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A Quantile Panel-Type Analysis of the Relationship Between Carbon Price and Energy Inflation in the EU-27

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This paper examines the relationship between carbon prices and energy inflation within the EU-27 using a quantile panel-type causality approach. The results indicate that carbon prices significantly contribute to energy inflation at middle to high quantiles, whereas no causality is observed at low quantiles. These findings underscore the necessity for gradual adjustments in carbon pricing, promoting renewable energy, and providing targeted support for vulnerable households to mitigate the inflationary impacts while achieving climate objectives.

I. Introduction

The European Union (EU) ranks as the third highest emitter of greenhouse gases, following China and the United States. In response to the urgent need to reduce emissions and mitigate severe climate impacts, the EU has introduced the ambitious Fit-for-55 plan (Riechmann et al., 2022). This initiative aims to cut emissions by 55% from 1990 levels by 2030, with the ultimate goal of achieving net-zero emissions by 2050. Transitioning to a carbon-neutral society necessitates strategic use of complementary approaches (Hassan et al., 2022). One key strategy employed by the EU is carbon pricing, which is recognized as an effective method to address pollution by incorporating environmental costs into market transactions (Olasehinde-Williams, 2024). By doing so, carbon pricing incentivizes businesses and individuals to consider their environmental impact in decision-making.

The effectiveness of carbon pricing in reducing emissions is well-established. Research indicates that while carbon pricing policies are largely successful in achieving emissions reduction, they are also closely linked with energy costs (Känzig, 2021). The relevance of carbon pricing to energy inflation has therefore steadily gained prominence on the EU agenda (Alola et al., 2019, 2021; Olasehinde-Williams & Akadiri, 2024). This study examines the causal links between carbon price and energy inflation in the EU, employing a quantile panel-type causality framework to analyze annual data for EU-27 countries spanning 2005 to 2020.

Theoretically, the primary goals of carbon pricing are to account for the external costs of greenhouse gas emissions, discourage the use of fossil fuels, and promote a shift towards cleaner energy sources. By raising the cost of fossil fuel-based energy, higher carbon prices are capable of influencing energy prices (ICC, 2023; Saint Akadiri et al., 2019). It is therefore expected that carbon prices should significantly predict energy inflation in the EU. Furthermore, energy consumption is the principal cause of carbon emissions; thus, energy prices naturally serve as predictors of carbon prices. When the prices of fossil fuel-based energy are low (or high), energy demand typically increases (or decreases), assuming supply remains constant, leading to a corresponding rise (or fall) in emissions and carbon allowance prices (Duan et al., 2021).

Existing literature on carbon pricing and inflation highlights the theoretical connections established above. On one hand, several studies argue that changes in carbon prices are linked to changes in energy costs, which contribute to general inflation (Wang & Nguyen Thi, 2022). Carbon pricing mechanisms, such as the European Union Emissions Trading Scheme (EU ETS), have been shown to increase costs in energy-intensive sectors (Ha et al., 2023; Olasehinde-Williams & Akadiri, 2024; Song & Taamouti, 2021; Usman et al., 2022). On the other hand, research also documents the influence of energy prices on carbon price determination during the initial phase of the EU ETS (Alberola et al., 2009; Hintermann, 2010; Mansanet-Bataller et al., 2007). This same pattern has been observed in the sec-

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ond phase of the EU ETS (Aatola et al., 2013; Lutz et al., 2013; Schandl et al., 2016).

The key contributions of this study include the following: Firstly, although carbon pricing has gained increasing attention in research, most existing studies have primarily examined its effectiveness in reducing carbon emissions, with carbon taxes being the most extensively explored form of carbon pricing. This study addresses the gap by exploring an economic side effect of carbon emissions trading within the EU-27. Secondly, previous studies considering the inflationary impact of carbon pricing have mostly focused on aggregate inflation. Our study extends these analyses by concentrating specifically on energy inflation. Thirdly, due to fluctuations in energy prices, carbon prices can exhibit varied responses, often showing an asymmetric pattern across various locations in the carbon-energy price distributions (Chevallier, 2011). Despite the clear policy relevance of this phenomenon, there has been limited research investigating this asymmetric effect thoroughly. This study addresses this limitation by employing a quantile panel-type causality framework, which is particularly well-suited for this analysis. The method provides insights into the varying degrees of predictability between carbon prices and energy inflation across different quantiles.

