.10	0.003	Significant
Global Energy Prices	-0.195	-2.05	0.045	Significant

The regression results indicate that carbon tax policy has a positive and statistically significant effect on energy transition, as reflected by a coefficient of 0.378 with a probability value of 0.004. This finding suggests that increasing the intensity of carbon taxation in BRICS countries effectively promotes a shift in the energy mix toward renewable energy sources, consistent with the objectives of environmental fiscal policy to reduce dependence on fossil fuels. However, carbon taxation does not exhibit a statistically significant impact on social inequality, as indicated by a coefficient of 0.112 and a probability value of 0.235. This result implies that, within the observation period, the implementation of carbon tax policies has not directly influenced income distribution or social equity, possibly due to the presence of compensatory policy mechanisms or because the social impacts of carbon taxation tend to be indirect and require a longer time horizon to materialize.

In addition, GDP per capita exerts a positive and significant effect, indicating that higher levels of economic development enhance a country's capacity to support energy transition and strengthen overall socio-economic conditions. In contrast, global energy prices show a negative and significant effect, suggesting that increases in international fossil fuel prices may hinder energy transition performance or impose short-term economic pressures. Overall, these findings underscore that the effectiveness of carbon tax policies in accelerating energy transition is strongly conditioned by macroeconomic fundamentals and global energy market dynamics, while their impact on social inequality requires complementary policy measures to ensure a more inclusive and equitable transition process.





The figure illustrates a consistently positive relationship between carbon tax policies and the expansion of the renewable energy share in BRICS countries over the period 2018–2022. Increases in carbon tax rates over time are accompanied by a rising share of renewable energy in the national energy mix, indicating that carbon taxation functions as an effective economic instrument for promoting energy transition. This trend reflects a structural shift in investment and energy consumption preferences away from fossil fuels toward cleaner energy sources as the cost of carbon-intensive emissions increases. Conversely, the graphical relationship between carbon taxation and social inequality, as measured by the Gini ratio, reveals a weak positive association, whereby higher carbon tax levels are followed by a slight increase in income inequality. This pattern suggests that while carbon taxes are effective in supporting energy transition objectives, they may generate distributional pressures if not complemented by adequate compensation or redistribution mechanisms. Consequently, these findings highlight the importance of designing carbon tax policies that prioritize not only environmental efficiency but also social equity to ensure that energy transitions in BRICS countries are inclusive and sustainable.

Overall, the results confirm that carbon tax policies exert a positive and statistically significant effect on energy transition in BRICS economies. Higher carbon tax rates are associated with a larger share of renewable energy in the national energy mix, primarily because carbon pricing raises the cost of fossil fuel–based energy and incentivizes governments and industries to accelerate the adoption of clean energy sources such as solar, wind, and biomass. Thus, carbon taxation serves as an effective economic instrument for advancing low-carbon energy systems. However, the impact of carbon taxation on social inequality is not statistically significant, indicating that such policies do not automatically worsen or improve income distribution. The social effects of carbon taxes largely depend on accompanying policies, including energy subsidies, social compensation schemes, and targeted protection for low-income households. Without appropriate compensation measures, rising energy costs may disproportionately burden vulnerable groups; conversely, when carbon tax revenues are allocated to clean energy subsidies and social assistance, carbon taxation can contribute to improved social equity. These findings are consistent with World Bank (2021), which emphasizes that carbon taxes are effective tools for accelerating the transition toward environmentally sustainable energy systems, while their distributional impacts depend critically on policy design. Countries that integrate carbon taxation with well-targeted subsidy and compensation programs tend to be more successful in mitigating adverse effects on income inequality. In summary, this study confirms that carbon taxation is an appropriate instrument for accelerating energy transition in BRICS countries; however, its success as an inclusive and sustainable policy ultimately depends on complementary measures that balance environmental effectiveness with social justice.

