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When Does Trade Become Green?

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Abstract: This paper explores whether trade openness contributes to environmental sustainability in European emerging economies, focusing on the role of renewable energy. Using panel data for 13 Central, Eastern, and Southeastern European countries from 2006 to 2021, we estimate fixed effects models to assess the relationship between trade openness (TO), renewable energy consumption (REC), and CO_2 emissions per capita. The baseline model shows that both TO and REC are negatively associated with emissions. However, when including an interaction term between TO and REC, we find that trade openness alone does not significantly reduce emissions, while the interaction term is negative and statistically significant. This suggests that the environmental benefits of trade are conditional on the presence of a strong renewable energy sector. Our findings underscore the importance of integrated trade and energy policies and support recent literature emphasizing that trade can become "green" only under specific structural conditions.

Keywords: trade openness, CO_2 emissions, renewable energy, panel data

1. Introduction

Climate change and environmental degradation have brought renewed attention to the relationship between economic openness and sustainability. As countries pursue trade liberalization to stimulate growth, concerns are rising about its potential environmental costs. The effect of trade openness on CO_2 emissions remains a debated issue in the literature, with mixed evidence regarding whether increased trade contributes to pollution or promotes cleaner technologies through knowledge spillovers and competition.

For emerging European economies, which are undergoing structural transitions and aligning with EU climate frameworks, this question is particularly relevant. These countries face the dual challenge of increasing international competitiveness while reducing environmental impact. Renewable energy is often cited as a key element in this process, yet its interaction with trade policy remains underexplored.

This paper investigates whether trade openness can contribute to lowering CO_2 emissions, and under what conditions such effects are observed. Using panel data for 13 Central, Eastern, and Southeastern European countries over the period 2006–2021, we examine the combined role of trade openness and renewable energy in shaping environmental outcomes. By introducing an interaction term between trade openness and renewable energy use, we aim to capture the conditional effects of trade on emissions in the presence of clean energy strategies.

2. Methodlogy

The empirical analysis is based on a balanced panel dataset comprising 13 European emerging economies: Albania, Bosnia and Herzegovina, Serbia, Montenegro, North Macedonia, Bulgaria, Romania, Croatia, Czechia, Hungary, Poland, Slovakia, and Slovenia. The variables used in the analysis include GDP per capita (GDPpc), the share of renewable energy in total final energy consumption (REC), and trade openness (TO), measured as the sum of exports and imports relative to GDP. Data are retrieved from the World Bank's World Development Indicators [1] and the Our World in Data database [2].

To assess the relationship between trade openness and environmental sustainability, we estimate a fixed effects (FE) panel model that controls for unobserved, time-invariant country-specific heterogeneity. The baseline model is specified as follows:

$$CO_{2_{it}} = \alpha + \beta_1 TO_{it} + \beta_2 REC_{it} + \beta_3 GDPpc_{it} + \mu_i + \varepsilon_{it} \quad (1)$$

where i denotes countries, t denotes time, and μ_i captures country-specific fixed effects. Robust standard errors clustered at the country level are used to correct for heteroskedasticity and serial correlation.

In the extended specification, we introduce an interaction term between trade openness and the renewable energy share to examine whether the environmental effect of trade openness depends on the extent of renewable energy use:

$$CO_{2_{it}} = \alpha + \beta_1 TO_{it} + \beta_2 REC_{it} + \beta_3 GDPpc_{it} + \beta_4 TO_{it} \cdot REC_{it} + \mu_i + \varepsilon_{it} \quad (2)$$

The interaction model allows us to explore conditional marginal effects, providing insights into the circumstances under which trade becomes environmentally beneficial.

3. Results and Discussion

We begin the empirical section by visually exploring the relationships between CO_2 emissions per capita and the key explanatory variables (Figure 1). The first panel illustrates a weak positive association between TO and CO_2 emissions, as suggested by the slightly upward-sloping trend line, though the scatter remains wide. The second panel displays a clearer positive relationship between GDPpc and emissions, indicating that higher levels of income are associated with increased environmental pressure. In contrast, the third panel reveals a strong negative association between REC and CO_2 emissions. This suggests that greater reliance on renewable energy is systematically linked with lower per capita emissions across the observed countries. These patterns indicate that while economic activity tends to correlate with higher emissions, renewable

energy may play an essential role in mitigating this effect. The relationship between trade openness and environmental performance, however, appears more nuanced and merits further investigation through multivariate analysis.