II. Methodology and Data

This study aims to examine the relationship between carbon pricing and energy inflation by exploring their causal link within a quantile panel-type causality framework, utilising annual panel data for EU-27 countries from 2005 to 2020. The concept of causality, as introduced by Wiener (1956) and Granger (1969), is vital for understanding dynamic interactions in time series data (Song & Taamouti, 2021). The primary motivation for employing Granger causality tests is to evaluate predictability, which is of significant importance to economists, policymakers, and investors. These tests determine whether one variable can forecast another. Several panel Granger causality tests have been developed to this end. However, much of the existing literature predominantly focuses on detecting Granger causality at the mean level, often neglecting potential causal relationships across the entire conditional distribution. A quantile-based approach is deemed more suitable for this research as it encapsulates the full conditional distribution of the dependent variable and demonstrates greater resilience to outliers (Wang & Nguyen Thi, 2022). Consequently, this study assesses the predictive capability of carbon prices on energy inflation through a panel non-causality test across quantiles. Non-causal relationships in quantiles between variables y_t and x_t are tested as follows:

$$QEINF_{it}(\tau|EINF_{it-1}) = \beta_{01i}(\tau) + \sum_{j=1}^p \beta_{11,ij}(\tau)EINF_{it-j} + \sum_{j=1}^p \beta_{12,ij}(\tau)CP_{it-j} \quad (1)$$

Table 1. Panel data non-normality Geary runs test

Geary LM Test Statistic	P-value
-7,055**	0.029

Note: This table reports results obtained from the panel data non-normality Geary runs test. ** denotes statistical significance at the 5% level.

$$QCP_{it}(\tau|CP_{it-1}) = \beta_{02i}(\tau) + \sum_{j=1}^p \beta_{21,ij}(\tau)EINF_{it-j} + \sum_{j=1}^p \beta_{22,ij}(\tau)LENVT_{it-j} \quad (2)$$

The empirical analysis encompassed all EU-27 countries with the exception of Bulgaria, Croatia, Cyprus, Lithuania, Malta, Romania, and Sweden due to insufficient historical data. Energy inflation data was sourced from the International Monetary Fund's Global Database of Inflation, as prepared by Ha et al. (2023). The ICE EUA Carbon Futures Index, which represents the price of the European Union carbon market within the European Union Emissions Trading Scheme, was used as a proxy for carbon pricing.

III. Empirical Findings

To justify employing a quantile panel-type causality framework, we first conduct tests for non-normality in the panel data. As shown in [Table 1](#), the null hypothesis of normality is rejected at the 5 percent significance level. This finding indicates the presence of non-normality, which must be addressed in the empirical analysis. The deviation from normality substantiates the use of quantile-based methods (Mishra et al., 2019).

To gain an initial understanding of the nature, strength, and significance of the relationship between carbon prices and energy inflation, a correlation test was conducted. The correlation plot shown in [Figure 1](#) reveals that there is a significant positive correlation between carbon prices and energy inflation in the EU-27. This finding indicates that higher carbon prices are associated with increased levels of energy inflation within the region. This constitutes the first evidence from this study suggesting that carbon price is a valuable predictor of energy inflation in the EU-27.

Finally, quantile-specific causal relationships between carbon prices and energy inflation are estimated and reported in [Table 2](#). The summary of the outcomes is as follows. Firstly, no causal relations are detected between carbon prices and energy inflation at the very low quantiles (10th and 20th). This suggests that carbon price and energy inflation do not have predictive power over each other at very low levels. Secondly, one-way causal effects from carbon price to energy inflation are detected at the lower-middle quantiles (30th and 40th). This indicates that carbon price can significantly predict movements in energy inflation between the 30th - 40th percentile distribution of energy inflation, but energy inflation does not significantly predict carbon prices within this quantile range. Thirdly, feedback causal relations are detected between carbon price and energy inflation in the middle to high quantiles (50th