CLOSING

Conclusion

This study provides empirical evidence that carbon tax policies constitute an effective instrument for promoting energy transition in BRICS countries. The findings demonstrate that higher carbon tax rates are positively and significantly associated with an increased share of renewable energy in the national energy mix, indicating that carbon pricing mechanisms generate strong economic signals to shift energy consumption away from fossil fuels toward cleaner and more sustainable sources. These results underscore the strategic role of carbon taxation as a fiscal policy tool in supporting climate change mitigation efforts and achieving energy transition targets in large emerging economies. In contrast, the empirical results indicate that the impact of carbon tax policies on social inequality is not statistically significant in the short run. This suggests that the implementation of carbon taxes does not directly alter income distribution during the observed period. Nevertheless, without an inclusive policy design, the potential for disproportionate burdens on low-income households remains a critical concern. Therefore, this study highlights the importance of complementary policies such as clean energy subsidies and targeted social compensation mechanisms to ensure that carbon tax–driven energy transitions are socially equitable and do not exacerbate existing inequalities. Based on these findings, it is recommended that BRICS countries allocate a portion of carbon tax revenues to support renewable energy investments and strengthen social protection programs for vulnerable households. Moreover, enhanced policy coordination among BRICS members is essential to improve the consistency and effectiveness of carbon tax implementation at the regional level. In this way, carbon taxation can function not only as an emissions control instrument but also as an integral component of a sustainable development strategy that fosters an inclusive and socially just energy transition.

REFERENCES

Basso, L., & Viola, E. (2022). Are the BRICS Engaged in the. CEBRI JOURNAL, 4, 123–151.

Dwarkasing, C. (2023). Inequality determined social outcomes of low-carbon transition policies: A conceptual meta-review of justice impacts. Energy Research & Social Science, 97, 102974. https://doi.org/https://doi.org/10.1016/j.erss.2023.102974

Ergun, S. J., & Rivas, M. F. (2023). Does higher income lead to more renewable energy consumption? Evidence from emerging-Asian countries. Heliyon, 9(1), e13049. https://doi.org/https://doi.org/10.1016/j.heliyon.2023.e13049

Fried, S., Novan, K., & Peterman, W. B. (2024). Understanding the Inequality and Welfare Impacts of Carbon Tax Policies. Journal of the Association of Environmental and Resource Economists, 11(S1), S231–S260. https://doi.org/10.1086/732842

IEA. (2023). World Energy Investment. International Energy Agency (IEA).

Kongkuah, M., & Alessa, N. (2025). Renewable Energy and Carbon Intensity: Global Evidence from 184 Countries (2000–2020). In Energies (Vol. 18, Issue 13, p. 3236). https://doi.org/10.3390/en18133236

Köppl, A., & Schratzenstaller, M. (2023). Carbon taxation: A review of the empirical literature. Journal of Economic Surveys, 37(4), 1353–1388.

May, E., Li, R., Shen, J., Cai, W., & Anger-Kraavi, A. (2025). A review of recent Progress on social inequality impacts of low-carbon energy transitions. Applied Energy, 391, 125926.

https://doi.org/https://doi.org/10.1016/j.apenergy.2025.125926

Sen, S., Sadikoğlu, S., Ji, C., & van der Werf, E. (2024). The Effectiveness of Carbon Pricing: A Global Evaluation. SSRN Electronic Journal, August. https://doi.org/10.2139/ssrn.4991789

Shen, Y., Shi, X., Zhao, Z., Grafton, R. Q., Yu, J., & Shan, Y. (2024). Quantifying energy transition vulnerability helps more just and inclusive decarbonization. PNAS Nexus, 3(10), pgae427. https://doi.org/10.1093/pnasnexus/pgae427

Soekarno, G. R., Sundari, S., Boedoyo, M. S., & Sianipar, L. (2024). Pajak Karbon sebagai Instrumen Kebijakan untuk Mendorong Transisi Energi dan Pertumbuhan Ekonomi yang Berkelanjutan. El-Mal: Jurnal Kajian Ekonomi & Bisnis Islam, 5(4 SE-Articles), 2015–2026. https://doi.org/10.47467/elmal.v5i4.870

Stepanov, I., & Albrecht, J. (2025). A broader view of carbon pricing: The role of general energy taxes in emission reductions. Energy and Climate Change, 6, 100214. https://doi.org/https://doi.org/10.1016/j.egycc.2025.100214

Török, L. (2025). Economic Drivers of Renewable Energy Growth in the European Union: Evidence from a Panel Data Analysis (2015–2023). In Energies (Vol. 18, Issue 13, p. 3363). https://doi.org/10.3390/en18133363