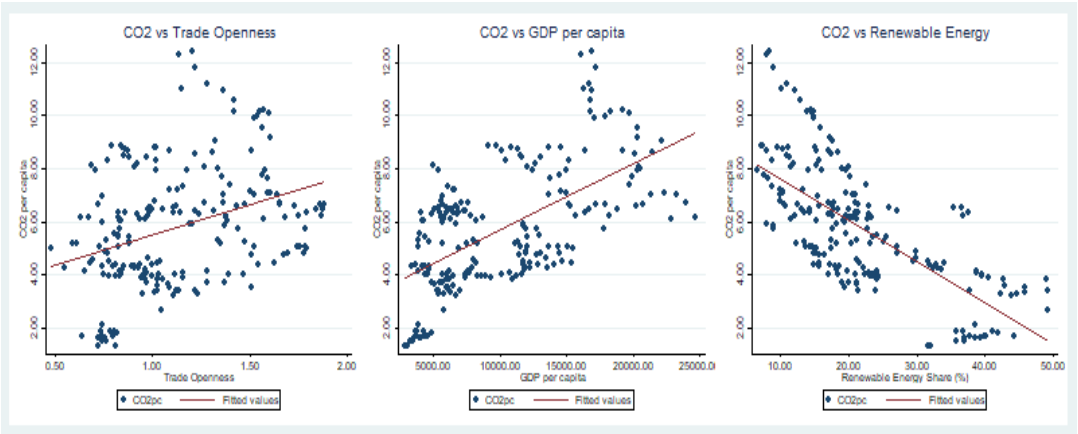

Figure 1. Bivariate relationships between CO_2 emissions and key explanatory variables

Table 1 presents the results of the fixed effects panel regressions for the baseline and interaction model. In the baseline model (1), TO is negatively and significantly associated with CO_2 emissions per capita, suggesting that greater integration into international trade may contribute to environmental improvements. This result aligns with the hypothesis that trade can foster cleaner production processes, especially in transitioning economies. REC is also negatively associated with CO_2 emissions and statistically significant at the 1% level, confirming the expected mitigating effect of clean energy on environmental degradation. In contrast, GDP per capita does not exhibit a statistically significant effect in either model, indicating that income level alone does not determine carbon outcomes within this group of countries.

In interaction model (2), the interaction term between TO and REC is introduced to explore conditional effects. While TO and REC individually lose statistical significance, the interaction term (TO × REC) is negative and significant at the 1% level. This finding implies that the environmental benefit of trade openness becomes stronger in the presence of higher shares of renewable energy. In other words, trade is more likely to reduce emissions when countries are simultaneously investing in clean energy sources. These results underscore the complementary relationship between trade and renewable energy in achieving environmental goals. They suggest that trade liberalization alone may not be sufficient to reduce emissions unless accompanied by a strong commitment to sustainable energy strategies.

Table 7. Regression results: Baseline vs. interaction model

Variable	(1) Baseline Model	(2) Interaction Model
TO	-1.516***	0.421
REC	-0.038***	0.048
GPDpc	0.003	0.002
TO x REC		-0.091***
Constant	7.982***	6.068***

Notes: Robust standard errors clustered at the country level. *** $p < 0.01$.

The empirical results provide novel evidence that the environmental impact of trade openness is not uniform but instead depends on the domestic energy mix. The negative and statistically significant interaction term between TO and REC highlights the importance of renewable energy in shaping the environmental effects of trade. Specifically, the marginal effects plot (Figure 2) illustrates that trade openness reduces CO_2 emissions more strongly as the share of renewable energy increases. This supports the view that the environmental benefits of trade are conditional, and not automatic.

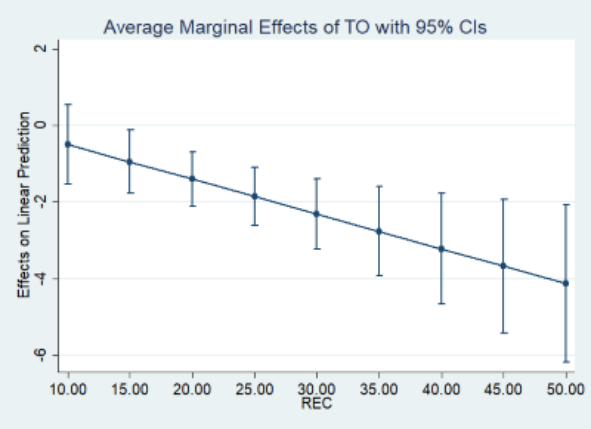

Figure 2. Marginal effects of trade openness across renewable energy levels

Our results suggest that trade openness contributes to lower CO_2 emissions only when accompanied by a higher share of renewable energy. This aligns with Ho and Iyke [3], who find a negative long-run effect of trade openness on emissions in Central and Eastern European countries. Additionally, recent threshold studies [4] show that trade's environmental impact becomes favorable only beyond certain institutional or energy-related thresholds. These findings support our main conclusion: trade can become "green," but only under specific structural conditions.

4. Conclusions

This paper provides evidence that the effect of trade openness on CO_2 emissions in emerging European economies depends on the share of renewable energy. Trade openness can support environmental goals when accompanied by a shift toward cleaner energy sources. Policy coordination between trade and energy strategies remains essential for achieving sustainable development.

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