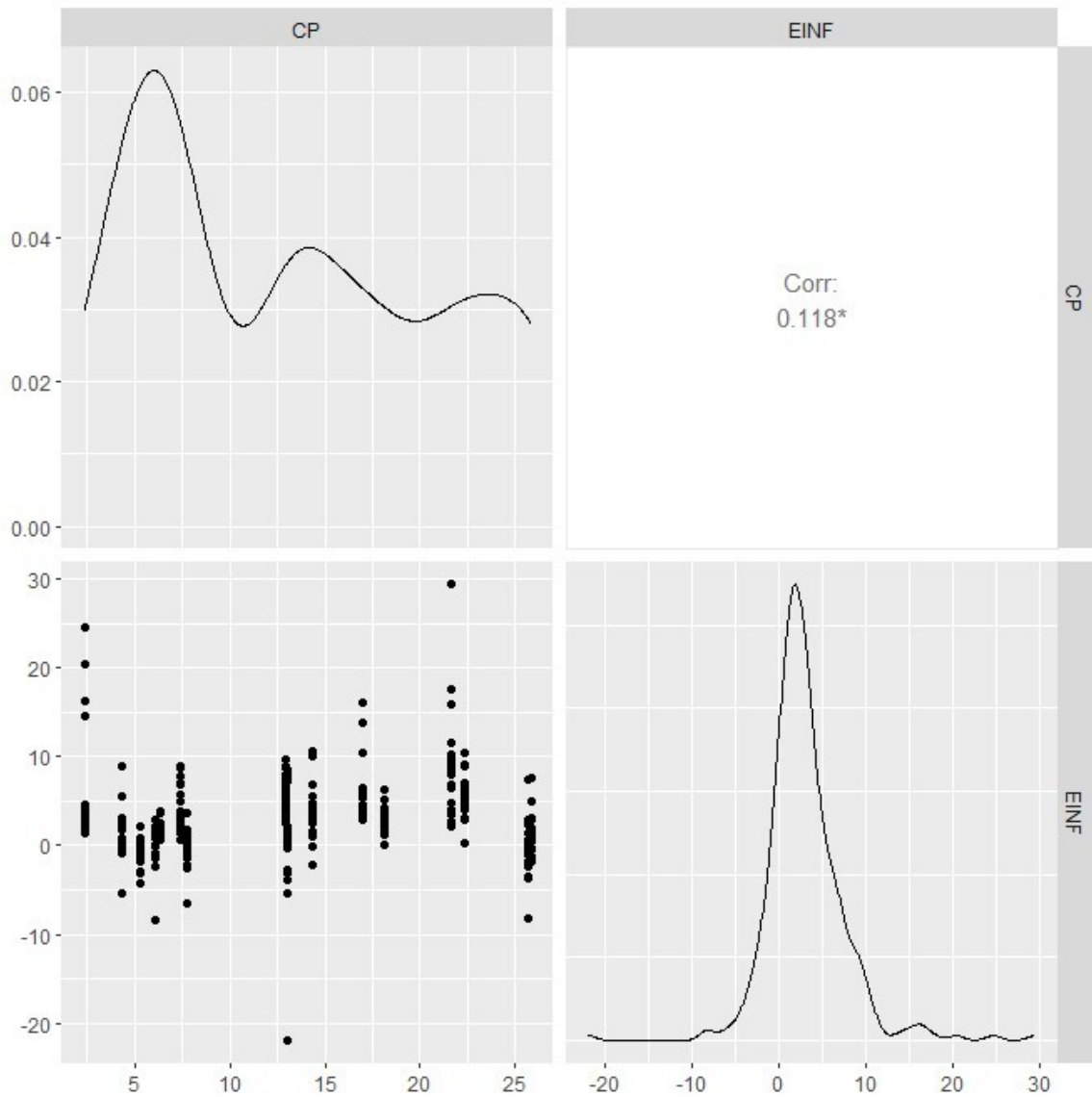


Figure 1. Correlation matrix and plots.

Note: This Figure plots correlation matrix among the series. * denotes statistical significance at the 10% level.

to 90th). This shows that carbon price and energy inflation significantly predict each other's movements at middle to high levels in the EU-27. Overall, the findings reveal that energy inflation and carbon prices are interconnected and exhibit a dynamic and asymmetric relationship. In comparison to existing literature, this study confirms the past findings of Song and Taamouti (2021), Usman et al. (2022), and Ha et al. (2023), which argued that carbon prices significantly influence energy inflation. This study also supports past findings that claim energy inflation significantly influences carbon prices (see Aatola et al., 2013; Hintermann, 2010; Lutz et al., 2013; Mansanet-Bataller et al., 2007; Schandl et al., 2016). These findings have implications for policymakers, especially in managing inflation expectations in response to carbon pricing policies.

IV. Conclusion

This study provides an analysis of the relationship between carbon prices and energy inflation in the EU-27, using a quantile panel-type causality framework. The findings offer insights into how carbon prices influence energy inflation across different quantiles of the energy inflation distribution. Specifically, the results indicate that carbon prices do not predict energy inflation at the very low quantiles, but significant one-way causal effects are detected at the lower-middle quantiles (30th and 40th percentiles). Additionally, strong feedback causal relationships are observed in the middle to high quantiles (50th to 90th), where both carbon prices and energy inflation are mutually predictive.

These results suggest that the impact of carbon pricing on energy inflation varies across different levels of energy inflation. At moderate to high levels of inflation, carbon prices become more influential, with significant predictive power. This indicates the potential for carbon pricing to

Table 2. Quantile panel-type causality results (carbon price and energy Inflation)

Null hypothesis	Quantile	Coefficient	P-value	Causality detected
CP $\neq$ EINF	0.1	-0.115	0.347	No
	0.2	0.199	0.352	No
	0.3	0.550 ^{***}	0.002	Yes
	0.4	0.677 ^{***}	0.000	Yes
	0.5	0.692 ^{***}	0.000	Yes
	0.6	0.582 ^{***}	0.000	Yes
	0.7	0.418 ^{**}	0.024	Yes
	0.8	-0.159 [*]	0.075	Yes
	0.9	-0.261 [*]	0.084	Yes
EINF $\neq$ CP	0.1	-0.009	0.770	No
	0.2	0.022	0.444	No
	0.3	0.044	0.161	No
	0.4	0.052	0.130	No
	0.5	0.086 ^{**}	0.024	Yes
	0.6	0.118 ^{***}	0.003	Yes
	0.7	0.112 ^{***}	0.008	Yes
	0.8	0.109 ^{***}	0.009	Yes
	0.9	0.133 ^{***}	0.003	Yes

Note: ^{***}, ^{**} and ^{*} denote statistical significance at 1%, 5% and 10 % levels, respectively.

affect energy costs at higher inflation levels, underscoring the need for careful consideration in policy implementation. At lower levels of inflation, the relationship is less pronounced, indicating that the inflationary effects of carbon pricing are more constrained during periods of lower energy price growth.

Overall, this study enhances the understanding of the dynamics between carbon prices and energy inflation in the EU-27, offering implications for both economic and environmental policy within the region. Policymakers should consider gradual increases in carbon prices, particularly during periods of high energy inflation. The study's findings suggest that carbon prices have a stronger inflationary impact at higher inflation quantiles. A gradual adjustment could help mitigate the risk of exacerbating energy inflation, ensuring that economic growth and household affordability are not disproportionately affected. In addition, given the findings of significant inflationary effects at higher quantiles, it may be important to provide compensation or financial support to vulnerable households that could be disproportionately affected by rising energy costs. Programs such as energy vouchers or tax rebates could help offset the impact of higher energy prices driven by carbon pricing. Lastly, policymakers might adopt a flexible ap-

proach to carbon pricing, regularly monitoring its impact on energy inflation. If inflationary pressures become too severe, temporary adjustments to carbon pricing levels or complementary policies could be employed to alleviate cost pressures on consumers and businesses while maintaining long-term climate objectives.

It is important to note that while the findings of this study provide insights into the relationship between energy inflation and carbon price, certain limitations remain. One key limitation is that the European Union Emissions Trading Scheme has experienced several phases marked by structural and compositional changes, which are not considered in this analysis. Future research could explore the implications of these phase-specific changes. Additionally, the study is limited to the EU-27, and the distinct nature of the region's economy may affect the generalizability of the results, particularly for less developed areas. Expanding this research to include other regions with different economic characteristics would be a useful avenue for further investigation.

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